DOMESTICATING ENERGY EFFICIENCY TECHNOLOGIES: UNDERSTANDING THE ‘ADOPTER’ PERSPECTIVES OF UK HOMEOWNERS IN EXISTING HOUSING

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DECLARATION

"I certify that the work contained in this thesis, or any part of it, has not been accepted in substance for any previous degree awarded to me, and is not concurrently being submitted for any degree other than that of Doctor of Philosophy being studied at the University of Greenwich. I also declare that this work is the result of my own investigations, except where otherwise identified by references and that the contents are not the outcome of any form of research misconduct."

Sign……………………………………. **(Student)**

Date……………………………………..

Sign …………………………………… **(Supervisor)**

Date……………………………………

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ABSTRACT

The largescale adoption of energy efficiency technologies (EET) within existing housing stock presents a significant opportunity for the UK government to meet challenging climate change goals and reduce household energy consumption. However, despite the availability of innovative technologies and policy interventions, EET adoption rates remain low particularly within the UK's large owner-occupier sector. Prevailing dominant academic discourses are preoccupied with identifying factors for non-adoption based on assumptions of economic rationality and technological efficiency. In contrast, the research approach in this thesis focuses on elucidating the reasons why a small proportion of homeowners have succeeded in adopting EET, and explains how they learn to live with and embed innovative EET into their everyday lives.

Using the conceptual lens of Domestication theory (DT) applied to the activities of early adopters of technology, this research provides a sociotechnical perspective of peoples everyday interactions with EET. The theoretical approach is interrogated through a qualitative methodology based on 26 semi-structured householder interviews. A two-tiered analysis is undertaken inclusive of both the material and symbolic dimensions of multiple technology adoption. This occurs through an unfolding domestication process both at the household and technology specific level. Findings highlight a dynamic, multifaceted and multidimensional process of domestication, which embodies practical, social, technical and aesthetic values. In particular, it is concluded that domestication of technologies occurs simultaneously alongside a broader continuous process of household change that contributes to energy efficient sociotechnical re-configuration. The specific nature of sociotechnical interactions can support, speed-up or slow down successful domestication of EET.

This research makes a unique contribution to academic understandings of DT and offers scope for its theoretical modification. In addition, it contributes to debates on the interaction between sustainability policy, energy efficiency technologies, homeowners' every day experiences and domestic practices. Finally, more detailed elucidation of the dynamic four phase domestication model can contribute to achieving wider diffusion of household energy efficient technologies.

ABBREVIATIONS

ANT	Actor-network theory
ASHP	Air source heat pump
BB	Biomass Burner (e.g. wood stove)
CCC	Committee on Climate Change
CHP	Combined heat and power
CSH	Code for Sustainable Homes
CO2	Carbon dioxide
DCLG	Department for Communities and Local Government
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DT	Domestication Theory
EE	Energy efficiency
EET	Energy efficiency technology/technologies
ENERPHiT	Passive House Retrofit standard
EPBD	Energy Performance of Buildings Directive
EST	Energy Saving Trust
EWI	External wall insulation

FIT	Feed-in Tariff
GSHP	Ground source heat pump
HECB	Household energy consumption behaviour(s)
HH	Household(s)
ICT	Information and communication technology
IPCC	Intergovernmental Panel on Climate Change
IWI	Internal wall insulation
kWh	Kilowatt hour (unit of energy)
LZC	Low and zero carbon
MVHR	Mechanical ventilation with heat recovery
ONS	Office for National Statistics
POST	Parliamentary Office of Science and Technology
SPV	Solar Photovoltaics
RHI	Renewable Heat Incentive
SAP	Standard Assessment Procedure
SCOT	Social construction of technology
STHW	Solar thermal hot water
STS	Science and technology studies

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Chapter 1: Introduction to PhD study

1.1 Introduction

This research seeks an understanding of the developing relationships between HH, energy consumption, everyday life, technology adoption and usage in efforts to improve housing energy efficiency. It is set against a policy backdrop in which existing housing and HH (hereafter HH) consumption have become linked to government climate change mitigation strategies. The study aims to provide a sociotechnical perspective on the adoption of energy efficiency technologies (hereafter EET) by homeowners using the conceptual lens of 'domestication theory'; and through a focus on early adopters of technology; it explores the emergent sociotechnical relationships and everyday interactions between EET adoption and living with low carbon EET.

The chapter begins with a brief introduction to the research problem, its underlying rationale and the context of the study. It then highlights the limitations of existing policy approaches and of the dominant research discourses in order to identify a research gap. This will be followed by a statement of the primary aim and objectives of the research; the proposed research methodology; an outline of the thesis structure; and contributions of the research to the literature to conclude the chapter.

1.2 Overview of the Research Problem

1.2.1 Housing retrofit and environmental policy

It is widely accepted that one of the key instruments in reducing the human causes of global warming is the widespread adoption of technologies that save energy (e.g. Boardman et al. 2005; Boardman, 2007; Cabinet Office, 2011; CLG 2009b; Power 2008; Roy, Caird & Potter, 2007). The potential benefits and values of which can only materialise once they have been adopted and used appropriately (Egmond, Jonkers & Kok, 2006; Ozaki & Shaw, 2014). The accompanying trend in rising HH energy consumption also suggests the need for reducing energy use behaviours in buildings in order to meet environmental commitments.

12.2.2 Low adoption of energy saving technologies

For the UK government the large scale adoption of new and established low and zero carbon (LZC) or EET within existing housing stock presents a significant opportunity to meet climate change mitigation goals, i.e. reducing its carbon emissions to 80% by 2050[1] and reducing HH level energy demand (CLG 2009b; DECC, 2010, 2011, 2012; Palmer & Cooper, 2011). However, despite government-driven policy, product innovations and market availability of a range of EET for domestic use, there is evidence of detrimentally low levels of EET adoption in the UK. This has led to growing concern that government environmental goals will be unmet (Boardman, 2007; DECC, 2010; Lomas, 2010; Power 2008; Ravetze, 2008) and is exacerbated by the fact that the housing sector represents a major energy user.

Additionally, over 70% of homes that will exist in 2050 are already built; yet, private homeowners occupying existing older buildings (not new builds) – one of the largest housing tenure groups – are perceived as having the lowest rates of adoption of EET (Boardman et al. 2005; Palmer & Cooper, 2011; Power, 2008; Ravetze, 2008; Wright, 2008). Bringing the energy efficiency standard up to the scale of the existing stock is

[1] Against the 1990 baseline.

perceived a complex social and technical challenge. In recognition of this challenge, the government has introduced several policy instruments designed to incentivise uptake of EET by homeowners and increase their control over energy consumption (e.g. the Green Deal,[2] Feed in Tariff, Smart Meters, etc.) (DECC, 2010; Jones, Lannon & Patterson, 2013; Monkhouse & Dibb, 2012; POST, 2012; Pettifor, Wilson & Chryssochoidis, 2015).

Despite the introduction of an array of regulatory and non-regulatory interventions (including public information campaigns, financial and non-financial incentives, and increased public knowledge of the benefits of EET), many HH (HH) appear reluctant to retrofit EET (Dowson et al. 2012; DECC, 2010; Ravetze, 2008; Wetherill et al. 2012). In particular, policy efforts appear to have been delivered piecemeal and perceived to be failing due to continued low uptake of EET and trends in rising HH energy demand (Jones et al. 2013; Lomas, 2010; Pettifor, Wilson & Chryssochoidis, 2015; Ravetze, 2008).

Evidence suggests that where take-up has occurred within the existing housing sector it has been largely among a small group of 'early adopters' rather than the mainstream of society (Fawcett & Killip, 2014; Nair, 2012; Risholt & Berker, 2014). This has often been accompanied by inconsistencies in HH adoption of such technologies, i.e. overlooking simple easy to install measures (e.g. loft insulation) for more costly technical ones (e.g. Boilers; SPV) (Crosbie & Baker, 2010; DECC, 2010). Furthermore, whilst many people undertake a range of domestic modifications largely through home renovations, very few of these materialise into EE gains at a rate and scale desired by government (DECC, 2010; EST, 2011; Maller & Horne, 2011; Pettifor, Wilson & Chryssochoidis, 2015; Ravetze, 2008). Given these trends, it seems critical to understand the motivations of this small group of homeowner EET

2 This policy became defunct in 2015 and is discussed further in Chapter 3.

adoptees. This is an area that is under-examined in existing research and so forms the basis for the deeper research investigation in this PhD.

1.3 Existing Dominant Research and Policy Discourses

1.3.1 Problems of a technology-driven policy

The dominant normative research and policy discourses highlight the sociotechnical challenges in the retrofitting of technologies. They recognise that improving the EE of buildings is only part of the solution and that this needs to be combined with energy consumption reduction in order to contribute to wider environmental policy goals. They concede the need for an integrated behavioural and technological intervention approach to HH contributions to environmental goals (e.g. DECC, 2010; 2012; Janda 2011). In particular, there is a need to recognise energy use in a building and its environmental performance as a social and technological challenge (Stern & Aronson, 1984 in Janda 2011; Ozaki & Shaw, 2014). According to Gram-Hanssen (2014:393), this means 'understanding that houses are owned, occupied and retrofitted by (the same) people', therefore reinforcing the 'need to focus on the human dimensions of the retrofitting process', including EET adoption.

However, the delivery of a low carbon and sustainability agenda appears disconnected from this research evidence. Firstly, it does this through a primarily technology-driven policy approach by focusing on overcoming barriers to the adoption of cost-effective EET (DECC, 2010, 2012). Secondly, it does this through policies designed to target HH adoption of EET in order for this to contribute to a nationwide goal of diffusion of increased EE across the existing housing sector (DECC, 2010, 2012). In this, success has often been equated with numbers installed or performance-based environmental outcomes (energy use – before and after – interventions) and not on user outcomes (e.g. how people learn to live with such technologies) (Crosbie & Baker, 2010; Guy & Shove, 2000; Janda, 2011; DECC, 2011).

1.3.2 A technology-driven policy approach

Increasingly, research[3] has criticised the inadequacy of a technology-driven policy approach in advocating purely 'technological' or 'technical solutions' and of its conceptualisations of HH as 'rational actors'. This often lacks an understanding of the role of the human and user dimensions. For example, the energy saving value of EET in housing can only materialise once they have been implemented and used correctly by HH (e.g. Caird & Roy, 2010; Egmond, Jonkers & Kok, 2006; Maller & Horne, 2011).

Furthermore, research has highlighted another erroneous presumption that technological solutions alone, through a 'one-hit', will inadvertently deliver multiple benefits. For example, it assumes that not only will the technology improve the environmental performance of the building (thereby reducing its carbon emissions at the HH level) but that it may also have 'automatic' spill over 'double dividend' benefits for the individual HH consumer. It could also result in reduced fuel costs, improved quality of life, and may lead to other environmentally beneficial practices emerging (Caird & Roy, 2010; Maller & Horne, 2011).

Thus within this technology-driven approach, existing policies and legislation highlight the important role of technologies in tackling CC and other policy agendas (e.g. saving money, tackling fuel poverty). This research sits within a policy discourse where CO2 reduction and environmental goals are black-boxed into EET (e.g. Rydin, 2012). Although, there is much evidence to suggest that the EET adoption problem is not only a building or appliance problem but also one of human behaviour - lifestyle and cultural. However, policy continues to overlook this by seeking technical and legislative solutions rather than tackling the fundamental questions of how we live.

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[3] Largely from sociological theoretical perspectives (e.g. Ozaki & Shaw, 2014).

1.3.3 Rational individual consumer

The policy presumption of rationality assumes that the process of adoption of innovative technical solutions by homeowners is a straightforward *rational* linear path leading to individual adoption, energy demand management and use reduction. In this context, the individual HH adopter is conceptualised as open to government intervention – willing to exercise consumer choice once they realise the benefits of EET and then adopting and 'correctly' using such technologies (Janda, 2011; Judson & Maller, 2014; Maller & Horne, 2011; Ozaki & Shaw, 2014). Furthermore, this sits in contrast to extensive research evidence that suggests the potential risk that carbon saving benefits could be cancelled out through rebound effects arising from increased consumption of energy in the home following technology adoption (e.g. Gillingham, Rapson & Wagner, 2014; Janda, 2011; Maller & Horne, 2011).

Critics of this technology-driven (or techno-rational) approach argue that this provides a partial and limited picture of the complexity of human interactions involved and what happens to technologies in the home and their implications on HH energy consumption behaviour (hereafter HECB) (Crosbie & Baker, 2010; Lomas, 2010; Ozaki & Shaw, 2014; Maller & Horne, 2011). This highlights the sociotechnical challenges underlining the issue of low adoption and use and the need for widening the scope to understanding the sociotechnical relations between building technologies, users and everyday – energy consumption – practices. This research seeks to build on this dimension.

1.3.4 Dominant research discourses

The techno-rational policy stance for improving the energy performance of buildings and reducing HH energy demand should not be surprising. After all, it aligns with dominant empirical research discourses on housing EE and sustainability that also focus on improving building energy performance through technical measures (Crosbie & Baker, 2010; Maller & Horne, 2011). This has typically included: analysis and evaluations of policy and regulations for EE retrofitting (Boardman et al. 2005; Natarajan & Levermore, 2007; Ravetze, 2008; Roberts, 2008); the processes and practicalities for retrofitting through a barriers and drivers framing (e.g. Brown, 2001; Dowson et al. 2012; Guy & Shove, 2000; Sweeney et al. 2013; Weber, 1997); evaluations of costs, cost-effectiveness and benefits of measures (e.g. Boardman et al. 2005; Booth & Choudhary, 2013; Jakob, 2006; Tovar, 2012), aspects of occupant building use (Lowe & Oreszczn, 2009), and energy demand reduction in light of technology adoption and use (Firth, Lomas & Wright, 2010; Shipworth et al. 2010), etc. These technical analyses have often relied on aggregated data, simulations, predictive models and quantitative methodologies (e.g. Summerfield, Lowe & Oreszczn, 2009; Johnston, Kavgica, et al., 2010; Lowe & Bell, 2005; Utley & Shorrock, 2009). Although they are important to understanding energy demand and use in domestic buildings, they appear to overlook or simplify the fundamental role of the building occupants and miss the qualitative aspects of human interactions within houses (Crosbie & Baker, 2010; Gram-Hanssen, 2011, 2014; Janda 2011; Lomas, 2009; Stephenson & Leaman, 2010; Shove, 2010; Stephenson & Leaman, 2010).

1.3.5 Determinants of individual behaviour

In particular, the issue of the persistence of low adoption of 'building-specific' EET has often been found less explicitly and coherently articulated within the dominant and normative research discourses, particularly within technical, economic and socio-psychological disciplinary perspectives (Darnton et al. 2006; Faiers, Cook & Neame, 2007). They often veer towards attempting to understand determinants of individual energy consumption behaviours – often through predictive psychological approaches – and how to voluntarily encourage pro-environmental behaviour change, albeit through the articulation of differing models and interventions (e.g. Abrahamse et al. 2005; Chatterton, 2011; Faiers, Cook & Neame, 2007). Many of the models or approaches have again been critiqued for their over-emphasis on individualistic aspects of decision-making (e.g. purchase decisions) and identifying determinants of behaviour whilst seeming to underplay wider social and cultural aspects of technology adoption and use in discussions (Crosbie & Baker, 2010; Darnton, 2005; Shove, 2010; Maller & Horne, 2011).

1.3.6 'Barriers-drivers' framing of low adoption of EET

Additionally, this approach has been accompanied by a tendency to emphasise narrow consumer-related 'barriers-drivers' framing of the problem of low adoption of EET (e.g. Blake, 1999; Kollmuss & Agyeman, 2002; Sweeney et al. 2013; Weber, 1997) which often focuses on identifying barriers which can then be removed through designing policy enablers or drivers (Caird & Roy, 2010; DECC, 2012; STSC, 2012). The dominant literature highlights a range of influences, which present barriers to individual adopters, which include cognitive, personal, practical, economic, technical, social and institutional factors (Blake, 1999; DECC, 2012; Sweeney et al. 2013).

