Chapter 1
Introduction: Smart Homes and Their Users

Abstract This chapter introduces the book, its rationale and objectives, and the new data sources on which much of the analysis is based. Smart home technologies (SHTs) are now commercially available amid the promise of a smart home future. But there is a dearth of informed research on the users and use of SHTs in real domestic settings. This book is one of the first attempts to explore systematically how and why people use SHTs, and what impact this has on different aspects of everyday domestic life. A field trial of 20 households using commercially-available SHTs provides new data on in situ usage. This household-level data is contextualised by national-level market studies using both surveys and content analysis of industry marketing material. These new datasets are used throughout the empirical and analytical chapters of the book.

1.1 The Smart Home Promise

Smart technologies are pervasive. Embedding information and communication technologies (ICTs) in consumer appliances like phones and TVs and in infrastructures like cities and grids promises enhanced functionality, connectivity, and controllability. Major technology developers, service providers and energy utilities are lining up to extend smartness beyond specific devices to the home as a whole, and link these smart homes into the meters, wires and pipes of the utility networks. The advent of smart homes may ensure smart technologies become a commonplace feature of people's lives, whether they are wanted or not (Haines et al. 2007).

Throughout this book, we use the term 'smart homes' as a generic descriptor for the introduction of enhanced monitoring and control functionality into homes. In essence, a smart home collects and analyses data on the domestic environment, relays information to users (and service providers), and enhances the potential for managing different domestic systems (e.g., heating, lighting, entertainment) (Firth et al. 2013). We use 'smart home technologies' or SHTs as a collective term for the many different hardware and software components of a smart home. Smart home technologies (SHTs) comprise sensors, monitors, interfaces, appliances and devices

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networked together to enable automation as well as localised and remote control of the domestic environment (Cook 2012). Controllable appliances and devices include heating and hot water systems (boilers, radiators), lighting, windows, curtains, garage doors, fridges, TVs, and washing machines (Robles and Kim 2010). Sensors and monitors detect environmental factors including temperature, light, motion, and humidity. Control functionality is provided by software on computing devices (smartphones, tablets, laptops, PCs) or through dedicated hardware interfaces (e.g., wall-mounted controls). These different SHTs are networked, usually wirelessly, using standardised communication protocols. The diversity of available SHTs means the smart home has many possible configurations and, by implication, many different kinds of 'smartness' (Aldrich 2003).

Irrespective of the particular technological configuration of a smart home, its purpose—according to technology developers—is "to improve the living experience" at home in some way (Gračanin et al. 2011; McLean 2011). This may be through new functionality such as remote control and automation of appliances, through enhancement of existing functionality such as heating management, through improved security (e.g., simulating occupancy when the home is empty), or through the provision of assisted living services by monitoring, alerting, and detecting health incidents (Orpwood et al. 2005). Smart homes are also the end-use node of a smart energy system that allows utilities to respond to real-time flows of information on energy demand from millions of homes. This also opens up the possibility of homes responding to utilities' needs for demand to be curtailed or shifted when supply networks are constrained (Darby 2010).

SHTs are increasingly on sale both off-the-shelf and with professional installation. Examples available in the UK include British Gas' Hive system for controlling heating and hot water systems, and RWE's SmartHome system for heating, appliances and lighting. The global market for smart homes and appliances (including fridges, washing machines, tumble dryers, dishwashers and ovens) is projected to grow at a 15% compound annual rate from $24 bn in 2016 to over $50 bn by 2022 (Zion 2017). Other market forecasters put the numbers still higher: $138 bn by 2023 (M&M 2017). Global consumer research carried out in seven countries worldwide, including the UK and Germany, suggests a high level of market support (GfK 2015). Over half the consumers surveyed expressed a general interest in smart homes, and 50% believe SHTs will have an impact on their lives over the next few years (GfK 2016). Over half a million households in Germany will have smart appliances or devices by 2019, driven by widespread adoption of smart phones (Harms 2015). However, actual levels of uptake of SHTs are still low, and smart product sales are dominated by internet-connected TVs (Harms 2015).