For example, various studies highlight a lack of awareness, unrealistic expectations, hassle, disruption and a lack of trust in contractors amongst the other issues reflected in people's experiences of barriers (e.g. EST, 2010; 2011; Roy et al. 2009; Sweeney et al. 2013; Whitmarsh et al. 2011; Weber, 1997). These factors are often seen to be complex and interrelated, and thus indicate that technology adoption is not a rational or money saving matter alone. However, this aspect is the one which existing policy discourses appear to over-emphasise, e.g. the 'money-saving' messages of the Green Deal policy.

Therefore, energy policy prioritises technological solutions and cost reduction considerations over detail understandings of HH preferences and lifestyles, which are likely to have a significant effect on adoption probability (Islam & Meade, 2013). People are not rational decision-makers motivated by saving money alone but can seek other social, cultural and environmental benefits from technology adoption (e.g. Caird &Roy, 2010; Ozaki & Shaw, 2014). The non-economic reasons come from social and anthropological approaches which suggest greater complexity in people behaviours (Whilhite, 2007; Guy & Shove, 2003) which includes a complex combination of practical, social, material and aesthetic values are embodied in everyday energy use or consumption practices (Gram-Hanssen, 2011; Shove, 2003; 2010).

1.3.7 Research gaps

One key dimension that appears under-researched relates to the theme of what it is like living with low carbon technologies and their usability. It has often been highlighted that buildings with specific low carbon EET have often been designed with insufficient knowledge of their users, their individual requirements and usability issues, e.g. aesthetics and ergonomic attributes, symbolic, social and cultural values, etc. – all of which could play a significant role in their adoption (building technologies) and subsequent effective use and energy reduction (and of the buildings as a whole) (Caird & Roy, 2010; Gram-Hanssen, 2011, 2014; Ozaki & Shaw, 2014).

Existing empirical research examining both technology adoption and user dimensions constitutes a relatively smaller body of literature when compared to the dominant normative and well-established literature examining technical aspects of buildings, environmental behaviours and energy use (often in their silos). First, whilst numerous studies have examined adoption of single EET (specifically single micro-generation technologies such as solar photovoltaic technology) (e.g. Keirstead, 2007; 2012; Schelly, 2014) very few have considered adoption of multiple technologies at once (e.g. Stiess & Dunkleberg, 2013; Nair, 2010). For instance, the Green Deal policy suggested no single solution alone could improve the energy efficiency of a building, thus the need to combine conventional insulating measures with more innovative micro-generation technologies.

Furthermore, whilst existing policy has tended to measure success in terms of numbers installed, this does not accurately reflect adoptee experiences of that 'success'; it does not account for why people do or do not adopt measures and their lived experiences over time once they have adopted (Gram-Hanssen, 2014). Thus, the evidence points to the need to examine 'why some change does occur'. Moreover, why such change should be viewed less as a one-off event and more as a process of change in which the correct use and embedding of EET does not unfold instantly but more slowly over time in HH (e.g. Gram-Hanssen, 2014; Maller & Horne, 2011; Ozaki & Shaw, 2014).

Additionally, there has been disproportionate analysis in studies on new-build housing developments, and/or those within the social housing sector, and of social housing tenants' perspectives where technology is implemented as requirements of building and planning policies (e.g. Decent Homes standard, CESP) (Behar & Chui, 2013; Chahal, Swan & Brown, 2012; DECC, 2012; Lees & Sexton, 2012; Ozaki & Shaw; 2014). Here, the installation dynamics and user relationship to technology is often imposed. In contrast, the perspectives of homeowner occupiers of existing housing have been under-researched within the normative low adoption discourse.

More specifically, what appears poorly understood and under-researched is an understanding of who this small group of *adopters* are; the type of EET they adopt and why; their decision-making processes and experiences of adoption (in terms of purchase, acquisition, installation, use/disuse, adaptations) of EET in their everyday lives; how the attributes and functionality of EET are actually conceived by the occupants of the buildings; why some measures are adopted whilst others are not; and the implications of this for wider diffusion and embedding of EET across society. Furthermore, there are suggestions[4] that in addition to examining how 'people react to and what they do with technologies', it is pertinent to ask 'why change has

4 Broadly based on the literature reviewed in this study.

occurred' and 'what has changed in people's lives'. Domestication theory (DT) proposes to tackle such questions.

1.3.8 Domestication Theory – an alternative approach

Critically, within this research discourse very few people have used the lens of DT to examine the actions of this group of early technology adopters. The existing literature has suggested low adoption is a sociotechnical challenge and/or problem. This highlights the justification for the adoption of a sociotechnical perspective in this research inquiry, one that enables recognition of the complex dynamic interactions between both human (social) and non-human (technological artefacts) elements (as highlighted by Bijker, 1993; Bijker & Law, 1992 and others). DT offers a sociotechnical and interdisciplinary perspective and an alternative theoretical perspective on technology–society relationships. DT through its STS positioning asserts technology and society mutually shape each other at every level.

To date, few studies have utilised DT in the way that this research seeks to examine the adoption of housing EET. These have been relatively small (e.g. Aune, 2007; Behar & Chui, 2009; Juntunen, 2014; Lees & Sexton, 2012) and typically limited to either overseas and/or renewable technology focused cases (e.g. Aune, 2007; Juntunen, 2012; 2014).[5] There appear to be no detailed case studies of owner-occupiers in existing housing within the UK. This scarcity is because traditionally domestication theorists had predominantly focused on understanding how particular discrete technologies such as the TV, telephone and computers areintegrated into everyday contexts and not building-specific, non-discrete technologies. However, this research unconventionally develops its scope further through its application by examining people's relationships and interactions with building-specific EE technologies.

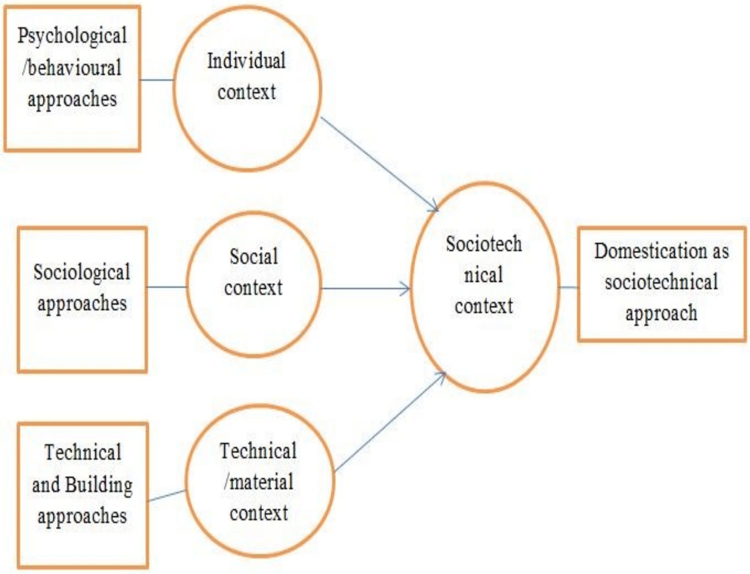
[5] Chapter 7 reviews this literature further.

DT emphasises technology–-society relations. The domestication process refers to the taming of technology or where technology (material and non-material artefacts) is adopted from the public realm – through its ‘acceptance, rejection and use’ – and taken into the private everyday domestic life of its users (Silverstone, Hirsch & Morley’s, 1992,; 1994). It is conceptualised as a dynamic process of HH technology mediated consumption rather than mere rational individual consumption.

Through the sociotechnical perspective – represented in the use of the domestication lens – this research seeks to challenge assumptions of economic rationality and technological efficiency in EET adoption and use suggested by the normative research discourses in this topic (highlighted above). In particular, through the use of the domestication lens, this method provides an alternative and holistic approach that ‘represents a shift away from models that assumed adoption of innovations to be rational, linear, mono causal and technologically determined’ (Juntunen, 2014, p. 5).

The sociotechnical approach using the DT lens occupies a middle ground between behavioural, psychological, and technical approaches and seeks to complement existing frames of knowledge, by recognising their strengths and weaknesses (but does not seek to substitute them either). It does this by recognising the discontinuities between them, e.g. a gap between these dominant approaches in integrating understandings of the role of material (non-human aspects) contexts of behaviour. Unlike the individualistic rational cognitive models of behaviour, it offers both a practical and symbolic perspective of the adoption and use of a given technology by HH. Through a sociotechnical perspective, it seeks to resolve this by taking into consideration the agency of both technology and individuals within a social context, and connects it with the often missing material dimensions of social life and technological contexts (see Figure 1).

Figure 1 Summary of the conceptual basis of this research



This approach has developed in contrast to the perceived limitations of the dominant theoretical approaches discussed above. DT provides a unique sociotechnical perspective that challenges presumptions of rationality and efficiency in adoption and use thereby seeking to fill numerous conceptual gaps. For example as illustrated in Figure 1, in relation to understanding the adoption of EET, behavioural and psychological approaches have often placed too much emphasis on individual decision-making – cognitive processes - around EET purchasing. Moreover, sociological approaches place too much emphasis on the social contexts of behaviour and everyday practices. Finally, technical and economic approaches place a 'rationalistic' and 'techno-centric' focus on finding the correct building interventions and desirable performance or policy outcomes – none of these than tackle the fundamental questions of how we live with technologies.

These approaches nevertheless offer useful insights into parts of the research problem, their fundamental limitations lie in the fact that they appear to conceptualise technology adoption as a singular event (ending at the point of purchase or installation) whereas DT perceives this to be an ongoing process. Importantly, they do not go far enough in explaining the complexities surrounding technology adoption and use in terms of what happens to technologies after their purchase once in the home and how people live with them. In particular, they do not offer an adequate in-depth insight into the process of user interactions with technologies and how relationships and meanings are formed; and the lived experiences and embedding of technology adoption (purchase, installation, use, non-use, etc.) and their social and environmental consequences. Understanding of this complex dimension of how people live with technologies once they are bought into the home appears underdeveloped in the dominant policy and research discourses is an aspect this research perspective addresses.

An inherent rationale embedded in the use of DT for this research is that it would provide a sociotechnical perspective, which originates from Science and Technologies Studies (STS). This approach focuses attention upon the need to examine the reciprocal relationships between technology and society (Smith & Marx, 1994 in Sawyer & Jarrahi, 2014). A key approach of STS is the social shaping of technology (SST) which asserts that society decides what technology is needed, produced and then used (or not), hence technology is not only shaped by the social context but also shapes it (MacKenzie & Wajcman, 2006). Therefore, DT provides an opportunity to explore the 'contextual influences, processes of development, adoption, adaptation, and use of new and established technologies in people's social worlds' (Jones and Orlikowski 2007 in Sawyer & Jarrahi, 2014:4).

1.4 Research Aim and Objectives

The central research question underpinning this research is:

'To what extent can the application of Domestication Theory (DT) advance our current understandings of the processes of adoption and embedding energy efficiency technologies (EET) into the everyday life of homeowners?

The key objectives of the empirical study are to:

1. outline through user experiences the processes of adoption and embedding EET into their homes and everyday lives;

2. determine whether domestication theory offered an effective explanatory tool for the analysis of how homeowners adopt and embed EET into their homes and everyday lives; and

3. consider the policy implications for government and industry in relation to goals to increase HH EET adoption and reducing energy consumption.

1.5 Research Methodology

The primary aim of the study was to address the research question of whether DT could advance a more effective understanding of how and why some HH appear to succeed in adopting and embedding EET into their everyday lives. Linked to this aim is the objective of establishing whether this could help aid a more holistic perspective of the research problem and identify potential solutions that could ultimately contribute to government policy goals for increasing technology adoption, thereby contributing to reducing domestic HH energy consumption.

The sociotechnical perspective provides the basis for the methodological approach adopted in this research. The empirical research investigation seeks to develop the proposed alternative framing of the research problem through the following. Firstly, it specifically focuses on homeowner 'early adopters' rather than non-adopters. Secondly, through the deployment of a qualitative methodology and using DT it develops a research, analytical and conceptual framework (moving away from individual deterministic behavioural models).

A central objective is to explore the extent to which Silverstone, Hirsch and Morley's (1992) 'four phase' domestication framework (appropriation, objectification, incorporation and conversion) offers an effective explanatory tool for analysis of how homeowners adopt and embed EET into their everyday lives. It is used both as a conceptual and analytical framework for the empirical investigation and data analysis.

Given the complexity of the research problem and interest in uncovering in-depth meanings and experiences of homeowner adopters in relation to technologies, a qualitative and inductive methodological approach was developed. The domestication lens could enable deep qualitative investigation into micro-level HH practices of everyday life (Haddon, 2006).

In particular, empirical investigation for this thesis puts forward a homeowner perspective. This is achieved through 23 semi-structured HH interviews – recruited through purposive sampling (via voluntary self-selection) principally from England and encompassing a relatively diverse socio-demographic profile (in terms of gender, age, HH size, ethnicity, education, employment and income). DT was utilised both as a conceptual and analytical framework for data analysis, whilst ensuring explanatory power in relation to the research problem. Thus, transcribed data was analysed using DT's 'four phases' as a prime framework for analysis and supplemented by an interpretive and inductive thematic approach using Nvivo software. Existing research (e.g. Aune, 2007; Berker et al. 2006; Haddon, 2006) using this theory suggests that its strength lies in the practicality of qualitative case study approaches and hence is suited for analysis of homeowner user experiences and narratives.

The collected qualitative data derived primarily from semi-structured interviews with homeowners were analysed (using the domestication framework) through a two-tiered (parallel) analytical approach:

- Firstly, the dataset was analysed using **technology as a unit of analysis** – examining the domestication of a selection of individual non-discrete EETs (e.g. those cases where HH had implemented external wall insulation, and/or micro-generation technologies). Similar to Juntunen's study (2014); and
- secondly, the entire dataset was analysed for a broader whole house **HH level of analysis** where a suite of EETS were integrated symbolically and materially into the house contributing to its energy efficient sociotechnical reconfiguration; and examining all the HH experiences and perceptions of domesticating EET into their domestic life. Similar to Aune's study (2007).

This two-tier approach sought to demonstrate through the differing application of the domestication lens how it could provide multidimensional layers of insights into the same phenomenon.

1.5.1 Rationale for a two-tiered research analysis

A two-tiered analysis was developed in response to the need to understand the sociotechnical dimensions and for its use as a practical analytical tool for interrogating a large qualitative dataset. The proposed two-tiered analysis would enable a more in-depth unpacking of both social and technical dimensions - although DT itself does not prescribe, how analysis of the interactions between the social and technical should be undertaken. The justification for a two tiered analysis is supported by the fact that this research problem is interested in a holistic perspective of how users engage with technologies at different levels. Therefore, it is interested in what is happening both at the HH level and at the level of technology and how they then reveal the sociotechnical interactions. This two-tiered approach is supported by how existing research that has applied it in many different ways and itself conceptually regarded as a process operating at different levels. For example, existing research has focused on how users engage with technology at different levels; where aspects of mutual shaping may vary between differing HH with differing technology types and due to a number of complex variables (Coutard & Guy, 2007; Juntunen, 2014; Lee & Sexton, 2012).

In particular, Aune (2007) focuses analyses on material changes represented through the renovation process at the 'whole' house level. In contrast, Juntunen (2014) takes the technology as a focus of his analysis where domestication lens is loosely used in the examination of a range of diverse renewable decentralised technologies. These examples demonstrate the flexibility in the use of the D lens. Aune and Juntunen's approaches (bringing together the strengths/weaknesses of each approach) suggested that the nature of the sociotechnical perspective sought in this research could only be accommodated by taking on a two-tiered analysis of the HH and technology perspective. By taking a broad macro view of the whole house, level accompanied by the micro level of the individual technologies provides a more comprehensive sociotechnical insight – which will enable a deconstruction complexity of the sociotechnical relations in a less reductive way.