Smart homes have increasingly important public policy implications. Progress with smart grids and smart metering has helped integrate heterogeneous and distributed renewable energy sources, and improve energy efficiency in commercial buildings. However, less success has been achieved in homes even though the residential sector accounts for around one third of total energy consumption (Covrig et al. 2014). This helps explain why smart homes are one of the EU's 10 priority action areas in its Strategic Energy Technology Plan: "Create technologies and services for smart homes that provide smart solutions to energy consumers". Behind this strategic policy objective lies "the Commission's vision for the electricity market [which] aims to deliver a new deal for consumers, smart homes and network, data management and protection" (EC 2015). A wide range of publicly-funded projects across the EU are designed to engage consumers in this vision (Gangale et al. 2013). Underlying the EU's strategic goals for a smart home future are clear assumptions that households seek a more active role in the energy system. The Commission argues that "communities and individual citizens are eager to manage energy consumption…" (EC 2015; EESC 2015). From this policy perspective, smart homes are enabling technologies to meet a latent demand by households for home energy control and management. Smart homes are seen as an integral part of a smart and efficient energy system, helping to reduce overall demand and alleviate supply constraints during periods of peak load (Firth et al. 2013; Lewis 2012). Widespread diffusion of smart homes in the UK has long been anticipated in policy documents (DECC 2009; HMG 2009) and is seen as an important 'building block' of the smart grid (DECC-OFGEM 2011). Smart home experts agree that "climate change and energy policy will drive UK smart home market development" (Balta-Ozkan et al. 2013a).

1.2 What About the Users of Smart Home Technologies?

Scientific research on smart homes is burgeoning alongside a proliferation of technology development and commercial applications. Behind both the technology developers and researchers advancing applied knowledge in this field is a clear sense of purpose: smart homes will "undoubtedly make our lives much more comfortable than ever" (Lin et al. 2002). But will they?

A growing number of social science researchers are asking: Who are the users of smart homes, and why do they want or need them? Will the technological promise of "customized, automated support that is so gracefully integrated with our lives that it disappears" be fulfilled (Cook 2012)? Might there be unexpected or perverse consequences? Are smart homes an inevitability or a choice? And how will smart home technologies actually be used in practice?

Despite the broad range of potential and assumed benefits of SHTs, a clear user-centric vision is currently missing from a field being overwhelmingly 'pushed' by technology developers (Rohracher 2003; Solaimani et al. 2011). Existing research on SHTs has focussed on the technological challenges involved in delivering smart domestic environments (Cook 2012). Much of this work has given no consideration to smart home users at all (Wilson et al. 2015). This is a critical oversight because the overall success of SHTs depends on their adoption and use by real people in the context of their everyday domestic lives.

SHT developers are already recognising the challenge of gaining the trust and confidence of prospective users (Harms 2015). Market research has found the most significant barrier to adoption is upfront cost, followed by lack of awareness and privacy concerns (GfK 2016). Several studies have examined prospective users' concerns about SHTs in more depth using small samples in technology demonstration labs, deliberative workshops, or focus groups (Balta-Ozkan et al. 2013a, 2014; Paetz et al. 2012). These studies have confirmed interest in the energy-management potential of smart homes, but have also identified market barriers to adoption including cost, privacy, security, reliability, and the interoperability of different technologies. Privacy and trust-related issues have delayed or halted smart-meter rollouts (AlAbdulkarim and Lukszo 2011; Hoenkamp et al. 2011). Similar issues may arise with data collected by internet-enabled SHTs within the home (Balta-Ozkan et al. 2013b; Cavoukian et al. 2010). A wider set of sociotechnical concerns with SHTs includes an increased dependence on technology, electricity networks or outside experts, and the proliferation of non-essential luxuries inducing laziness in domestic life (Balta-Ozkan et al. 2013b).

Summarising this literature, Balta-Ozkan et al. (2013b) define five key design criteria for SHTs to encourage consumer acceptance:

(i) *Fit with users' current and changing lifestyles*: SHTs should be easy to use (Park et al. 2003), 'fit in' with household routines both practically and aesthetically, and should be able to evolve over time (Edwards and Grinter 2001).
(ii) *Administration*: SHTs should not require high levels of user knowledge or the regular intervention of experts for installation, troubleshooting and maintenance (Paetz et al. 2012).
(iii) *Interoperability*: SHTs should be interoperable across manufacturers to enable 'piecemeal' development as new technologies are introduced into evolving home networks (Edwards and Grinter 2001).
(iv) *Reliability*: SHTs should not fail or act unpredictably, but should accurately sense and monitor homes, interpret user requirements and be able to cope with crashes (Friedewald et al. 2005).
(v) *Privacy and security*: SHTs themselves, and the information they gather about users must be private and secure (Cook 2012).

As well as these challenges for SHT design and consumer adoption, there is also a critical need for research on how SHTs are used in situ. Many studies rely on interviews, workshops or focus groups with *prospective* smart home users or experts (e.g., Balta-Ozkan et al. 2013b; Paetz et al. 2012). There is a dearth of research exploring how people *actually* use SHTs and what sorts of challenges emerge from their use. The small number of available studies in this field have focussed on special interest groups such as enthusiasts and hobbyists (e.g., Brush et al. 2011; Mennicken et al. 2014; Mozer et al. 2005) or groups such as Orthodox Jews with very specific reasons for pursuing home automation (Woodruff et al. 2007). These studies also tend to be quite short-term, capturing rich snapshots of how SHTs are used in context but neglecting longer-term trajectories of domestication or rejection.

Two recent review papers clearly identify a wider interest in the use of SHTs in situ or ‘in the wild’ (Mennicken et al. 2014; Wilson et al. 2015). These reviews raise issues and questions that are more situated and social than the instrumental concerns of consumer acceptance studies. Mennicken et al. (2014), for example, identify three core themes linked to identity and meaning, to the complexity of homes and domestic life, and to control and controllability.

First, SHTs should not merely ‘fit in’ with current household aesthetics and routines, but need to actively support and augment households’ social goals and values. Davidoff et al. (2006), for example, identified the importance to domestic life of ‘enrichment activities’ such as boosting physical fitness, creative abilities, or teaching social and personal values. Such enrichment activities are vital in helping to create and sustain household identities, but potentially clash with attempts to automate or optimise the domestic environment. For example, it may be easy to automate switching lights off, but this reduces opportunities for parents to teach their children how not to be wasteful. Similar arguments have been made concerning whether and how smart homes support the construction of gender identities (Richardson 2009), create ‘homey’ homes (Takayama et al. 2012), or are consistent with religious or pro-environmental goals (Woodruff et al. 2007). In short, smart homes should be meaningful as well as functional.

A second theme for research on SHT users is the complexity of homes revealed by in-depth explorations of domestic life. Homes have a plurality of meanings and resonances: security, control, permanence, relationships, activities, status, identity, values (Aune 2007; Despres 1991). Household members have different domestic roles and relationships with technology (Mennicken et al. 2014; Nyborg 2015). Multiple householders must interact and negotiate their potentially conflicting wants and needs in order to achieve a relatively peaceful co-existence (Baillie and Benyon 2008). Domestic life is characterised by routines which also involve breakdowns, improvisations, compromises and conflicts (Davidoff et al. 2006). SHTs must be able to cope with this complexity and avoid deriving ‘mixed messages’ from the multiple signals they may receive (Mennicken et al. 2014).

Third, it is vital that SHTs do not overwhelm or overpower their users with too many options or hard-to-use controls (Park et al. 2003). Many users with pressing daily needs may have little interest in knowing everything a smart home can do or understanding exactly how it works. SHTs should therefore be easy to configure and control, allowing users to communicate with them in natural ways rather than being bombarded with too much information or options or having to learn complex technical languages (Mennicken et al. 2014).

Mennicken and colleagues conclude that “living in and with an actual smart home today remains an imperfect experience” (Mennicken et al. 2014). They call for more ‘in the wild’ research exploring how SHTs are integrated into existing homes and domestic life.

1.3 Purpose and Overview of This Book

We take these emerging questions about smart homes and their users as a starting point for this book. Our purpose is to explore systematically how and why people use smart home technologies (SHTs), and what impact this has on domestic life and control over the domestic environment. Throughout the book we draw on new evidence and analysis to deepen understanding of smart homes and their users (Table 1.1).

We start by developing a new analytical framework for understanding smart homes and their users (Chap. 2). Drawing on new empirical research combining both qualitative and quantitative data, we then explore how SHTs are perceived by potential users, how they can be used to link domestic energy use to common daily activities, how they may (or may not) be integrated into everyday life by actual users, and how they serve to change the nature of control within households and the home (Chaps. 3–6). We conclude the book by synthesising our new insights on smart homes and their users, and identifying important research questions and policy implications that need addressing if a smart home future is to be realised (Chap. 7).