At a more theoretical level, this approach focuses attention upon the need to examine the reciprocal relationships between technology and society (Smith & Marx, 1994 in Sawyer & Jarrahi, 2014). A key approach of STS is the social shaping of technology (SST) which asserts that society decides what technology is needed, produced and then used (or not), hence technology is not only shaped by the social context but also shapes it (MacKenzie & Wajcman, 2006). Therefore, this two-tiered approach enables analysis of the aspects of the mutual shaping of technology, which may vary between differing HH and across differing technologies.

1.5.2 Rationale for qualitative approach

As discussed the perpetuation of a techno-rational bias (Guy and Shove, 2003, p. 54; Crosbie & Baker, 2010) manifests not only in many aspects of government policy and empirical energy research but also in the methodologies adopted (Crosbie, 2006; Crosbie & Baker, 2010). These create a tendency for research to be more 'descriptive rather than explanatory' (Lutzenhiser, 1993 in Crosbie & Baker, 2010:73). Thus, Crosbie and Baker (2010) highlight a need for research methodologies to address both the social and technical aspects of HH energy consumption: by collecting data about the people who live in the buildings under examination; within which there is a need to understand complex cultural and sociotechnical factors driving HH energy demand. They and others (e.g. Guy & Shove, 2003; Maller & Horne, 2011) suggest that quantitative and modelling approaches (e.g. Ascione et al., 2011) alone are insufficient to understand social complexity and therefore need to be supported with qualitative research insights through, e.g. in-depth interviews and/or focus groups methods (Crosbie, 2006 in Crosbie & Baker, 2010, p. 78; Shove et al. 1998). Consequently, in light of this viewpoint this research through DT regards the sociotechnical and qualitative approach appropriate for the lines of enquiry proposed.

In particular, through semi-structured interviews with people, the research methodology draws firstly on the expert knowledge of users and of their everyday lives; and secondly, it draws on their memories, reflections, observations and meanings, which provide a multidimensional and in-depth picture of lived experiences and interactions with technologies. It is specifically interested understanding the social consequences of EET and seeks to find how people react to and what they do with technologies once in the home; and then examine what has changed in people lives.

Therefore, the sociotechnical perspective does not specifically set out to find cause–effect relationships but seeks to highlight the complexity and the uncertainty involved in the process of technological adoption, use and embedding (Crosbie & Baker, 2010; Sawyer & Jarrahi, 2014). From the deployment of this theory, this research study has been able to scrutinise its usefulness, contemporary relevance – particularly in its new application to non-discrete domestic EET – and highlight its scope for expansion and/or further development. These aspects will be expanded upon following empirical data analysis in the final chapters.

1.6 The Definitions and Scope of Study

For the purpose of this study, the focus of research is on existing residential housing (built before 2000 as a general rule and not new builds) which is privately owned by individuals (homeowners) who occupy exclusively with family members (with one or more occupants) in single houses. It includes historic houses in conservation areas but not those recognised as 'listed buildings'. This is because listed buildings are exempted from the EE requirements where compliance with it would 'unacceptably alter their character or appearance' (Building Regulation 21(3)). They thus have their own special set of rules and regulations for change discussed in further in Chapter 3.

This research conceptualises any building-specific technologies for improving the energy efficiency of housing as EET. These are also sometimes referred to as technological or technical interventions. Furthermore, EET adoption refers to any technical measure that is implemented or installed via retrofit or renovations to a house which HH (HH refers to households and/or householders) undertake with the express purpose of reducing energy use and improving thermal comfort in the home (EST, 2011). Additionally, the term 'adoption' takes on a broad definition and refers first and foremost to a *process* by which EET are bought into homes. The process includes the decisions to 'purchase', the act of buying a product, the act of installing into the home and then its use and the lived experience of it.

In this context, the terms 'retrofit' and 'renovation' are often used interchangeably, and are defined as any form of 'internal and external improvements, maintenance and repairs including extensions, double glazing, refurbishing existing kitchens or bathrooms, general decorating and both emergency and non-emergency repairs' (TNS-BMRB, 2011). However, the term retrofit is often used to denote changes relating to energy efficiency technical interventions in housing. Therefore, it is referred to as energy efficiency (EE) retrofitting, meaning measures, improvements or actions designed to be energy efficient or energy saving.

Furthermore, whilst the technical energy *efficiency* behaviours, such as the installation of loft insulation, are the focus of this research analysis, it will also discuss behavioural conservation measures. Oikonomou, et al (2006:4787) describe the distinction between "energy efficiency and energy conservation is that the former refers to adoption of a specific technology that reduces overall energy consumption without changing the relevant behaviour, while the latter implies merely a change in consumers' behaviour" (the distinctions are further highlighted in Chapter 4). Moreover, this research will examine a wide range of environmental behaviours relating to residential energy savings including installing insulation (e.g. loft, cavity wall, glazing, etc.), better energy management (e.g. turning thermostat down, changing energy tariff, etc.), and micro-renewables installation (e.g. photo-voltaic systems, heat pumps, etc.). This approach is based on research evidence suggesting a whole range of behaviour change actions will be required by HH to contribute in climate change mitigation strategies.

1.7 The Structure of the Thesis

This thesis is comprised of 13 chapters, including this introductory chapter. **Chapters 2** to **7** collectively represent the literature review. However, Chapters **2** and **3** specifically provide a contextual background for the sociotechnical research approach drawing on both key 'grey'[6] and scholarly academic interdisciplinary literature. The key themes covered in each chapter are summarised as follows:

Chapter 2 highlights key social trends, issues and debates within the field of housing sustainability and/or HH energy efficiency and consumption discourses. It highlights how and why the EE of housing has become a key part of tackling climate change and discusses how the existing housing stock, and contemporary energy consumption patterns create challenges to government energy policy interventions. It highlights the sociotechnical challenges underlining the low adoption discourse.

Chapter 3 outlines the policy and regulatory framework for the retrofitting of existing housing in the UK. It highlights how, in order to tackle climate change and reduce carbon emissions, the UK government has issued a range of policy statements, white papers, legislation, regulations and policies to support and promote EE in the existing housing stock; many of these overlap and contribute to other national policy agendas. It considers the effectiveness of the existing policy frameworks to address the challenges of improving the EE of the existing housing stock. This policy infrastructure also represents the material context in which housing EET are adopted.

[6] This refers to research and materials produced in either print or electronic formats by organisations outside of traditional commercial or academic publishing channels and which often originate from differing levels of government, academic, business and industry and other sources.

Chapter 4 reviews a wide range of key scholarly 'empirical' interdisciplinary studies. Due to the size and complexity of the existing body of literature and the overlapping themes, which encompasses this research area, it is divided into two parts. In particular, domestic EE consumption in the UK, covering the building at HH level, can broadly be divided between studies that measure its technical dimensions (its thermal or energy performance) and studies that examine occupant or user behavioural dimensions (e.g. how people use energy appliances or space heating). These two dimensions are explored in turn.

The first part reviews the technical analysis dimensions of EE retrofitting of existing residential buildings in the existing literature. This typically seeks to measure reductions in energy demand through the efficient design of the building, or from the integration of either insulation or renewable energy systems. Nevertheless, it highlights the difficulties in reaching the desired sustainable EE outcomes in housing through the technological interventions alone, and thus calls for examination of the occupant user dimensions. The second part of Chapter 4 reviews the behavioural dimensions in relation to the influence of the housing occupants (and energy consumption practices) on the building energy performance; and how behavioural interventions can exert significant influence on overall energy consumption at the HH level and in the environmental performance of houses.

Chapter 5 examines some of the key factors that affect EET adoption and use and energy consumption practices. Through an interdisciplinary perspective, it examines some of the complex factors that the existing literature has identified as being significant in determining aspects of people's adoption decision-making. This includes demographic, social, political, economic and psychological factors, as well as temporal and ideological structuring of domestic practices.

Chapter 6 outlines the dominant theoretical discourses from across key disciplines such as psychology and sociology. These have offered a range of insights into understanding how the public engage with environmental issues as well as the key theoretical models that have been used to understand, predict and change people's responses to energy and environmental issues (i.e. to promote voluntary pro-environmental behaviour). It also examines how these dominant approaches have shaped current policy interventions for energy use behaviour change. From a sociotechnical critical viewpoint in particular, the normative behavioural models and approaches appear to decontextualise 'behaviours' through the way they seek to generalise and seek causality in order to change them. The rationale for the domestication approach is introduced into the debate to highlight the complexity involved in the process of technology-mediated change.

Chapter 7 presents the research theoretical framework. DT is used both as a conceptual and analytical framework for the empirical investigation. The chapter is divided into three parts. The first part outlines DT as a sociotechnical theory and presents a rationale for its application. The second part traces the background theoretical context and origins of DT; it reviews existing literature relating to DT. The third part of this chapter presents the research framework based on DT and the review of existing DT studies.

Chapter 8 sets out the methodology used to respond to the research questions put forward in this chapter. The philosophical assumptions underlying the empirical research methodology are introduced, followed by a description of the overall research design and methods used. In particular, it emphasises the rationale for a qualitative approach based on the research aims and objectives. It highlights the need to identify and utilise an alternative conceptual and analytical perspective beyond quantitative methodologies to complement the sociotechnical and qualitative approach.

Chapter 9 to 11 present the research findings and discussion. The findings containing the analysis of the empirical data gathered from semi-structured HH interviews has been divided and presented across three chapters. **Chapter 9** presents the housing background and socio-demographic descriptive data analysis of the HH captured in the research sample. The main data analysis using the domestication lens is split between two differing scales of analysis: the 'whole house' and individual EET level. **Chapter 10** focuses on outlining a broader domestication process of EET at the '*whole house'* or building level; and **Chapter 11** presents analysis on the domestication of a selection of discrete *individual* EET. The main rationale of this analysis was twofold: first, to identify key factors that supported retrofitting of a suite of EET and integrated into the sociotechnical system of the house; and secondly, to expand analysis beyond questions which either support or illuminate each of the four phases of the domestication lens. The two-tiered analysis of empirical data was undertaken not just for contrasting purposes, but also for the complementary yet differing perspectives it could offer, in particular, to provide greater understanding of the complexity of interactions between EET adoption, use and everyday domestic life

Chapter 12 presents a discussion of the findings of the empirical investigation. First, it provides a summary discussion of the research findings using the four phases of DT conceptual framework, and provides an evaluation of the model's application and development within the context of housing EET retrofitting. Second, it provides proposals for theoretical expansion through the domestication framework's modification.

Chapter 13 concludes the analysis by summarising the entire research project. It systematically highlights how the research aims and objectives have been met and the key contributions it has made to our knowledge. It provides discussion of the implications for policy, which could aid the formulation of effective solutions that could increase EET adoption. It also provides an evaluation of empirical investigation and considers some of the limitations of the study; and finally, it identifies areas for future possible research.

Table 1 Outline of the structure of the thesis

		Contextual background	Chapter 1	Introduction
Literature Review			Chapter 2	Broad Context
			Chapter 3	Policy context
	Review of empirical scholarly studies	Existing research evidence	Chapter 4 -5	Technical and behavioural studies; Adoption studies
			Chapter 6	Review of theoretical models and approaches
		Theoretical Framework	Chapter 7	Domestication Theory - origins, conceptions, and research framework
Data Collection			Chapter 8	Methodology
Data Analysis & Discussion			Chapter 9	Findings A – Respondent Background
			Chapter 10	Findings B – Whole House Domestication
			Chapter 11	Findings C – Domestication of technologies
			Chapter 12	Discussion/Interpretation of Findings
			Chapter 13	Conclusion

1.8 Chapter Summary and Contributions to Knowledge

This chapter highlighted the central problem and rationale underpinning this research study. It seeks to expand through a sociotechnical perspective existing social science and interdisciplinary perspectives of environmental debates and issues of EE, everyday energy consumption and the built environment. Through the DT perspective, it seeks to challenge the dominant normative research[7] and policy discourses around energy saving technology adoption and embedding. The research holds implications for improved policy understandings of energy demand management issues and for interventions that seek to increase the diffusion and embedding of EET amongst homeowners across the UK.

In particular, the empirical study will make a unique contribution to the field: (1) its application of DT within the context of domestic and building-specific EET is novel; (2) the methodology will result in the collection of significant new data on decision-making processes and experiences of homeowners of existing housing living with a package of innovative technologies – through their adoption, use/disuse and adaptations in their everyday lives; and (3), the originality of the research will make a contribution to academic understandings of DT and its relationship to the social study of technology developed uniquely through HH perspectives – which focus on the interaction between sustainability policy, energy efficient technologies and homeowners' experiences and everyday domestic practices. In sum, the original contribution to knowledge of this thesis is in using DT to present and analyse in-depth evidence about how and why HH adopt and embed EET into their everyday lives.

[7] As developed by, e.g. Crosbie and Baker, 2010; Guy and Shove, 2000; Gram-Hanssen, 2010, 2014, and others.

Chapter 2: Broad Contextual Background

2.1 Introduction

Through a sociotechnical perspective, this chapter highlights how and why the energy efficiency (EE) of housing has become a key part of tackling climate change. Thus, it discusses how the existing housing stock and contemporary energy consumption patterns challenge government EE policy. In particular, it highlights the sociotechnical challenges of reducing household/householder (HH) energy demand, which is not simply about adopting EE measures and technologies alone, but is also reliant upon changing everyday energy consumption behaviours. It will outline some of the human and non-human (technological) factors influential in the housing EE discourse, through the key broad debates and issues in this area – discussed in further detail using the following sub-categories:

- Sustainability, energy and climate change goals;
- National policy goals;
- Inefficient existing housing stock;
- Low housing stock replacement rates;
- Increasing HH energy consumption;
- Increasing housing renovations and low adoption of EE measures;
- Aspects of sustainable housing and energy efficient technology retrofit.

2.2 Sustainability and Climate Change Goals

There is now widespread political acceptance that there is a link between energy use and climate change, i.e. that the burning of fossil fuels releases carbon dioxide (the main greenhouse gas) into the atmosphere which contributes to global warming (IPCC, 2007; Office of Climate Change, 2006[8]). Improving the EE of domestic buildings was conceptualised as a sustainable strategy, which could help to tackle the problem of reducing greenhouse gas emissions (specifically CO_2 emissions). Reducing CO_2 emissions through developing mitigation strategies is a global priority supported by the UK government (DETR, 2000; 2009; Blewitt, 2008). Key milestone strategies were set out in *The UK Low Carbon Transition Plan* (HM Government, 2009), the *Climate Change Committee Report* (CCC, 2008) and the *Stern Review* (Office of Climate Change, 2006).

The UK government recognises that tackling climate change is not only a technical problem but also a social one, and any effective measures need to address both areas. In particular, it favours solutions that embrace a sustainable approach to resource use and management, including using energy more efficiently and using alternatives such as renewables that limit harm to the environment (DETR, 2000; EST, 2011b; Blewitt, 2008).

Hence, at the heart of the UK government's sustainability and climate change agenda are broad aspirations to protect the environment by reducing pollution levels and the amount of waste sent to landfill, protecting areas of natural landscape and biodiversity, and flood prevention, as well as enforcing the regulations that keep water and air clean. Therefore, improving the EE of buildings is, by extension, a way of protecting the environment. There is an accompanying expectation of spill-over benefits (e.g. double dividend effects) of people adopting a more sustainable way of

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8 E.g. *Intergovernmental Panel on Climate Change Fourth Assessment Report*; Office of Climate Change, *Stern Review*, 2006; reports on the potential threats and challenges of climate change.

living – through efficiency in their use of energy and energy conserving actions, as well as in water consumption and waste management (DCLG, 2012[9]; DEFRA, 2004; HM Government, 2009a[10], 2009b[11]; Blewitt, 2008).