Table 1.1 Chapter-by-chapter outline

This Chapter: Introduction: Smart homes and their users	Sets out rationale and objectives of book. Summarises new data collected on in situ usage of smart home technologies
Chapter 2: Analytical framework for research on smart homes and their users	Reviews scientific literature on smart homes and their users. Develops analytical framework which inter-relates nine prominent research themes
Chapter 3: Perceived benefits and risks of smart home technologies	Analyses results of national survey of UK homeowners on the benefits and risks of smart home technologies. Contrasts user perceptions with industry marketing material
Chapter 4: Routines and energy intensity of activities in the smart home	Develops novel methodology for using smart home data to make inferences about which activities are happening at what times. Compares energy intensity and routineness of different activities within and between households
Chapter 5: Domestication of smart home technologies	Analyses data from in-depth interviews with householders both before and after installation of smart home technologies. Shows ways in which smart home technologies are incorporated into or rejected from domestic routines
Chapter 6: Control of smart home technologies	Identifies different forms of control by users of smart home technologies. Relates forms of control to dynamics of domestic life within households
Chapter 7: Conclusions and implications for industry, policy and research	Draws out common themes from empirical and analytical research on smart homes and their users. Outlines critical research needs and potential smart home contributions to public policy objectives

1.4 New Data and Analysis

In the empirical chapters of the book (Chaps. 3–6) we draw on a wealth of new data on the users and use of SHTs (Fig. 1.1). All these new datasets have been made publicly available via open-access data repositories (Table 1.2). Household-level data were collected from actual users of SHTs as part of an SHT field trial in the UK by the REFIT project team (see Acknowledgements). Complementary market-level data were collected through a national survey of UK homeowners and a content analysis of industry marketing material in the UK, EU and globally. Although much of this new data is from the UK where the authors are based, the analysis is broadly consistent with studies from other countries and regions including Australia (Strengers 2013), New Zealand (Ford and Peniamina 2016), the US (Karlin et al. 2015), Europe (BPIE 2017a, b), and globally (GfK 2016).

The REFIT project ran from 2012 to 2015 in the UK with the aim of understanding the use of SHTs and their potential impact on household energy demand (see Acknowledgements). It centred on a SHT field trial which ran for just over two years from April 2013 to August 2015 in Loughborough, UK (Fig. 1.2). In early 2013 the REFIT project team began recruiting households through posters, newspaper adverts and targeted leaflet drops. These recruitment materials presented the trial as an opportunity to experience new SHTs related to energy management, security and convenience in the home. The materials placed no emphasis on potential energy or financial savings. Responding households completed a screening survey to ensure diversity against the following criteria: household composition; experience with smart technologies; property type and age; existing energy efficiency or micro-generation technologies; and length of stay in the current home.

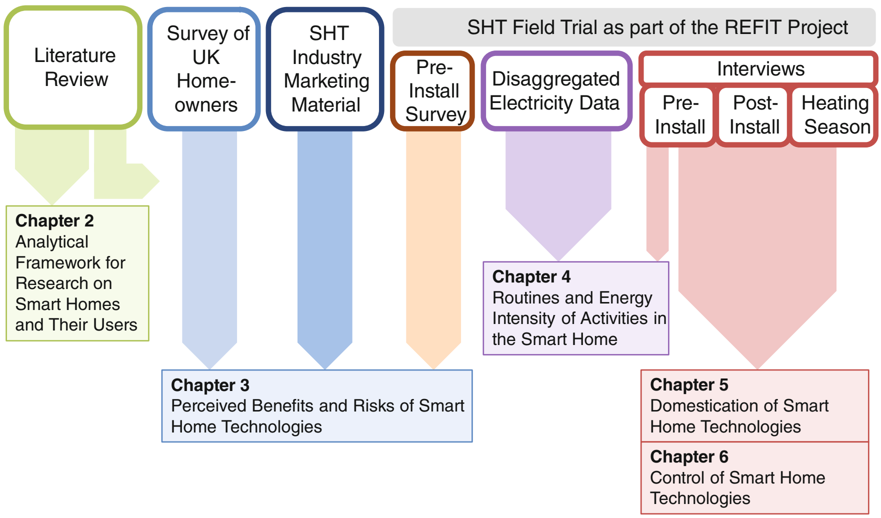

Fig. 1.1 New datasets analysed in this book

Table 1.2 Open access data repositories

Dataset	Use in this book	Open access repository
Data from *national survey* of consumer perceptions of smart home technologies	See S in Fig. 1.2; explained further in Chap. 3	ReShare data repository of the UK Data Service: URL = http://reshare.ukdataservice.ac.uk/852366/
Qualitative *interview data* from 20 households participating in the SHT field trial	See I1, I2 and I3 in Fig. 1.2; explained further in Chaps. 5 and 6	ReShare data repository of the UK Data Service: URL = http://www.reshare.ukdataservice.ac.uk/852367/
Electrical load measurements at 8 s intervals from 20 households participating in the SHT field trial	See A in Fig. 1.2; explained further in Chap. 4	Strathclyde University Knowledge Base: URL = http://dx.doi.org/10.15129/9ab14b0e-19ac-4279-938f-27f643078cec
Building survey data (including appliances) from 20 households participating in the SHT field trial	See A in Fig. 1.2; explained further in Chap. 4	Loughborough University FigShare: URL = https://doi.org/10.17028/rd.lboro.2070091
Sensor measurements (e.g., air temperature) from 20 households participating in the SHT field trial	Additional open access dataset generated by the SHT field trial but not analysed in this book	Loughborough University FigShare: URL = https://doi.org/10.17028/rd.lboro.2070091

A final sample of 20 households were selected, spanning a range of household types including single occupancy, dual-income families with children, and retired couples. Household members ranged in age from 10 to 74, and were drawn from professions that included students, carers, IT consultants and those not currently in paid work (Table 1.3).

All participating households were offered the same set of three SHTs. Each set of SHTs fulfilled three criteria: (1) they were commercially available; (2) they were functional, reliable and allowed the research team access to data; (3) they offered a range of smart home services including energy management, security and home monitoring, and automated and remote control of devices. These criteria ensured that the data generated on how SHTs were used in situ were representative of current smart home market developments. Multiple SHT systems were used to span a range of functionality. Although this created inter-operability risks, multiple systems performing specific tasks arguably mirrors the real-life experience of 'piecemeal' smart home installations (Edwards and Grinter 2001).

The three SHT systems installed in participants' homes during the SHT field trial were:

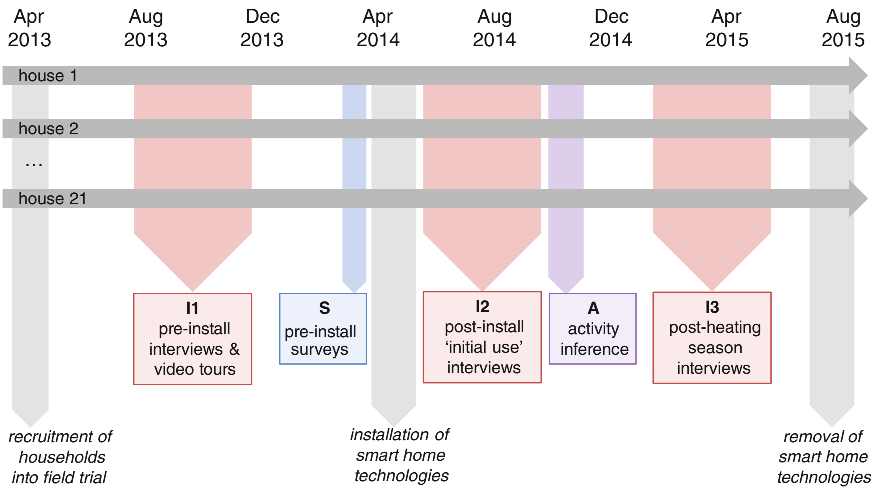

Fig. 1.2 Timeline of data collection during SHT field trial as part of the REFIT project

(i) *RWE Smart Home*: The *RWE* system provided monitoring and control functions for individual space heating radiators and home security. *RWE Smart Home* controllers were connected to each house's broadband router to allow the remote control of smart devices and the activation of automation 'profiles'. Each house was given up to 10 smart radiator thermostats, six door and window sensors, four motion sensors, an alarm/smoke detector, three room thermostats, two wall-mounted switches (which could be configured to activate any profile or combination of profile) and a remote control (which could be configured in the same way as the wall-mounted switches).

(ii) *British Gas Hive*: The *Hive* system allowed users to set up to six heating and hot water schedules per day (e.g., between the hours of X and Y to ensure a temperature of Z). It also allowed users to configure reminders based on their location (e.g., turn the heating off when arriving at work). One difference between the *Hive* and *RWE* systems is that the *Hive* system controlled the heating system as a whole and did not allow users to distinguish between different rooms or zones within the house. The *Hive* system was incompatible with some boilers so was only installed in 14 homes.

(iii) *Vera Z-Wave*: The *Vera* system provided households with real-time feedback on electricity use as well as the ability to control up to four electric appliances via smart plugs. The system also enabled the automation of these four appliances through either time, event or rule-based profiles. The *Vera* system could be remotely accessed and controlled via an online interface.