Additionally, policies to increase building EE appear to support wider, multiple political agendas. These include energy security (i.e. obtaining better security of energy supply with lower dependence on imported fuel); economic goals (i.e. increased employment and economic activity); contributing to fuel poverty reduction goals and climate change goals (i.e. reducing CO_2 emissions). All of which appear to reinforce the 'low carbon' 'sustainability' agenda (DECC, 2009; HM Government, 2005; Monkhouse & Dibb, 2012; Wetherill, Swan & Abbott, 2012; UKGBC, 2008).

2.3. National Policy Goals

The UK's low carbon sustainability agenda is government driven and underpinned by a package of national and international policies and regulations. However, this agenda also appears challenged by a number of existing characteristics of the built environment and trends in domestic energy consumption – examined in more detail in the following sections.

Through the Climate Change Act 2008, the government has set out ambitious and legally binding requirements to reduce greenhouse gas emissions to at least 80% by 2050 (i.e. to below 1990 levels). It recommends a greater role for EE in meeting such targets (CCC, 2008). It also places a special priority on reducing carbon demand in the short term, whilst new low carbon energy generation systems and paths are being developed. It has set targets for demand reduction in the UK across different sectors

9 Reflected in the *National Planning Policy Framework*.
10 *The UK Low Carbon Transition Plan*.
11 *The UK Renewable Energy Strategy*.

and over time (e.g. the EU's 20% CO_2 reduction target set for 2020) – in line with the longer-term target of reducing emissions by 80% (or more) by 2050 (DECC, 2009; Monkhouse & Dibb, 2012; Wetherill, Swan & Abbott, 2012). A number of other drivers originating from an international and EU level set key UK targets – discussed further in Chapter 3.

Additionally, approximately, 50% of UK energy is used in buildings, and of this 27% is used within the domestic sector, which accounts for 29% of UK carbon dioxide emissions. This figure is likely to increase if steps are not taken to reduce energy consumption (DECC, 2010, 2011). This means that housing contributes to over a quarter of the UK's carbon emissions, with more than 26m homes in the UK each contributing to an average 5.1 tonnes of CO_2 emissions per year, equating to a total of 129.4 million tonnes of CO_2 per annum (Palmer & Cooper, 2011). A large proportion – 82% – is used for space and water heating, whilst the remainder is split between cooking and appliances. Hence, improving domestic EE represents a major opportunity to cut energy use and CO_2 emissions (CLG, 2009b). Therefore, demand reduction for space heating and substitution of remaining demand through renewable sources is a key to meeting the EU's 20% CO_2 reduction target set for 2020 (DECC, 2009, 2010, 2011).

2.4 Inefficient Existing Housing Stock

The challenges of the housing sector as a major energy user (Palmer & Cooper, 2011) are exacerbated by the fact that a large proportion – over 70% – of homes that will exist in 2050 are already built (Wright, 2008; Boardman et al. 2005). Of this, private homeowner occupiers (70%) constitute the largest and most energy inefficient component of the residential housing sector (Power, 2008; Ravetze, 2008). Estimated figures suggest that retrofitting EET is required for 'approximately 25.8 million units of the existing housing stock that will still be occupied by 2050 and the rate at which heat is lost in them will have to be halved over the next 42 years' (Boardman, 2007,

p. 56). Hence, improving the EE of the entire UK existing housing stock has become a key of focus of government policy interventions (DECC 2010; Utley & Shorrock, 2008; Power, 2008; Ravetze, 2008).

The UK building stock has seen major changes in the last 50 years, in its form, fabric and function. In particular, while the energy performance of much of this stock is generally low, its economic, social and cultural values remain high (Ravetze, 2008; Hand, Shove & Southerton, 2007). The poor existing condition of the existing housing stock and the amount of energy it consumes is dependent upon a variety of factors, e.g. dwelling size and type, age, ownership, construction details, function, heritage status, occupant behaviour, etc. (Lowe et al. 2012; Ravetze, 2008; Rydin, 2013).

Variations in housing conditions, age and performance are a typical feature of most Western developed countries. Furthermore, much of the UK's housing existing stock is old or traditional vernacular (built more than 50 years ago, mainly with coal fires and outdoor sanitation) and of a poor quality. For example, many houses often contain poorly performing and 'hard-to-treat' solid walls, single glazing and un-insulated roofs/floors, and suffer from significant thermal heat loss. Many of the houses that continue to exist today were built before implementation of stringent building regulations or assessment of their environmental or energy performance (Burton, 2012; Dowson et al. 2012; Lowe et al. 2012; Ravetze, 2008; UKGBC, 2008; Rydin, 2013).

The majority of the existing house stock was typically built before the Second World War, and accounts for most of the dwellings in the least efficient Energy Efficiency Rating (EER) Bands F and G (DECC, 2010a; Power, 2008; Ravetze, 2008). Moreover, approximately two million of the existing houses have a Standard Assessment Procedure (SAP) rating below 30, where the national average is around 50 (Boardman et al. 2005). Therefore, many homeowners were likely to be 'lockedinto' living in energy inefficient houses unaware of, and with very little control over, the level of carbon emissions, their buildings contributed. Therefore, policy seeks to improve the fabric of the current and future housing stock as well as the energy consuming services within domestic properties (Beddington, 2008; Power, 2008; Sustainable Cities Institute, 2009).

2.5 Low housing stock replacement rates

A further area of concern relates to the low rates of replacement and renovation of existing housing, rates of new build construction and the debate over demolition versus renovations. The fact that 70% of the current housing stock will continue to exist in 2050 implies that 30% of the 2050 housing stock remains to be built (Wright, 2008). However, there have been concerns that there are low levels of new housing construction (Boardman, 2007, p. 36), although recent figures of annual housing completions in England totalled 114,440 in the 12 months to June 2014 – an increase of 7% compared with the previous 12 months. These figures suggest that building levels are improving. Furthermore, the present rate of demolition in the UK is low – resulting in less than 0.01% of the total stock demolished each year (Boardman, 2007; Ravetze, 2008). The current average annual replacement rate of the national housing stock was estimated to be less than 1% per year (GOFS, 2008; Ravetze, 2008).

These conditions invariably feed into policy goals to increase the rate of adoption of EET by the existing building stock. Retrofitting EET is an attractive option because it is seen as a potential contributor to policy goals and also because demolition action is not yet regarded as a viable alternative due to its likely negative environmental impact (Boardman et al. 2005; Power, 2008). The decisions over whether to demolish, build new, or to just retrofit are often contingent upon a number of other factors, e.g. the perceived cost-effectiveness of the proposed changes, conservation of heritage attributes, life cycle analysis and status and the likely environmental and community impacts. However, the continued existence of a large quantity of 'already' built housing by 2050 will mean the need to retrofit EET will far outweigh the demolition option (Burton, 2012; Boardman et al. 2005; Power, 2008).

2.6 Rising Household Energy Consumption Trends

In addition to the poor quality of the existing housing stock, there are concerns that government efforts to reduce HH level emissions are likely to be challenged by the nature of rising HH energy consumption patterns. One figure suggests that domestic consumption constitutes 31% of the UK's electricity demand (DECC, 2011). This rising consumption is often associated with new technical developments and consumption of technology, economic growth, national prosperity and cultural and lifestyle changes (Martiskainen, 2007; Ravetze, 2008; Lomas, 2010) – all of which are expected to continue to rise and undermine policy goals (Chitnis & Hunt, 2012; Firth, Lomas & Wright, 2010).

Additionally, an increase in the size of the UK population, combined with a fall in the size of HH, means that by 2050 the number of HH will increase by 23% and 'if nothing else changed, a 23 per cent increase in energy consumption' (Boardman, 2007, p. 6). Critically, existing uninsulated and leaky housing wastes energy due to its poor construction and through misuse by the occupants. Linked to this is the social value of the existing building which encompasses the different needs, expectations and budgets of homeowners and occupiers, which are likely to determine the type of energy-related domestic practices or behaviour undertaken in them (Dowson et al. 2012; Gram-Hanssen, 2010; Hand, Shove & Southerton, 2007). Importantly energy is an abstract value that is wrapped up in a combination of practical, social, material and aesthetic values and embodied in its consumption in everyday domestic practices.

2.6.1 Space heating

HH use energy for a range of everyday domestic practices: heating, lighting, cooking, cooling, washing, ventilating and for appliances (EST, 2011; Which, 2011). One influential consumer report by *Which?* (2011) suggests that space heating is the largest area (60%) of HH consumption (by end use), followed by lighting appliances (19%) and water heating (18%); cooking or catering activities is the lowest (3%). Other figures suggest that space heating accounts for a slightly higher 65% of a UK home's energy use, and ventilation heat loss is estimated to be around 20% (Utley & Shorrock, 2008). Thus, the energy use in existing housing not only wastes energy due to poor construction but also due to the operation and use of space heating technologies by their occupants.

2.6.2 Appliances

Over the last 30 years, there has been an increasing proliferation of electrical appliances in homes, and in the ownership of a greater variety of newer technical appliances[12] alongside established technologies (e.g. white goods[13]) (Martiskainen, 2007; Ravetze, 2008; Lomas, 2010). It is the growing number of domestic electrical appliances that is often connected to the observed trend in increasing energy consumption in buildings. It is generally recommended that when consumers are seeking to replace older appliances they use the energy labelling standard to identify new energy efficient ones (EST, 2006; 2011; *Which?*, 2003). Although, many newer appliances use significantly less energy than older appliances, they can still use more energy because of their increasing numbers, being left on for longer and being left on standby. Therefore, energy wastage is a key problem in the UK, arising specifically from habitual inefficient HH energy consumption behaviour (HECB). Other actions include the use of cars for short journeys; leaving appliances on standby; leaving mobile phone chargers plugged in; leaving lights on in unoccupied rooms; boiling

[12] E.g. PlayStations, home Wi-Fi, laptops, kitchen gadgets, exercise machines, garden equipment, mobile phones.
[13] E.g. TVs, washing machines, hobs, fridge freezers, dishwashers.

more water than is needed and so forth (EST, 2006, 2011; Martiskainen, 2007; *Which?*, 2003).

2.6.3 Poor HH linkage between energy consumption and climate change

A further challenge for government policy is the failure by many people to link their HECB to climate change. This failing is perceived to be exacerbated by the 'invisibility' of energy in everyday energy consumption practices (Martiskainen, 2007; *Which?*, 2003; Pierce, Schiano & Paulos 2010; Hargreaves, Nye & Burgess, 2010). A national 'energy' poll (National Energy Foundation, 2014[14]) of British consumers highlights some of the shortcomings in understanding and knowledge of domestic energy use issues. For example, this survey states:

Most British adults say they would like to reduce their energy consumption, either because of the financial cost of using energy (four in five, 81%) or because of the environmental impact (seven in ten, 70%). However, around two thirds of British adults (64%) do not know the most effective way to make a typical home energy efficient (loft insulation). This is despite three in five (56%) saying they would be confident in making improvements to their home to make it energy efficient.

Furthermore,

British adults are not consistent in their estimation of energy consumption across a range of everyday, HH items. While a majority (61%) assume the correct energy consumption for a light bulb, less than half accurately estimate the correct energy consumption of everyday HH appliances such as a power shower (44%), a kettle (42%), an electrical convector heater (42%) and a tumble drier (38%). (National Energy Foundation, 2014, p. 3)

[14] ComRes for the National Energy Foundation (NEF) interviewed 2,058 GB adults from 5–7 September 2014. The data was weighted to be representative of all GB adults aged 18+.

2.7 Missed Opportunities for EE alongside Home Renovations

A further relevant area that government policy seeks to influence is in the rising trend in home renovation practices. It is reported that in the UK about £24–£27 billion every year is spent on a range of internal and external home improvements, interior redecoration, new kitchen and bathrooms, essential maintenance and repairs (TNS-BMRB, 2011; Green Building Council, 2008, p. 2). However, there is concern that very little of this goes towards retrofitting EE measures.

Furthermore, renovation activity is frequently carried out to suit homeowners' aspirations and is 'embedded within HH cultural practices and is an integral part of homemaking' (Maller & Horne, 2011, p. 60). According to an English Housing Condition Survey[15]: '41% of the United Kingdom's housing stock (particularly those built before 1919) has had at least one major alteration since being built'. Moreover, 'across the total UK housing stock, the most common alterations are the rearrangement of internal space (16%), extension for amenity (15%), and extension for living space (14%)' (Hand, Shove & Southerton, 2007, p. 669). Similar undertakings were deemed highest amongst owner-occupiers who tend to have higher incomes and a greater stake in their properties (than social tenants do) and thus more likely to want to make improvements (EST, 2011).

Therefore the vast majority of home renovations involve the reconfiguration and modernisation of existing housing, but seem to be without any explicit consideration for EE and thereby fail to contribute towards reducing carbon emissions (Maller & Horne, 2011; EST, 2011). For policymakers, this trend is perceived as a missed opportunity to contribute towards climate change goals (Stiess & Dunkleberg, 2012; Weiss et al. 2012). This is something that the former Green Deal policy sought to

[15] From 2001 cited in Hand, Shove & Southerton, 2007, p. 669.

address. For example, through the aptly named 'Green Deal Home Improvement Fund' it sought to incentivise and subsidise various EE measures for homeowner occupiers who were already thinking about/or undertaking home renovation activities (Cabinet Office, 2011; EST, 2011).

Moreover, this innocuous trend (of renovation without EE) also suggests that an examination of the complex socio-cultural and practical reasons that underpin people's reasons for undertaking renovation works could help in understanding the low adoption of EET (Burton, 2012; Maller & Horne, 2011). For example, some suggest that examining the social and cultural dimensions could reveal that people may be seeking to meet other values, needs and desires from their homes, affecting the technology they appropriate and the various changes they make to their home through renovations (Hand, Shove & Southerton, 2007; Maller & Horne, 2011). Thus, the key challenge for government policy is to ensure that forthcoming renovations are energy efficient ones. Government began addressing this issue through a mix of regulations and policies discussed further in Chapter 3.

In terms of progress to date with retrofitting EET, one report suggests that 'almost three quarters of homes have double glazing installed throughout the whole property. Cavity wall insulation is present in 68 per cent of homes with cavity walls. Loft insulation is the next most common measure, with 65 per cent of homes with lofts having at least 125mm in place. The least common EE measure reported is currently solid wall insulation, with only two per cent of solid wall homes having the measure in place'[16] (DECC, 2012). These figures suggest 'that whilst significant progress has been made in the installation levels of some EE measures there is plenty of remaining' yet unused 'potential in the domestic sector' (DECC, 2012, p. 28). More specifically, in relation to the installation of the more advanced domestic micro-generation technologies (e.g. solar panels) that are likely to have greater impact on reducing

[16] DECC, 2012: data derived from secondary analysis of a range of statistical sources, p. 28. Equivalent comparative figures for how much is spent on EE retrofitting measures could not be found at this point.

domestic energy consumption, uptake remains significantly low in the consumer market. There is concern that if this trend continues it will mean that national targets are unlikely to be met (DECC, 2012).

Higher upfront costs are cited as a key reason for low adoption of EET. These are considered to act as a deterrent to its greater adoption, particularly of the 'advanced' measures. For example, energy efficiency measures such as internal or external insulation cladding are considered substantially more costly and disruptive than simple cavity wall injection. Furthermore, whilst the unsubsidised cost of a cavity wall injection is approximately £500, external solid wall insulation could cost from £10,000–£14,000 (EST, 2011; McDonald, 2013). Thus, solid wall properties with 'hard-to-treat' walls would ideally require the more costly external/internal wall insulation – yet most private HH are unlikely to be able to afford its capital cost and the accompanying disruption (EST, 2011; McDonald, 2013; *Which?*, 2003). Hence, in recognition of this particular difficulty the government has sought to address the issue through its ECO funding – discussed in Chapter 3.