Table 1.3 Participants in SHT field trial as part of the REFIT project

House ID[a]	Household size	Age of household members	Occupation of household members
House 1 (H1)	2	55–64	University administrator
		65–74	Retired health visitor
House 2 (H2)	4	25–34	Technical specialist
		35–44	Full-time mother
		Under 18	Pre-school
		Under 18	Pre-school
House 3 (H3)	2	55–64	Semi-retired mechanical engineer
		65–74	Retired homemaker
House 4 (H4)	2	55–64	Retired IT sales support consultant
		55–64	Retired university administrator
House 5 (H5)	4	45–54	Senior IT developer
		45–54	Senior lecturer
		Under 18	At school
		Under 18	At school
House 6 (H6)	2	45–54	Retired IT manager
		55–64	Semi-retired social work tutor
House 7 (H7)	4	35–44	Electronics and software engineer
		35–44	Health visitor (on maternity leave)
		Under 18	Pre-school
		Under 18	Pre-school
House 8 (H8)	2	65–74	Retired greengrocer
		75–84	Retired
House 9 (H9)	2	55–64	Company director
		55–64	Company director
House 10 (H10)	4	35–44	Retail manager
		35–44	Homemaker
		Under 18	Pre-school
		Under 18	Pre-school
House 11 (H11)	1	65–74	Retired
House 12 (H12)	3	55–64	Technical
		45–54	Professional
		18–24	Student
House 13 (H13)	4	25–34	Control engineer
		25–34	Teacher
		Under 18	Pre-school
		Under 18	Pre-school

(continued)

Table 1.3 (continued)

House ID[a]	Household size	Age of household members	Occupation of household members
House 14 (H14)	Dropped out of trial		
House 15 (H15)	1	45–54	Community nurse
House 16 (H16)	6	45–54	Product manager—automation
		45–54	IT accounts manager
		18–24	Student
		Under 18	At school
		Under 18	At school
		Under 18	At school
House 17 (H17)	3	55–64	Researcher
		55–64	Care assistant
		Under 18	At school
House 18 (H18)	2	65–74	Retired textiles engineer
		65–74	Retired IT support
House 19 (H19)	4	45–54	Analyst programmer
		35–44	Not in paid work
		Under 18	At school
		Under 18	At school
House 20 (H20)	3	55–64	IT process analyst
		55–64	Homemaker
		25–34	Student
House 21 (H21)	4	35–44	Speech therapist
		25–34	IT product manager
		Under 18	At school
		Under 18	At school

[a]Houses were numbered sequentially from H1–H21. House 14 dropped out of the trial, so House 21 was recruited to ensure a sample size of 20

Each SHT system had its own user interface which was accessible via an internet-connected computer, smart phone or tablet app. Each SHT system also offered a range of control options including:

- time profiles in which devices could be switched on or off between specified times (*RWE*, *Hive*, *Vera*);
- event profiles in which an event (e.g., touching a remote control button) could trigger pre-specified outcomes (*RWE*, *Vera*);
- rule profiles in which participants could establish rules (e.g., 'if door/window is open, turn radiators on/off', or 'if motion detected, trigger alarm') (*RWE*, *Vera*).

Collectively, the three SHT systems installed as part of the SHT field trial provided a wide range of control and automation possibilities for heating, hot water, electrical appliances and security systems.

Figure 1.2 provides an overview of the SHT field trial as part of the REFIT project, and the points at which datasets analysed in this book were collected. These are explained further in relevant chapters but are summarised here as:

- pre-install survey of perceived benefits and risks of SHTs (45 individual members of 18 households); see S in Fig. 1.2, and Chap. 3 for details.
- one-month of real-time electricity data captured by smart meters, plug monitoring and *Vera* systems, and then disaggregated to the appliance level (10 households); see A in Fig. 1.2 and Chap. 4 for details.
- interview and video ethnography data before installation of SHTs (20 households), and interview data after installation of SHTs (10 households); see I1, I2 and I3 in Fig. 1.2 and Chaps. 5 and 6 for details. To manage exposure to the research team, the 20 households participating in the SHT field trial were divided into two groups of 10 for post-installation research: one group of 10 took part in successive in-depth interviews on SHT usage (reported here); the other group of 10 participated in design-focussed activities on retrofit decision support (Kane et al. 2015).