2.8 Aspects of Sustainable Housing and EET retrofit

2.8.1 Definition of housing EE retrofit

In general, for the purposes of this research EE refers to installing or using technologies (and associated changes) in a way that means using less energy to produce energy saving outcomes (Martiskainen, 2007; POST, 2012[17]; Poortinga et al. 2003). Thus, the retrofitting of EET (also referred to as EET adoption) at the building level, and at its simplest, refers to the incorporation of changes to its structure (fabric) or its systems 'after its original construction and occupation'. Furthermore, it is typically undertaken with the expectation of improving amenities for the building's occupants and/or improving the performance of the building, which can allow for significant reductions in energy and water usage (Burton, 2012; Chahal, Swan & Brown, 2012, p. 2; Rhoads, 2010, p. 6). Within this context, the process of change could typically either include the adoption of a single or combination of measures, broadly divided into: 'fabric, systems, appliances, feedback systems and control measures' (Burton, 2012; Chahal, Swan & Brown, 2012, p. 2), some of which may have direct or indirect impact on energy use, savings and efficiency (Poortinga et al. 2003).

EE measures installed as part of a housing retrofit can be further distinguished by placing the differing attributes of each measure within a continuum. These attributes are defined by the degree to which they deliver EE performance (and to some extent by their costs), and the extent to which they are perceived to be 'qualitatively different' from each other (Boardman, 2007; Clark, 2010; Shorrock, Henderson & Utley 2005; Lowe et al. 2012). For example, basic measures (cheap or shallow options) are typically delivered by draught proofing, cavity wall and loft insulation;

[17] The actual energy reduction from a baseline and that would otherwise be used without the presence of the intervention (POST, 2012).

more advanced measures and with the highest achievable carbon and energy impact (costly or deep) are considered to be delivered by, e.g.: solid wall insulation, replacement of existing heating and ventilating systems, micro-generation renewables and ‘passive house’ principles (Boardman, 2007; Clark, 2010; Killip, 2009; Lowe et al. 2012; Shorrock, Henderson & Utley 2005). Importantly, it is the ‘fabric first’ or ‘fit-and forget’ measures such as insulation to a building’s envelope (i.e. walls, floors, roof and windows) which are perceived to be critical for the EE of houses and often promoted by government and the building industry (EST, 2010, 2011; Institute for Sustainability, 2012; Rydin, 2012; BRE, 2003). This contrasts with a lack of a clear government consensus to date, specifying best practice for the order and extent to which differing EE measures should be implemented – even though it primarily advocates a technology-driven approach.

Some do not consider increasing the EE of the existing stock to be a ‘technically’ difficult task (Rydin, 2012; Burton, 2012). Any technical area that needs to be addressed as part of an energy efficient and sustainable retrofit (and ideally not addressed through a single measure) requires the integration of multiple actions (Burton, 2012; Rydin, 2012; Institute for Sustainability, 2012). For example, the key ‘sustainability’ principles are said to be to: ‘reduce heat loss in winter and heat gain in summer (avoid overheating); minimise all energy demands; enable adequate ventilation; re-use existing materials; reduce residential water consumption; and where renewables need to be part of the mix to move towards zero carbon goals’ (Burton, 2012, p. 1). However, this comes with the caveat that even once adapted to sustainability principles, the buildings have to be used sustainably too – through a more sustainable lifestyle (Burton, 2012, p. 8). The influential role of human – occupant – behaviour is discussed further in Chapter 4.

Additionally, and as discussed already, the envelope of a house can be improved by adoption or retrofitting a number of EET:

- adding insulation to the walls (e.g. internal or external wall insulation options for solid walls), roofs (through loft insulation) and floors (underfloor insulation); and inexpensive insulation for cavity walled properties;
- installing double, triple or secondary glazing to help prevent heat loss through windows (counting towards envelope measures);
- draught proofing windows and doors (inexpensive yet effective);
- upgrading an old boiler or other appliances to an energy efficient model (help towards reducing energy consumption);
- water saving and efficiency features in taps and other water consuming devices (easy to retrofit); and
- installation of renewable micro-technology (sometimes referred to as sustainable technologies) (Burton, 2012; Institute for Sustainability, 2012).

In particular, best practice for retrofitting EET ideally advocates a 'whole-house' and/or a sequential approach and would include a package of measures installed into existing dwellings. This is the most effective approach as no single measure could be prescribed for all housing types. Nevertheless, they are also dependent on contextual components, i.e. the form of construction (BRE, 2003; EST, 2010, 2011; Institute for Sustainability, 2012).

2.9 Chapter Summary

This chapter has highlighted the sociotechnical challenges of increasing the EE of the existing housing stock and why it has become a key part of tackling climate change and energy demand reduction. In particular, it has highlighted how despite public awareness of the need to make homes energy efficient, and the availability of viable tried, tested and established conventional and innovative technologies, the problem of low adoption of EET persists, particularly in the private home owning sector of existing housing. Therefore, one of the questions for policymakers is not necessarily which measures to encourage, but how to incentivise more people to retrofit a range of EET measures (beyond single measure adoption).

Furthermore, whilst there is policy recognition that rising energy use in buildings and in HH is very much a sociotechnical problem, often in practice the 'socio' part has been underplayed and the technical/technological solutions promoted – suggesting a mostly technology-driven policy approach. Chapter 3 will specifically discuss and evaluate the main policy and regulatory frameworks – which represent the material and technical context underlining the housing EE policy delivery framework targeting occupiers of existing housing.

Chapter 3: Policy Context of Housing Energy Efficiency Retrofit

3.1 Introduction

As part of its carbon reduction strategies, the UK government has issued a range of instruments in recent years – policy statements, white papers, legislation, regulations and policies – designed to support and promote rapid consumer EE adoption in existing housing stock (Caird & Roy, 2008; DEC, 2012; 2013; Wetherill, Swan & Abbott, 2012). It is argued (e.g. Caird & Roy, 2008; Crosbie & Baker, 2010; Ozaki & Shaw, 2014) that current policy approaches represent an overly technocratic approach. This approach seeks to remove some of the perceived technical, economic, institutional and behavioural challenges (some already identified in Chapter 2) (POST, 2012) to help increase EET adoption rates in the existing home-owning housing sector (POST, 2012).

Nonetheless, greater scrutiny of this policy and its regulatory context is pertinent to understanding the basis from which individuals or HH make decisions and choices (the focus of empirical analysis in this study) about whether or not to adopt EET. This chapter provides a policy overview and evaluation of the effectiveness of UK housing policies, particularly focusing on those, which influence the existing private sector housing stock. It begins with an examination of international and European policies, before exploring the national level energy targets, polices, planning, and building regulatory framework. It then moves on to examine the role of local authorities and the mechanism for the homeowner owner occupiers.[18]

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[18] The policy overview uses both grey and academic literature sources.

3.2 International and European Policy Influences

A number of international commitments, such as the United Nations Framework Convention on Climate Change (1992), the linked Kyoto Protocol (1998) and the Copenhagen Accord (United Nations 2009), set the global milestone of 'keeping global warming under two degrees Celsius. These therefore set the basis for the UK's climate change and energy policy (Abbott, Swan & Wetherill, 2012; DECC, 2014; POST, 2012). Under the Kyoto Protocol, the UK has assumed an international legal obligation to reduce its greenhouse gas emissions.

At the European level, EU law sets requirements for member states in a wide range of areas, including electricity and natural gas markets, emissions of greenhouse gases and air pollutants, EE and renewable energy. The European Climate Change Programme – formed mainly in order to meet the EU's obligations under the Kyoto Protocol – has established a number of directives that aim to reduce greenhouse gas emissions. The UK is therefore bound to give legal effect to EU directives specifically relating to EE and housing, i.e. Climate and Energy Package, Emission Trading System (EU ETS), various directives on the energy performance of buildings, the Eco-Design of Energy-Related Products (ERP) Directive (Abbott, Wetherill & Swan, 2012:2; DECC, 2009; DECC, 2014;[19] POST, 2012). For example, the Directive on the Energy Performance of Buildings sets out a 20% reduction in CO_2 by 2020 and a 20% renewable energy target for 2020 (DECC, 2014).

3.3 National Level Energy Targets and Policies

Consequently, a combination of international, European and national commitments have informed the policy, regulatory and legal framework for EE policies within the UK. The core means of tackling climate change and domestic EE are contained in the

[19] UK National Energy Efficiency Action Plan.

Climate Change and Sustainable Energy Act 2006, the Climate Change Act 2008 and the Energy Act 2011. The Climate Change Act 2008 sets out legally binding national 'carbon budgets' over the next 40 years, i.e. targets to reduce carbon emissions by 34% by 2020, and a minimum of 80% by 2050 to a baseline of 1990 (as set by the Kyoto Protocol); and to generate 15% of UK energy needs by renewable sources by 2020 (DECC, 2009, 2014; Jones, Lannon & Patterson, 2013).

Furthermore, the Energy Act 2011 brought forward the date for achieving the zero carbon goals to 2016 and provided the legal framework for the Green Deal policy. Until they both became defunct following the change of government in 2015, they were two of the key mechanisms driving the low carbon and climate mitigation agenda. In conjunction with these aims, the government had devised a number of non-mandatory policies, which were intended to assist in the delivery of its key national targets. They included: the Green Deal (defunct); Energy Company Obligations (ECO); the Green Investment Bank (defunct); the Feed-in Tariff (FiT); and the Renewable Heat Incentive (RHI) (Dibb & Monkhouse, 2012:15; Jones, Lannon & Patterson, 2013). The key policy mechanisms applicable to existing housing in the UK are summarised in Table 3.

3.4 National Planning and Building Regulatory Framework

The national EE goals for housing are also reflected in the planning and buildings regulatory framework as well as policies for the built environment. Those of particular relevance to the EE retrofitting of existing housing stock in terms of their regulation, construction and use, are contained in a number of key policies, acts, regulations and incentive schemes (Abbott, Wetherill & Swan, 2012; Dibb & Monkhouse, 2012).

Firstly, there are key legislative instruments:

- The Town and County Planning Act 2008 – planning (land use) legislation for England and Wales;
- The Planning and Energy Act 2008 – enables local planning authorities to set requirements for energy use and EE in local plans; and
- Building Regulations, Part L1 (B) – designed to ensure that mandatory minimum standards are set with which all buildings proposing refurbishment need to comply (Planning Portal n.d.).

A number of supplementary tools accompanies these and policies which are intended to help measure energy performance of buildings, such as:

- The National Planning Policy Framework (NPPF) (DCLG, 2012) – sets out the government's planning policies for England;
- The Standard Assessment Procedure (SAP)[20] which enables measurement and comparison of the EE of buildings based on costs (BRE, n.d.); and
- Energy Performance Certificates (EPC) which are required when a property is sold bought or rented and rates the actual energy performance of a building (DCLG, 2014).

However, the SAP and EPC do not provide a comprehensive account of the EE of existing buildings. For example, properties that are in private ownership (either privately rented or owner occupied) are subject to regulation via the EPC only when being sold or rented (DCLG, 2014; Monkhouse & Dibb, 2012). Hence, the EPC or SAP ratings of many existing properties remain unknown in government policymaking.

There are a number of land use and development planning policies, from the national to local levels that have the potential to support the EE of existing domestic buildings. For example: the NPPF; the London Plan and Local Plans originating at local planning authority or borough level.

3.4.1 National planning policy

Furthermore, following the devolution (1998) of powers to Scotland, Wales and Northern Ireland[21] and subsequent reforms to the national planning system, each country now has their own strategic planning policy frameworks. The English planning policies are specifically outlined here as this forms the policy backdrop for the HH participants in this research. The NPPF sets the government's planning guidance for England.

The NPPF, which came into force in March 2012, forms the overall framework of national planning policy, and is a material consideration in local decisions on planning applications for new and existing development proposals. It must be taken into account in the formulations of the local development plans (i.e. Local Plans formerly known as Local Development Frameworks) and Neighbourhood Plans (DCLG, 2012).

The NPPF contains an explicit reference to the need to *'actively support energy efficiency improvements to existing buildings'*. Furthermore, all Local Plans will need to be developed in conformity to it. While the NPPF appears to provide a strong strategic goal for EE nationally, it does not articulate what EE, nor do the types of

[21] Following the devolution of power to the Northern Ireland Assembly, the Welsh Assembly and the Scottish Parliament, each country of the UK has its own planning system that is responsible for town and country planning (UK Parliament n.d.).

measures (except for renewable technology measures) mean that it considers appropriate and how targets ought to be achieved.

3.4.2 New build policies

As expected, the NPPF sets out the requirements for new build housing and is supported by a number of key national policies, in particular: Allowable Solutions, the Zero Carbon Homes Policy and the Code for Sustainable Homes (ARES, 2016). However, the latter two were withdrawn by government in 2015 and thus hold serious knock-on effects for the low carbon agenda (Dunton, 2015).

A key mechanism still in place is the 'Merton Rule' which requires new commercial buildings of over 1,000 square meters to generate at least 10% of their energy needs using on-site equipment powered by renewable energy (sun, wind or water). This rule, together with the introduction of the FiT scheme, arguably kick-started the renewable market sector by significantly helping to reduce the payback time of photovoltaic and wind/hydro turbine renewable energy capital costs (Dunton, 2015; Green Building Press, 2015).

However, there are rising concerns of the detrimental impact such 'policy reversal' is likely to have on achieving climate change goals. Future proposals to reduce the FiT and RHI subsidy are likely to add to the problems, particularly for the renewables industry as these changes could undermine confidence in existing and new technologies (in terms of their development, market growth and adoption). There are also now calls for the 'Merton Rule' to become a possible 'stand-in' for the scrapped Zero Carbon Homes Policy (Dunton, 2015;

Green Building Press, 2015).

Nevertheless, it should be noted in this context that sustainable housing through new build is still a small (1–2%) addition to the overall existing housing stock (Ravetze, 2008; Rydin, 2011). In the absence of the previous EE policies (discussed here) any forthcoming new builds[22] will not necessarily be as energy efficient as they could be; this will increase the numbers of inefficient housing units contained in the existing stock (Dunton, 2015; Green Building Press, 2015).

3.4.3 Building regulations

The current building regulations provide mandatory and optional minimum standards with which all building works must comply. The regulations contain two components: Part L1 (A) (ODPM, 2005, 2006) is applicable to all new buildings, seeks compliance with a series of design and construction features and standards aimed at minimising domestic energy consumption. However, of most relevance to existing stock is the second component – Part L1 (B) (ODPM, 2005, 2006). This sets out numerous minimum requirements and standards which must be adhered to where any improvement or renovation is carried out in an existing home, e.g. 'the insulation of walls and other fixed building elements such as floors, windows and roofs and the EE of heating and lighting' (Abbott, Swan & Wetherill, 2012:3). However, there are some 'overriding' circumstances where Part L1 (B) requirements will not need to be met. These are where 'the insulation is not cost effective' where the 'measures may compromise the design e.g. making the floor area too small or the floor uneven', or in the preserving of 'the historic character of listed buildings' (Todd, 2012:5–6).

22 Some large-scale refurbishments (e.g. 'gutting') of existing housing requiring planning permissions are considered in the same way as 'new build' in local authorities, hence this policy change affects not just new build.

Building regulation compliance required 'standards to be achieved for the "Thermal Elements" (walls, floors and roofs), "Controlled Fittings" (windows, doors and similar fittings) and "Controlled Services" (heating, hot water, ventilation systems and lighting)'. Regulations 'apply whether as part of an extension, dividing a house into flats, replacing windows, extending a heating system, applying render to a gable wall, or changing a building's energy status' (Todd, 2012:3).

There are key areas where the building regulations require energy-efficiency measures for some renovation (and at various points in the renovation process). 'For example, nearly everyone replacing a new central heating boiler is required to install a high-efficiency condensing boiler, and also to fit heating controls if these are not already present' (EST, 2011; ODPM, 2005; Todd, 2012). When more than half the inside surface of an external solid wall is stripped back to the brickwork, internal solid wall insulation must be installed. Under 'consequential improvements' of the regulations, building owners undertaking larger scale and expensive extensions or renovations and in which planning permission is more than likely, they are required to make energy-saving improvements across the property (and not just in the planned extension/renovation). This rule only applies for buildings or to sites over 1000 m^2, and therefore excludes the vast majority of small-scale home improvements (EST, 2011; ODPM, 2005). Nonetheless, many types of building works or home improvements will not require building regulatory or planning approval.

3.4.4 Listed buildings and conservation areas

Listed buildings are exempted from the EE requirements where compliance would 'unacceptably alter their character or appearance' (Building Regulation 21(3)). Therefore, its overall intention 'is to exempt works to improve EE that would otherwise be refused listed building consent'. Similarly, all buildings in conservation areas are exempted from the EE requirements where compliance would unacceptably alter the character or appearance of the building, whether or not it is listed. This is different from the requirements of planning law regarding conservation areas, which requires consideration only of the impact of proposed development on the character and appearance of the area (English Heritage, 2011; ODPM, 2005; Todd, 2012:5–6).

This aspect of the building regulations connects with another challenge of the existing historic housing stock, which often seems at odds with the differing regulatory frameworks at work at the building level. For example, local authorities often have to manage the competing interests embodied within historic buildings either with 'listed' status or conservation area designations, and protected and regulated under the Planning (Listed Buildings and Conservation Areas) Act 1990 (Historic England n.d.; ODPM, 2005; Planning Portal n.d.) and with those that operate alongside the planning regulations (which seek to prevent inappropriate development and influences its quality). However, the historic building and planning regulations by their very purposes may be inhibiting some of the existing housing from becoming more energy efficient, particularly due to the prioritisation of the preservation of existing historic features over EE measures.

Conservation and planning controls are often claimed to act as a barrier by affecting the cost and practicability of certain EE retrofit interventions for much older existing housing (Dowson et al. 2012; Hunt, 2012). Moreover, it is suggested that relatively more modern dwellings, with simpler house construction types and without a clear heritage value, appear to support simple retrofit measures (Lowe et al. 2012:6; Rydin, 2011).

3.4.5 Role of local authorities

As a result of the national and/or sub-regional policy mandates (set out above) local authorities have a key obligation to reduce their carbon emissions, which must result in significant improvements to all existing residential building stock. However, in terms of establishing targets and actions for the improvement of EE standards, local authorities exercise greatest influence over their own stock and social housing in the hands of registered social landlords, while having very little influence over privately owned housing within their jurisdiction. Thus, local authorities have limited power, or control, over improvements to existing private owner housing stock. There is scope for local authorities to determine the EE of new builds; and some scope for to influence EE where there are changes to existing housing stock that requires planning permission. They have the least scope for influence when it comes to changes to existing housing that do not require local planning applications and therefore do not fall under the radar of their influence (DECC, 2012; Wetherill, Swan & Abbott, 2012).

In recognition, of this limitation, many local authorities appear to undertake a nominal advisory role, particularly in relation to the private home- owning sector, e.g. they offer advice on energy use, and behaviour change, and energy saving; about suggest ways to make the home more EE;, and highlighting any local funding and grant incentives available to help fund EE improvements. In many cases, local authorities[23] have also partnered with other organisations (e.g. the Energy Saving Trust) in this advisory role.

Table 2 Key mechanisms supporting housing energy efficiency

Level	Tool	Name
International		United Nations Framework Convention on Climate Change (1992)
		Kyoto Protocol (1998)
		Copenhagen Accord (United Nations, 2009)
EU		European Climate Change Programme (EU 2006) directives: • Climate and Energy Package • Emission Trading System • Directive on the Energy Performance of Buildings Eco-design of Energy-related products (ERP) Directive
National	Legislation	Climate Change and Sustainable Energy Act 2006
		Warm Homes and Energy Conservation Act 2000
		Energy Act 2011
	Legislation	Climate Change Act 2008
		Town and County Planning Act 2008 Localism Act 2011 Planning (Listed Buildings & Conservation Areas) Act 1990
		Planning and Energy Act 2008
	Mandatory Standards	Building Act 1984 UK Building Regulations Part L1(A) - new buildings Part L1(B) - existing homes
		Standard Assessment Procedure (SAP)
		Code for Sustainable Homes
		Energy Performance Certificates (EPC)
		Feed-in-Tariff (FiT)
		Renewable Heat Incentive (RHI)
	Statutory	London Plan
	Statutory	Local Plans (local authority statutory development plans)

3.5 Key EE Mechanisms for Homeowners of Existing Housing

The following section examines in further detail some of the key mechanisms that fall outside the statutory mandatory regulatory framework and are applicable to delivery of EE in existing housing with components targeting the private home owning sector, e.g. the Green Deal; ECO; FiT; RHI; and smart meters (Dibb & Monkhouse, 2012:15; Fawcett & Killip, 2014). It should be noted that since the election of the Conservative government in May 2015, the Green Deal policy has been withdrawn and is now non-operational. This holds serious implications for increasing EE in the private housing sector as well as wider existing housing stock energy goals.

3.5.1 The Green Deal

The Green Deal was launched in the autumn of 2012. It was heralded as the coalition government's 'flagship' policy aimed at improving home EE for the entire housing sector and therefore reducing greenhouse gas emissions across Great Britain. The Green Deal policy emerged from the Energy Act 2011, which recognised the importance of improving the EE of the UK housing stock. It outlined a strategy for reducing HH energy costs and residential sector carbon emissions to tackle the issue of fuel poverty and meet the government's carbon budget targets. During its short lifetime the policy was criticised for its low uptake levels, its poor design and the meagre savings offered (DECC, 2013; Guertler, Royston & Robson, 2013; Mallaband, Haines & Mitchell, 2012).

One particular component of the Green Deal, although accessible to all owners of housing stocks such as local authorities and housing associations, was primarily aimed at individual property owners looking for funding to improve the properties they own and/or manage. As part of the Green Deal package homeowners were offered an energy assessment and loan to finance EE measures for existing housing.

The loan was offered as a financial incentive and support for homeowners to install a range of EE measures without paying any upfront costs. The loan was tied to the property and repaid through a charge attached to the homeowner's energy meter. Under the scheme, the loan was repaid from the savings made on the homeowner's electricity bills; only after the loan was paid off could the homeowner take full advantage of the energy savings. The scheme also allowed customers pay for some or all of the improvements over time through their electricity bills (Cabinet Office, 2011; DECC, 2011).

The first step in accessing Green Deal finance was a mandatory energy assessment, the Green Deal Advice Report (GDAR), which provided recommendations for EE improvements. Typically, they recommended improvements such as insulation (solid wall, cavity wall or loft insulation), heating upgrades, draught proofing and renewable energy generation (e.g. solar panels or heat pumps). There were approximately 50 measures that the Green Deal supported. Some of the key measures are summarised in Table 4 (which also demonstrates the range of EE measures HH participants in this study have implemented). However, the measures supported through Green Deal finance recognised that no standard set of measures would be appropriate for every property. Hence, the energy assessment (which included an EPC rating and assessment based on HH energy consumption) provided an individualised set of recommendations for appropriate improvements which also depended on a number of factors: the work already done, the characteristics of the building and, in some cases, the geographical location (Cabinet Office, 2011; DECC, 2011; Dunton, 2015).

Table 3 Key measures supported by the Green Deal (DECC, 2011)

Heating, ventilation and air conditioning	Condensing boilers Heating controls Under-floor heating Heat recovery systems Mechanical ventilation (non-domestic) Flue gas recovery devices
Building fabric	Cavity wall insulation Loft insulation Flat roof insulation Internal wall insulation External wall insulation Draught proofing Floor insulation Heating system insulation (cylinder, pipes) Energy efficient glazing and doors
Lighting	Lighting fittings Lighting controls
Water heating	Innovative hot water systems Water efficient taps and showers
Microgeneration	Ground and air source heat pumps Solar thermal Solar PV Biomass boilers Micro-CHP

3.5.2 Energy Company Obligations

Introduced in January 2013, the ECO was designed to run in conjunction with the Green Deal to provide additional support in the domestic sector. In particular, it was intended to provide additional support for improvements in 'hard to treat' homes, and to deliver *affordable warmth* to those in fuel poverty. The ECO replaced two previous schemes, the Carbon Emissions Reduction Target (CERT) and the Community Energy Saving Programme (CESP). The ECO, funded by energy suppliers, placed legal obligations on the larger energy suppliers to deliver EE measures to domestic energy users. Hence, under the scheme they determined how much subsidy they provided to each consumer dependent upon individual circumstances and the amount of Green Deal finance being used. In terms of delivery, energy suppliers provided the ECO either directly to customers, or through organisations working together through pre-approved arrangements, such as Green Deal providers (DECC, 2013a). The ECO was designed with particular obligations[24] to be delivered both by social landlords in the social housing sector as well as to those on low incomes who could also be private owner-occupiers.

3.5.3 Feed-in Tariff and the Renewable Heat Incentive

The FiT and the RHI were primarily designed to encourage the adoption of small-scale renewable energy sources within all sectors of housing. Both schemes were essentially similar, e.g. the FiT aimed to reward with payment from energy companies anyone generating their own electricity from renewable low carbon technologies (e.g. sun, wind or water), the RHI did likewise for those producing clean, green heat (DECC, 2014, 2015; Ofgem, 2015).

Launched in 2010, the FiT scheme is often considered the more successful of the two policies, due to its longer presence and significantly higher uptake levels by HH. The

[24] The ECO contained three key obligations: the Carbon Saving Community Obligation; the Affordable Warmth Obligation; and the Carbon Saving Obligation.

scheme required the installation of a renewable energy technology before a HH could qualify for free energy and cashback for every unit of energy generated and more for any surplus supplied to the national grid. The policy was underlined by the government's view that the production of energy from renewable sources was sustainable and would make consumers less reliant upon ever-declining supplies of imported gas and oil, and protect against a future of power cuts, price increases – therefore supporting energy security and self-sufficiency (DECC, 2014, 2015; FOE, 2011).

The RHI was originally launched in November 2011 as a financial incentive scheme designed to encourage uptake of renewable heating among domestic consumers; it was aimed mainly at owner-occupied homes that were off the gas grid. There are approximately four million (UK) HH that use non-mains gas heating fuels such as oil, liquid petroleum gas and electricity. It was believed that HH without mains gas would have the greatest potential to save on their fuel bills and decrease carbon emissions. The scheme was relaunched in April 2014 and extended to cover all single domestic dwellings (to any homeowners, as well as private landlords, social landlords and self-builders[25]) and non-domestic building components (industry, businesses and public sector organisations) (DECC, 2014, 2015: FOE, 2011).

The scheme also stipulated which technologies it supported and would be eligible for payment. It included: air source heat pumps (ASHP); biomass-only boilers and biomass pellet stoves with back boilers; ground (and water) source heat pumps (GSHP); and flat plate and evacuated tube solar thermal panels (solar thermal technologies) (DECC, 2013:13, 2014, 2015). Another prerequisite of eligibility was that before renewable energy systems were installed it was essential to make the home energy efficient (through insulation, boiler upgrading, etc.). This was underlined by government recognition that renewable heating systems were more likely to work more efficiently in a well-insulated home. Therefore, all applicants were required to

25 Although the scheme was applicable to new build properties other than self-build.

complete a GDAR before applying to ensure that the minimum EE requirements were met, i.e. specifically loft and cavity insulation.

Whilst all these policies and instruments were designed to provide sources of funding to help increase the use of sustainable low carbon technologies, in practice renewable energy systems do not appear to be as commonly implemented and at the rates needed to meet UK carbon reduction targets (DECC, 2012). The danger is that low income HH, unable to afford the upfront capital costs of renewables such as solar panels, will lose out unless they or their social landlords get a fair share of these funds (JRF, 2012).

3.5.4 Smart meters

Smart meters are technological measures designed to put consumers in greater control of their energy use by providing them with detailed real-time information on their energy use and thereby encouraging them to adopt EE measures. The government requires energy companies to provide and install smart meters for their customers. The Smart Meter Scheme is promoted as a measure that will save money on customer energy bills and help in offsetting price increases. Moreover, whilst the smart meter itself does not save money, it is capable of providing near real-time information on energy use – through the in-home display expressed in pounds and pence[26] – and insight into how to lower bills, thus highlighting ways one can be more energy efficient (AECOM, 2011).

Additionally, the aim is for the technology to lead to the creation of innovative new tariffs and personalised plans individually tailored to fit people's lifestyles and energy consumption habits. However, the absence of a legal obligation on HH to have the meter installed holds implications for both its successful rollout across the housing

26 *Smart Meters: How they Work* (GOV.UK n.d.).

sector and potential knock-on effect on energy consumption reduction goals. Given that this scheme is still in its infancy, its impact is yet to materialise, but it does appear to offer feedback and choice, thereby addressing the perceived consumer 'information-deficit' (POST, 2012b).

3.6 Evaluations of Existing Policy

3.6.1 Policy weakness for existing housing sector

To date the UK has relied upon a wide mix of policy instruments to promote EE within the existing housing sector, as well as more targeted policy instruments for the private home-owning sector. These include a range of prescriptive, regulatory and control instruments; economic or market-based instruments; fiscal instruments and incentives; and other information and voluntary action or support instruments (Renaud & Goldberg, 2012). However, despite the wide range of policy initiatives being delivered they are increasingly criticised for being 'limited in scope' and delivered in a 'piecemeal', 'compartmentalised' way, and hence are not able to respond fully to the challenges of achieving the end goal of improving EE in housing (Dibb & Monkhouse, 2012:16). The key concern is whether the initiatives being delivered will add up and be 'effective as a whole' (Dibb & Monkhouse, 2012:16).

Whilst the current planning, building and other regulations set out mandatory requirements for the sustainability and EE of buildings, they nevertheless only set minimum standards, which are considered economically viable within the wider economic context. This is at the expense of anything more far-reaching or more stringent which is feared likely to result in increased building costs which developers, landowners and users would be liable to pay for and thus oppose (e.g. Dibb & Monkhouse, 2012; Rydin, 2011). This analysis suggests that planning and building regulations will not be enough on their own to achieve the levels of domestic emissions reduction that the government has committed to, due in part to their limited influence over much of the existing housing stock and changes in HH energy use (this aspect is examined in further detail in Chapter 4).

3.6.2 Policy emphasis on new build

In contrast, the existing policy tools appear more strongly directed towards governing EE in new build (and non-domestic) housing construction than existing buildings. This is not least because in a practical sense high performance levels can be more readily designed into new buildings than those already built (Lowe et al. 2012). In particular, homeowner-occupiers of the existing housing sector face particular challenges due to the perceived shortcomings of such policies. For instance, while, until recently, it has been mandatory for all new build housing to be zero carbon by 2016 (or to meet the Code for Sustainable Home Standards), there were no such equivalent standards for most existing housing renovations. The only exception has been where substantial external or development works were being proposed to an existing building which then required planning or building consent – in which case matters related to 'EE' would have to have been met similarly to the requirements of a new build. Therefore, these instruments were inapplicable to a large majority of small-scale 'internal' changes or renovations (EST, 2011)[27] undertaken and which fall outside of the scope of the planning and building regulatory system.