References

AlAbdulkarim L, Lukszo Z (2011) Impact of privacy concerns on consumers' acceptance of smart metering in the Netherlands. In: IEEE International Conference on Networking, Sensing and Control (ICNSC), Delft, The Netherlands, 11–13 April 2011. pp 287–292. doi:10.1109/ICNSC.2011.5874919

Aldrich FK (2003) Smart homes: past, present and future. In: Harper R (ed) Inside the smart home. Springer-Verlag, London, pp 17–39

Aune M (2007) Energy comes home. Energy Policy 35(11):5457–5465

Baillie L, Benyon D (2008) Place and technology in the home. Comput Support Coop Work 17:227–256

Balta-Ozkan N, Boteler B, Amerighi O (2014) European smart home market development: public views on technical and economic aspects across the United Kingdom, Germany and Italy. Energy Res Soc Sci 3:65–77

Balta-Ozkan N, Davidson R, Bicket M, Whitmarsh L (2013a) The development of smart homes market in the UK. Energy 60:361–372. doi:10.1016/j.energy.2013.08.004

Balta-Ozkan N, Davidson R, Bicket M, Whitmarsh L (2013b) Social barriers to the adoption of smart homes. Energy Policy 63:363–374. doi:10.1016/j.enpol.2013.08.043

BPIE (2017a) Is Europe ready for a smart buildings revolution? Buildings Performance Institute Europe (BPIE). Belgium, Brussels

BPIE (2017b) Smart buildings decoded. Buildings Performance Institute Europe (BPIE), Brussels, Belgium

Brush A, Lee B, Mahajan R, Agarwal S, Saroiu S, Dixon C (2011) Home automation in the wild: challenges and opportunities. In: Proceedings of the SIGCHI conference on human factors in computing systems, 2011. ACM, New York, pp 2115–2124

Cavoukian A, Polonetsky J, Wolf C (2010) SmartPrivacy for the Smart Grid: embedding privacy into the design of electricity conservation. Identity in the Information Society 3(2):275–294. doi:10.1007/s12394-010-0046-y

Cook DJ (2012) How smart is your home? Science 335(6076):1579–1581. doi:10.1126/science.1217640

Covrig CF, Ardelean M, Vasiljevska J, Mengolini A, Fulli G, Amoiralis E, Jiménez M, Filiou C (2014) Smart grid projects outlook 2014. JRC science and policy reports

Darby S (2010) Smart metering: what potential for householder engagement? Build Res Info 38 (5):442–457

Davidoff S, Lee MK, Yiu C, Zimmerman J, Dey AK (2006) Principles of smart home control. In: International conference on ubiquitous computing, 2006. Springer, Berlin, pp 19–34

DECC (2009) Smarter Grids: the opportunity. Department of Energy and Climate Change (DECC), London, UK

DECC-OFGEM (2011) Developing networks for low carbon: the building blocks for Britain's Smart Grids. Department of Energy and Climate Change (DECC) and Office of Gas and Electricity Markets (OFGEM), London, UK

Despres C (1991) The meaning of home: literature review and directions for future research and theoretical development. J Archit Plan Res 96–115

EC (2015) Communication from the Commission C(2015) 6317 final. Towards an Integrated Strategic Energy Technology (SET) Plan: accelerating the European energy system transformation. European Commission (EC), Brussels, Belgium

Edwards W, Grinter R (2001) At home with ubiquitous computing: seven challenges. In: Ubicomp 2001: Ubiquitous computing, 2001. Springer, Berlin, pp 256–272

EESC (2015) Changing the future of energy: civil society as a main player in renewable energy generation. European Economic and Social Committee (EESC), Brussels, Belgium

Firth SK, Fouchal F, Kane T, Dimitriou V, Hassan T (2013) Decision support systems for domestic retrofit provision using smart home data streams. In: The 30th international conference on applications of IT in the AEC Industry. Move towards smart buildings: infrastructures and cities, Beijing, China, 9–12 Oct 2013

Ford R, Peniamina R (2016) Smart homes: what New Zealanders think, have, and want. University of Otago, Dunedin, NZ

Friedewald M, Da Costa O, Punie Y, Alahuhta P, Heinonen S (2005) Perspectives of ambient intelligence in the home environment. Telematics Inform 22(3):221–238

Gangale F, Mengolini A, Onyeji I (2013) Consumer engagement: an insight from smart grid projects in Europe. Energy Policy 60:621–628. doi:10.1016/j.enpol.2013.05.031

GfK (2015) Smart home beats wearables for impact on lives, say consumers. GfK, Nuremberg, Germany

GfK (2016) Smart home: a global perspective. Paper presented at the CES 2016, Las Vegas, USA, 12 Jan 2016

Gračanin D, McCrickard DS, Billingsley A, Cooper R, Gatling T, Irvin-Williams EJ, Osborne F, Doswell F (2011) Mobile interfaces for better living: supporting awareness in a smart home environment. In: International conference on universal access in human-computer interaction, 2011. Springer, Berlin, pp 163–172

Haines V, Mitchell V, Cooper C, Maguire M (2007) Probing user values in the home environment within a technology driven Smart Home project. Pers Ubiquit Comput 11(5):349–359