Government policy has until accepted that any plan to achieve its 2050 targets cost effectively would need the input of renewable technologies (solar, wind, biomass, etc.). However, the current government's policy changes appear to undermine the ability to achieve the UK's legal obligations for reducing carbon emissions by 2050. The loss of the Zero Carbon Homes Policy and proposed cuts of subsidies in the FiT

[27] Which hold the potential to be turned into energy efficient renovations – changes seen as a missed opportunity by policymakers (EST, 2011).

for renewable EET could undermine the industry, the drive for market technology cost reductions and investor confidence in them (Green Building Press, 2015).

3.6.3 Greater policy support in social housing

It appears that most progress has been made in the EE of the social housing sector rather than the private sector. Historically, there have been numerous direct policy interventions based around obtaining minimum standards of social housing, i.e. Decent Homes; Warm Front, CESP, and CERT (now abolished and its functions superseded by ECO). For example, the Decent Homes together with CESP/CERT have ensured that approximately 90% of properties (social sector) have been upgraded to standards that include measures such as cavity wall and loft insulation and draught-proofing (CLG, 2010). One of the key requirements was to provide ‘a reasonable degree of thermal comfort’ for occupants – defined as both an efficient heating and effective insulation; any home with a standard assessment procedure (SAP) rating of 35 would meet the thermal comfort requirement.

Therefore, the social housing sector has to date benefitted more from a range of ‘sector exclusive’ government regulatory policies and initiatives aimed specifically at low income (or those on means tested benefits) social tenants only and not the ‘able to pay’ home owner-occupiers (Abbott, Swan & Wetherill, 2012; Dowson et al. 2012; Smith & Swan, 2012).

In order to support existing housing in the private sector, the government designed mechanisms within its key policies specifically to support homeowner occupiers. Here, there were a range of incentives available, which target efficiency improvements such as insulation via renewable obligations and the Green Deal, and micro-generation via the FiT and RHI schemes. The FiT/RHI/Green Deal schemes were intended to make it economically viable to invest in such improvements.

However, as this study will go on to show there are many factors that may influence a homeowner’s decision to install such technologies (including ignorance, inertia, intolerable disruption, alternative spending priorities, etc.); the private housing sector has been slow to adopt EET which consequently affects the energy performance of the existing private sector housing stock. It is this aspect of low adoption of EET within this sector that is the focus of this research and discussed further in forthcoming chapters.

3.7 Chapter Summary

In sum, HH adoption of EET is a key component of the UK's strategy to meet the sociotechnical challenge of climate change and a low carbon agenda, but this close examination of the existing regulatory and policy frameworks has shown that by and large it has very little scope to influence or encourage homeowner occupiers to increase take-up of EET. This is largely attributed to the emphasis on individual voluntary consumer choices for homeowners, and a weak mandatory and non-regulatory push at the right level. This raises the question of what policies will replace the ones currently being dismantled by government, and how any replacements will further inhibit or incentivise homeowners in EET adoption.

The following chapter sets out a literature review of a wide range of key empirical studies to provide an interdisciplinary and sociotechnical perspective in two parts: firstly, by reviewing studies that measure domestic buildings' technical dimensions of achieving EE; secondly, assessing the human – occupant or user – dimensions (e.g. how people use energy appliances or space heating) on household energy consumption behaviour (HECB); and with discussions of how both these aspects are likely to influence the overall building energy performance and reduction in HECB.

Chapter 4 Dominant discourses – The technical & Behavioural Dimensions

4.1 Introduction

The previous chapters highlighted how reducing carbon emissions at the micro-HH level within the existing housing sector will require a combination of both technical (e.g. retrofitting housing EET) and behavioural solutions (e.g. reducing room heating, changing tariffs). In particular, government policy is primarily reliant upon the voluntary take-up of solutions (EET adoption) as the regulatory and mandatory framework identified is limited in its scope to influence the existing housing sector and to encourage HH to reduce energy consumption. This highlights the need for further examination of how the dominant and normative research discourses (based on existing empirical studies) have framed and examined these twin dimensions.

This chapter provides a sociotechnical perspective on how the dominant research discourses are articulated. This is achieved through interdisciplinary reviews of a selection of key studies chosen to illustrate the main debates within the research on housing EE. The empirical research covering EE and conservation originates from across the disciplines of social and environmental psychology, sociology, geography, economics, marketing, engineering and other technical building sciences. Grey literature from government, industry and other organisational sectors has been extensively consulted. The debate within the existing research literature over how to improve housing EE (including installation of renewable energy sources) at the HH level can be usefully divided into three categories (DECC, 2011; Ravetze, 2008).

First, there is the research that focuses on the technical aspects, examining appropriate implementation and use of specific strategies and technologies (e.g. loft insulation, biomass heating systems, air tightness) and measuring their effects, i.e. predicted and/or achieved thermal or energy performance of retrofitted measures (e.g. Bell & Lowe, 2000; Boardman et al. 2005; Clinch, Healy & King, 2001; Jack, Lomas & Allinson, 2011; Lowe & Oreszczyn, 2008) and their cost-effectiveness (e.g. Booth & Choudhury, 2013; Jones et al. 2013).

Second, discussions over the factors affecting energy use in domestic buildings have given rise to studies that focus on the occupant or user behavioural aspects and consider the role of the individual energy consumer, their consumption decisions, attitudes, energy practices and use of energy-consuming devices (e.g. switching off devices instead of using standby mode) (e.g. Barr et al. 2006; Brandon & Lewis, 1999; Cooper et al. 2012; Firth, Lomas & Wright, 2010; Gardener & Stern, 2008; Gill et al. 2010; Swan & Ugursal, 2009).

Third, the first two aspects cannot be removed from their institutional and macro-level structures and processes, where studies and debates focus on appropriate regulatory and policy measures, norms, energy taxes, social marketing, energy scenarios, etc. (e.g. Bergman, Whitmarsh & Kohler, 2008; Corner & Randall, 2011; Jones et al. 2013; Laitner et al. 2009; Lomas, 2009; Natarajan & Ravetze, 2008).[28]

In this chapter these three aspects of existing empirical studies are broadly reduced into technical (Section B) and behavioural dimension themes (Section C). However, before proceeding further, the chapter begins by providing definitions of the HH energy behaviours (Section A) considered in this study.

[28] Although many studies often deal with all three themes.

4.2 Section A – What is Household Energy Consumption Behaviour?

As discussed in Chapter 2, the government's low carbon agenda (i.e. to reduce housing sector carbon emissions) aims to change individual HH energy consumption behaviour (HECB). Thus, for the purpose of this study it is important to understand how behaviour in relation to energy consumption is defined within the existing literature. As this chapter will show, a complex combination of practical, social, material and aesthetic values are embodied in everyday energy use or consumption practices.

Broadly, 'behaviours are considered to be complex, non-linear and affected by numerous factors' (e.g. psychological, social, contextual) (Darnton et al. 2006:5). The act of consuming energy is considered a form of behaviour (Abrahamse et al. 2005; Becker et al. 1981 in Martiskainen, 2007; Gram-Hanssen, 2010), and within a HH this behaviour relates to everyday activities that often require the use of energy, e.g. turning lights on or off, adjusting thermostat levels, using electric appliances, for cooking, washing, etc. (Abrahamse et al. 2005; Barr, Gilg & Shaw, 2006; Gardner & Stern, 2002, 2008; Martiskainen, 2007; Shove, 2003). The literature suggests that HH energy-saving behaviours can be divided into two simple groupings, as follows.

First, efficiency behaviours are considered to be one-off behaviours that require occasional actions. This includes one-off purchases or transactional 'investment' decisions (e.g. loft insulation, cavity insulation, double-glazing). Second, curtailment behaviours are those that require 'operational' use and 'repetitive efforts' or habitual behaviours (e.g. turning lights off, closing curtains, turning appliances off, or not leaving things on standby) to reduce energy use in homes (Barr, Gilg & Shaw, 2006; Gardner & Stern, 2002, 2008; POST, 2012; Martiskainen, 2007).

Sustainable consumption and pro-environmental behaviours are perceived to require both curtailment and efficiency behaviours through purchasing decisions (such as buying energy-efficient appliances) and repetitive actions (e.g. not leaving electrical goods on standby). Such behaviours also require wider resource efficiency behaviours (e.g. water saving and recycling waste) (Barr, Gilg & Shaw, 2006; Martiskainen, 2007; Gardner & Stern, 2002). There appears to be considerable debate within the existing literature over which behaviours are the most effective (Abrahamse et al. 2005; DECC, 2011; Jackson, 2005; Gardner & Stern, 2002). Some of these complexities will be examined further in Sections B and C.

From a policy intervention viewpoint, curtailment behaviour is considered more sustainable, durable and long term, yet it is also perceived, as the hardest to achieve as it requires time and resources and involves a less clear-cut process to deliver. In contrast, efficiency behaviour, although considered more short term, is a relatively easier strategy to implement and does not necessarily rely on behaviour change to take effect (Abrahamse et al. 2005; DECC, 2011; Darnton et al. 2006; Jackson 2005). Therefore, policy often appears to have favoured one-off actions (specifically insulation[29] as one of the most cost-effective solutions) for improving housing EE; such actions are perceived as key technical interventions likely to help reduce direct emissions from the housing sector (DECC, 2011; EST, 2011; *Which?* 2003).

However, it is accompanied by muted acknowledgement that it is curtailment behaviours (often referred to as pro-environmental behaviour) that foster more long-term, sustainable behaviour changes that could avoid the risk of the 'rebound effect' (discussed in Section B) arising from efficiency behaviours (which also deliver greater energy savings in the short term) (Darnton et al. 2006; DECC, 2012; DEFRA,

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29 Insulating measures include loft and roof insulation, cavity wall insulation, external and internal wall insulation, draught-proofing measures and sometimes double glazing or other efficient glazing forms.

2005; DEFRA & DTI, 2003). The sociotechnical dimensions of reducing the carbon emissions of homes and reducing HECB will be considered in turn in the remainder of this chapter.

4.3 Section B – Technical Dimension: Carbon Reduction through Retrofitting EET

4.3.1 Overview of technical studies

Technical analysis orientated research, largely originating from the technical sciences relating to building and construction, mainly adopts a focus on building performance and considerations of retrofitting, regulation, sustainability and EE issues (e.g. Boardman et al. 2005; Shorrock, Henderson & Utley, 2005; UKGBC, 2008).

Additionally, these methodological approaches demonstrate a significant bias towards practical case study evaluations of a range of technical interventions and quantification of their thermal energy performance, efficiency and CO_2 savings (e.g. Boardman, 2007; Clinch, Healy & King, 2001; Power; 2008; Shorrock, Henderson & Utley, 2005). This is accompanied by econometric and statistical evaluations and modelling of, for example, the housing stock characteristics and the engineering and technological aspects of EE. Econometric and statistical evaluations are often used in explaining observed variations between independent and dependent variables, and applying default assumptions about the building occupants (e.g. Ascione et al., 2011; Clinch, Healy & King, 2001; Kelly, 2011; Shorrock, Henderson & Utley, 2005; Swan & Ugursal, 2009). These approaches also explore the factors influencing residential energy use and consumption (e.g. Baker & Rylatt, 2008; Kelly, 2010; Shorrock, 2003; Summerfield et al. 2010) and/or factors causing different types of energy load profiles within residential buildings (e.g. Newborough & Augood, 1999; Yao & Steemers, 2005).

The overemphasis on technical issues in this research area has led some (e.g. Caird & Roy, 2008; Crosbie & Baker; 2010; Guy & Shove 2003; Gram-Hanssen, 2010; Ozaki & Shaw, 2014; Shove 2010) to criticise this approach, describing it as a 'techno-economic' approach that 'dominates the methodologies [in energy] studies' (Guy & Shove, 2003:11)

Nonetheless, technical studies beyond micro HH level have also considered wider macro-level perspectives on meeting national energy policy goals and of large-scale scaling up of existing housing stock, the role of demolition and other complexities in relation to delivering housing EE. Consideration of the technical aspects are necessary in order to get a more holistic perspective on the key issues involved in the adoption of EET in the context of the sociotechnical configuration encompassing the residential building – this will be outlined in the following sections.

4.3.2 Macro-level perspectives – meeting the 2050 target

At the national level, and in response to legally binding targets of 80% reduction in CO_2 emissions by 2050, there has been a drive to reduce emissions within the domestic existing housing stock (e.g. DECC 2011; EST, 2008b; Shorrock, Henderson & Utley, 2005). Therefore, there are numerous studies that offer a more macro-level perspective of the feasibility of large-scale adoption of housing EET and assess the EE potential of the UK housing stock (e.g. Eames et al. 2013; Jones et al. 2013; Reeves, 2009; Shorrock, Henderson & Utley, 2005). These studies can often show bias towards feasibility, and 'forecast' analyses largely utilising aggregated economic data and historic trend numeric data to predict future changes in energy consumption and CO_2 emissions. In particular, the studies preoccupied with evaluating the likelihood of achieving the 'deep cuts' needed in the UK's existing housing stock by 2050, contest the levels of carbon reduction that could be achieved through mainly technical interventions to the building. Their estimate of the level of carbon reduction that can be achieved ranges from 60% to 80%.[30]

For example, Bothwell, Saich and Mallion (2011) examine the possibilities of existing housing stock meeting the current government target of 80% carbon reductions by 2050. They refer to feasibility studies of three case study properties, for which, they suggest, it would only be possible to secure approximately 50–60% reductions of CO_2 at reasonable cost. They conclude that to achieve the desired 80% reduction would be extremely difficult without using costly renewables. Reeves' study (2009) reinforces the view that achieving CO_2 savings greater than 50% requires the adoption of advanced renewable technologies systems (i.e. solar photovoltaics) to offset emissions from gas and electricity and/or alternatives such as a switch to low carbon heat sources (e.g. combined heat and power (CHP)) will be necessary to meet policy goals.

Therefore, many of these macro-level, top-down focused studies have concluded that it is highly unlikely that the 80% reduction of energy consumption in existing housing stock will be achievable by 2050. In addition, there appears to be consensus that to achieve more than 60% carbon reduction will require relatively extensive advanced technical interventions to the existing stock (as proposed by Reeves, 2009). For example, the EST (2008b) using scaled-up modelling of the housing stock (using 82 dwellings of UK housing archetypes) stated that only through a package of measures implemented at a macro-scale (e.g. the decarbonisation of the grid) could the reduction of 80% or over be achievable. Adoption trends also suggests that HH are more likely to install low cost and easier to install 'low hanging fruit' or shallow measures, than the more costly and technically advanced measures (e.g. Chandler and Brown 2009; Crosbie & Baker, 2010; McKinsey & Company 2009; Reeves, 2009).

[30] E.g. Boardman at al. 2005; Boardman, 2007; Bothwell, Saich & Mallion, 2011; BRE, 2005; EST, 2008b; Natarajan & Levermore, 2007; Reeves, 2009; Shorrock, Henderson & Utley, 2005 – each study is likely to have had a differing set of criteria and methods and therefore slightly differing results.

Moreover, Jones, Lannon and Patterson (2013), through examining three large-scale 'whole house' retrofit programmes in Wales, analysed energy savings (using an energy and environmental prediction model), CO_2 reduction, costs, and benefits. They reported that the cost of measures rose in relation to the predicted savings. They also critiqued the government funding/incentives (e.g. Green Deal opportunities) for installing 'shallow' elemental measures to reduce CO_2 emissions by 10–30%, whilst asserting that large-scale financing of 'deep' (60–80% CO_2 reductions) whole-house packages of measures is not currently available and does not pay back.