Harms E (2015) Smart home—good things come to those who wait. Paper presented at the 8th international conference on energy efficiency in domestic appliances and lighting (EEDAL'15), Luzern, Switzerland, 26–28 August 2015

HMG (2009) The UK low carbon transition plan: national strategy for climate and energy. HM Government, London, UK

Hoenkamp R, Huitema GB, de Moor-van Vugt AJC (2011) The neglected consumer: the case of the Smart Meter Rollout in the Netherlands. Renew Energy Law and Policy Rev 4:269–282

Kane T, Cockbill S, May A, Mitchell V, Wilson C, Dimitriou V, Liao J, Murray D, Stankovic L, Stankovic V, Fouchal F, Hassan T, Firth S (2015) Supporting retrofit decisions using smart metering data: a multi-disciplinary approach. In: European Council for an Energy Efficient Economy (ECEEE) summer study on buildings, Hyeres, France, June 2015. pp 1009–1020

Karlin B, Ford R, Sanguinetti A, Squiers C, Gannon J, Rajukumar M, Donnelly KA (2015) Characterization and potential of Home Energy Management (HEM) Technology. Pacific Gas and Electric, San Francisco, CA

Lewis SCR (2012) Energy in the smart home. In: Harper R (ed) The connected home: the future of domestic life. Springer-Verlag, London, UK, pp 281–300
Lin Y-J, Latchman HA, Lee M, Katar S (2002) A power line communication network infrastructure for the smart home. IEEE Wirel Commun 9(6):104–111
M&M (2017) Smart home market by product, software & service, and geography—global forecast to 2023. Marketsandmarkets.com, Seattle, WA
McLean A (2011) Ethical frontiers of ICT and older users: cultural, pragmatic and ethical issues. Ethics Inf Technol 13(4):313–326
Mennicken S, Vermeulen J, Huang EM (2014) From today's augmented houses to tomorrow's smart homes: new directions for home automation research. Paper presented at the proceedings of the 2014 ACM international joint conference on pervasive and ubiquitous computing, Seattle, Washington
Mozer M, Dodier R, Miller D, Anderson M, Anderson J, Bertini D, Bronder M, Colagrosso M, Cruickshank R, Daugherty B (2005) The adaptive house. In: IEE seminar digests, 2005. IET, pp v1–39
Nyborg S (2015) Pilot users and their families: inventing flexible practices in the smart grid. Sci Technol Stud
Orpwood R, Gibbs C, Adlam T, Faulkner R, Meegahawatte D (2005) The design of smart homes for people with dementia—user-interface aspects. Univ Access Inf Soc 4(2):156–164
Paetz A-G, Dutschke E, Fichtner W (2012) Smart homes as a means to sustainable energy consumption: a study of consumer perceptions. J Cons Pol 35:23–41
Park SH, Won SH, Lee JB, Kim SW (2003) Smart home—digitally engineered domestic life. Pers Ubiquit Comput 7:189–196
Richardson HJ (2009) A 'smart house' is not a home: the domestication of ICTs. Info Syst Front 11(5):599
Robles RJ, Kim T (2010) Applications, systems and methods in smart home technology: a review. Int J Adv Sci Technol 15:37–48
Rohracher H (2003) The role of users in the social shaping of environmental technologies. Innovation: The Eur J Soc Sci Res 16(2):177–192
Solaimani S, Bouwman H, Baken N (2011) The smart home landscape: a qualitative meta-analysis. Toward useful services for elderly and people with disabilities, pp 192–199
Strengers Y (2013) Smart energy technologies in everyday life: smart utopia? Palgrave Macmillan, New York, USA. doi:10.1057/9781137267054
Takayama L, Pantofaru C, Robson D, Soto B, Barry M (2012) Making technology homey: finding sources of satisfaction and meaning in home automation. In: Proceedings of the 2012 ACM conference on ubiquitous computing, 2012. ACM, New York, pp 511–520
Wilson C, Hargreaves T, Hauxwell-Baldwin R (2015) Smart homes and their users: a systematic analysis and key challenges. Pers Ubiquit Comput 19(2):463–476. doi:10.1007/s00779-014-0813-0
Woodruff A, Augustin S Foucault B (2007) Sabbath day home automation: it's like mixing technology and religion. In: Proceedings of the SIGCHI conference on human factors in computing systems, 2007. ACM, New work, pp 527–536
Zion (2017) Smart home market: global industry perspective, comprehensive analysis and forecast, 2016–2022. Zion Market Research, Sarasota, FL