4.3.3 Scaling up UK building stock

Linked to the macro-level policy issue of meeting the 2050 target has been a policy goal to scale up retrofit into 70% of existing housing that is already built and will continue to exist in 2050. Numerous studies have considered this issue extensively through predominantly secondary analysis of statistical data to assess the EE retrofit potentials of the entire UK housing stock (e.g. Boardman, 2007b; Evans & Herring, 1989; Johnston, Lowe & Bell, 2005; Natarajan & Levermore, 2007; Shorrock et al. 2005). Typically, there has been an over-reliance on the use of building modelling and simulations based on small numbers of case study buildings, and a tendency to extrapolate the results to the entire building stock (although even extrapolation to the entire stock is limited). Therefore, whilst top-down modelling has to some extent been usefully used to predict aggregated UK housing stock energy consumption these models are not without their limitations – as this analysis illustrates.

Expressly, this approach is perceived to have limited predictive quality, mainly due to the large variations in the physical characteristics of the dwellings, occupant behaviour and the external climate across the UK housing stock (Booth and Choudhary, 2013). For example, the stock is ever changing (expanding), and is likely to be affected by the very low annual substitution rates from old to new and from those retrofitted. Many commentators (e.g. Boardman 2007b; Jones, Lannon &

Patterson, 2013; Ravetze, 2008) have stated their concern over the inertia of the building stock, arguing that it may take decades before any large-scale impact is made on overall energy consumption reduction. Moreover, it leads to treating the housing stock as homogenous, thereby ignoring the effects of more localised and HH (human dimensions) level heterogeneity of variables (e.g. socio-demographics and occupant end-use; differing physical characteristics of the house and the scope of differing EET adopted and the types of energy fuels used; costs as deterrents; as well as the geographical variations of housing stock) (e.g. Jacob, 2006; Jones, Lannon & Patterson, 2013; Kavgic et al. 2010; Kelly, 2011; Lomas, 2010; Ravetze, 2008). These complex variations in variables seem to make them of limited use for policy intervention at the HH level.

4.3.4 Role of demolition

In contrast to retrofitting solutions through EET adoption, some studies (e.g. Boardman et al. 2005; Boardman, 2007; Power; 2008) have highlighted the possible positive role that demolition could play in improving and accelerating the overall environmental performance of the entire existing housing stock (as an alternative to EET retrofits), thus helping to meet the 2050 targets. Most notably, Boardman et al. (2005) present their '40% house' report (also Boardman, 2007 'Home Truths') in which it is argued that it is more realistic to reduce domestic carbon emissions from homes by 60% between 1997 and 2050. This aim could be achieved through demolition of the most inefficient, 'leakiest' housing and then replacing it by building new EE housing.

However, critiques of this approach suggest that it does not adequately take account of the environmental effects of demolition and the issue of 'embodied energy'[31] (e.g. studies by Asif et al. 2002; Heath, Baker & Menzies, 2010; Menzies, 2010; Weir,

[31] That is the energy used in the production of the materials, which can contribute to the amount of energy used to complete either new build, retrofit or demolition.

1998). Moreover, such a strategy is likely to have energy, carbon and financial cost implications, notwithstanding the lack of political and social support for such a development practice (Hogan, 2011; Ravetze, 2008). Thus, demolition rates remain relatively low in the UK (less than 1% of stock annually) (GOFS, 2008; Ravetze, 2008).

4.3.5 The complexity of a single house case EE retrofit

This complexity of scaling up the EE into the entire housing stock is epitomised in a study by JRF (2012) which highlighted the reality of retrofitting a single house – a typical 1930s semi-detached property,[32] representative of a good proportion of the UK housing stock. Through their experimental practice based case study, implementation of EET and refurbishment took place in two stages, firstly with basic EE measures (e.g. double glazing), and then through advanced measures (e.g. renewables such as MVHR) which aimed to bring the building near to new build standards. The findings of this case study suggested that, through sequencing of installation it would be possible to achieve the challenging policy targets for existing stock, but only through a costly set of measures.

The study highlighted that the measures installed performed significantly worse *in situ* than 'as designed'. In particular, the study found failings in achieving design performance in some of the more advanced measures, including triple-glazed windows, while the fabric of the home only produced about 70% of what the project set out to achieve due to not being installed correctly. This high-profile study raised concerns over the high level of discrepancy observed within a *'flagship'* project intended to road-test EE measures (that the government promoted) which were to be scaled up as part of the former Green Deal policy. Moreover, *these results raise critical questions about the reliability of both the modelling assumptions and*

32 See Temple Avenue Project, York. The project focuses on improvements to the building fabric followed by improvements to the heating and ventilation system, and then measures that offset against the cost of hot water and energy use.

construction techniques used and which hold implications for the house building industry (JRF, 2012). In particular, this study highlights the challenges of the performance gap that numerous technical studies highlight – discussed below.

4.3.6 Performance gap

Doran and Carr (2008) cite research undertaken by BRE on the thermal transmittance of walls of 70 houses before and after the application of cavity wall insulation. The study found that the improvement in thermal resistance was on average around 38% less than expected. This thermal underperformance highlights some of the limitations of certain 'fit and forget' EE interventions that may not deliver due to poor installations, poor products and other failings. Bell and Lowe (2000), through an examination of three housing retrofit schemes using a combination of insulation measures, identify difficulties posed by variations (often small) in dwelling construction, which can have a disproportionate impact on costs, and by the design and use of mixed heating systems which could reduce overall heating efficiencies. Bothwell, Saich and Mallion (2011) highlight that one of the fundamental problems with retrofitting in existing and specifically older housing (in comparison to new build) is the issue of creating an uninterrupted insulated building envelope (i.e. at roof/wall junctions, party walls and ground floor levels).

Other studies (e.g. Asif et al. 2002; Harris, 1999; Menzies, 2010; Schmidt et al. 2004; Weir & Muneer, 1998; Weir, 1998) have highlighted how EE measures such as double glazing are likely to have a particularly high embodied energy in their production, which threatens to counter their installed benefits (i.e. the energy savings or carbon reduction achieved). These examples further highlight the complexities of the performance gap, specifically between the 'as-built' and 'as-designed' predicted performance and values of building and technical interventions in housing.

4.3.7 Other factors

The issue of the building-specific performance gap connects the discussion to a well-established knowledge area (e.g. Brown, 2001; Gillingham, Rapson & Wagner, 2014; Jaffe, Newell & Stavins, 1999; Jaffe & Stavins, 1994). However, how this is defined and expressed is often determined by the disciplinary viewpoint taken. From an econometric viewpoint (e.g. Jaffe, Newell & Stavins, 1999) this is sometimes referred to as an 'energy efficiency gap', which is assumed to result from 'market failure' 'between the most energy-efficient technologies available and those that are actually in use' (Newell & Stavins, 1999:3). In contrast, technological perspectives are likely to highlight the technological failure in terms of poor performance and the failure of individuals to implement the right measures, poor adoption of the appropriate measures, etc. (e.g. Fell & King, 2012; Lomas, 2010). Nevertheless, both perspectives appear to offer a complementary viewpoint of the issue.

There are numerous other reasons offered for this EE performance gap in housing interventions: climatic and geographic variations (e.g. the effect of insulation short-circuited by various climatic conditions such as wind washing and air looping) (Bernier et al. 2010; Lutzenhiser, 1993; Strengers, 2010); existing physical characteristics of houses (e.g. creating an interrupted building envelope in older houses (especially solid walled hard to heat homes)) (JRF, 2010, 2012); poor retrofit design and construction issues (e.g. poorly installed insulation) (JRF, 2010, 2012); technology not used as intended (e.g. solar panels, heat pumps, CHP etc.) (JRF, 2010); larger homes or extended homes increasing energy consumption (Jack, Lomas & Allinson, 2011) and using more energy for heating (Bernier et al. 2010; Lutzenhiser, 1993; Pierce et al. 2010; Strengers, 2010); the introduction of more electrical appliances in homes increases energy use (Bernier et al. 2010; Lomas, 2010). All such factors are perceived to affect the predicted performance of the building.

4.3.8 Rebound effect

The rebound effect or take back (where there is increased energy demand rather than its reduction) has often been forwarded as one explanation for the EE performance gap; it highlights the significant role that a building occupant's energy use could play in its environmental performance. Historically, there has been an inherent 'rationalistic' assumption that technical solutions will automatically result in HH energy demand reduction and thus directly result in a fall in greenhouse gas emissions – a claim that has been increasingly challenged by studies which highlight the rebound effect (e.g. Booth & Choudhury, 2011; Duxbury 2010; Gram-Hansen, 2012; Parker et al. 2005; Sanders and Phillips, 2006; Sorrell et al. 2009).

The rebound effect proposes that the theoretical energy savings predicted very rarely materialise, as EE can stimulate increased energy use rather than reduced consumption (Booth & Choudhury, 2011; Gram-Hansen, 2012; Sorrell et al. 2009). It asserts that the behaviour of the occupant may cancel the gains from any given efficient appliance or other EE measure (Dietze et al. 2009; Palborg, 1986).

Studies on rebound effects highlight how people living in similar types of dwellings with similar physical design and components can have substantially different energy consumption levels due to the different usage patterns of both the house and its heating systems by its users. There are numerous contested figures for how much of the reported savings are lost (directly or indirectly) through the rebound effect and increases in other carbon-intensive behaviour (e.g. Fell & King, 2012; Gram-Hanssen, 2010, 2011; Palm & Darby, 2014; Summerfield et al. 2010b). Gill et al. (2010)[33] reported that resident behaviours accounted for the observed variance in heat, electricity and water consumption of 51%, 37% and 11% respectively. These studies highlight the fact that improving the EE of housing through technical interventions is complex, something which needs to factor in the role of both the dwelling and its

[33] Evaluated a UK Eco Homes case study – deemed excellent under the Zero Carbon Homes Policy.

occupants – the human factors (Janda, 2011; Lowe et al. 2012; Palm & Darby, 2014; Stephenson & Leaman, 2010).

4.3.9 Technology adoption benefits

Despite the potential negative aspects of the rebound effect following EE retrofitting, it is still widely accepted in government policy that successful retrofits have the potential to provide significant reductions in CO_2 emissions (Booth & Choudhary, 2013; Jones, Lannon, & Patterson, 2013), and studies have shown vast improvements in thermal comfort and higher internal temperatures (e.g. Hong et al. 2009; Howden-Chapman et al. 2007; Jones, Lannon & Patterson, 2013). For example, Howden-Chapman et al. (2007), in evaluating the 'health' effects of insulating existing houses, found that this led to a significantly warmer, drier indoor environment and resulted in improved 'self-reported' health.

Other studies (e.g. Caird & Roy, 2008; Kierstead, 2007[34]) have suggested that the adoption of renewable and micro-generation technologies could arguably have the ability to produce a 'double dividend',[35] or 'spill over' benefits. This could mean HH consumers improving their home's energy efficiency and/or adopting other HH energy-saving behaviours (Bergman & Eyre, 2011; Brandon & Lewis, 1999; Caird & Roy, 2008; Kierstead, 2007).

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[34] Found evidence that the installation of PV encouraged households to reduce their overall electricity consumption by approximately 6% and shift demand to times of peak generation.

[35] In relation to 'combining clean technology with positive behavioural responses' (Caird & Roy, 2008:2).

4.4. Section C – Behavioural Dimensions

4.4.1 Occupant energy use

Running parallel to the technically framed research analyses of the feasibility of reaching the desired EE goals in existing housing, are studies that highlight the need for examining the contributions of behavioural interventions (the human dimensions) in supporting this aim. This moves the sociotechnical debate away from the building and technical interventions to a focus on its users and on how the occupants' behaviour contribute to overall HECB (Kavgic et al. 2010; Kelly, 2011). The research suggests that reducing energy demand is not simply about retrofitting and adopting EET: it also involves changing behaviour and everyday practices. It also asserts that changes in HH – user – behaviours are just as important as any technical intervention and have significant influence on overall energy consumption and carbon reduction at the HH level (e.g. in terms of how people use energy in their homes, their attitudes to energy use, the influence of energy costs, income) (e.g. Janda, 2011; Jones, Lannon & Patterson, 2013; Lomas, 2010; Lowe et al. 2012).

In particular, HECB is increasingly acknowledged in policy and research as central to finding solutions to current environmental problems. Hence, government policy seeks to encourage a shift towards more sustainable (water, energy and resource consumption) HH practices (Jones, Lannon & Patterson, 2013; Lomas, 2010; Lowe et al. 2012). In this debate, policy also acknowledges that most energy at home is used for heating rooms (60%), for lighting and appliances, water heating and cooking.[36] Following on from this policy perspective, numerous studies (indeed, this is a well-established and crowded research area; some examples are discussed below) focus on how a change in behaviour could curtail overall HECB by identifying the most effective actions HH can take to reduce energy consumption (e.g. Barr et al. 2006; Brandon & Lewis, 1999; Dietz, et al. 2009; Gardener & Stern, 2008; Gill et al. 2010; Staats, Harland & Wilke, 2004).

[36] As measured by end-use. Source: *Energy Consumption in the United Kingdom: 2012*, DECC and National Statistics.

4.4.2 Potential energy reduction actions

Most commonly, studies (e.g. Kolmuss & Agyeman, 2002; Steg & Vlek, 2009) in this debate emphasise personal (pro-environmental choices) behaviour, but do not always make the distinction between differing types of behaviour; for example, distinguishing between operating behaviour (e.g. turning off lights) and purchasing behaviour (e.g. purchasing CFL lightbulbs, nor do they always quantify how much personal behaviour change contributes to energy reduction. However, they do agree that at least half of our actual energy use is dependent on 'operating' behaviour, rather than specific technologies purchased and employed in a home (e.g. appliances, envelope measures and systems assume a complementary role). Hence, these studies identify the differences in conserving behaviours (habits and purchase related) and their role in differing levels of performance that are achievable (Barr, Gilg & Ford, 2005; Dillman et al. 1983; Staats, Harland & Wilke, 2004).

Laitner, Ehrhardt-Martinez and McKinney (2009:218) suggest that 'addressing the human dimensions of energy use may rival if not complement any purely technological based interventions'. The authors suggest that in the United States behaviour change trialled over a five-day period offered potential reductions of 20–25% in residential energy consumption over that period. They highlight the potential impact of changed habits, lifestyles and technology-based behaviours in terms of potential energy savings.

Moreover, Dietz et al. (2009) place the emphasis on how potential HH level interventions should incorporate a combination of behavioural, economic, engineering and technological elements. They examine a range of HH actions with behaviourally distinct categories that could reduce energy consumption with readily available technology and without appreciable changes in lifestyle. They suggest that the implementation of 17 different behavioural actions could save 20% of US HH emissions. Thus, 'occupant use' behaviour could have a significant influence in reducing the overall energy consumption at the micro HH and building level.

In addition to identifying actions for reducing HECB, studies have also tried to identify the determinants or underlying reasons for HECB. This line of enquiry corresponds to questions of why, despite improvements in EET and regulatory policy structures, there is a perception that HH energy use is increasing (as evidenced in the greater demands for heating, lighting and higher internal temperatures discussed in Chapter 2). Progressively in this debate, the achievement of thermal comfort has come to be perceived as the most significant determinant of HECB in domestic buildings (Cooper et al. 2012; Pyle, 2001; Shove, 2003)

4.4.3 Desire for thermal comfort

In trying to explain HECB, evidence suggests that people often seek the benefits of increased thermal comfort over other benefits from installing EE measures (Banfi et al. 2008; Cooper et al. 2012; Pyle, 2001), although there are significant variations in how much energy is consumed due to occupant comfort practices (Gram-Hanssen, 2010). The exact proportion of occupant influence is variable and contested across studies (Gardner & Stern, 2008; Janda, 2011; Stephenson, 2010).

Existing evidence highlights the fact that thermal comfort (attaining an adequate or desired level of warmth) needs are socially and culturally constructed and have complex cognitive and physical influences on how people perceive and use energy (Chappells & Shove, 2005; Shove, 2003; Wilhite et al. 1996). The occupants' thermal comfort practices (in terms of how they use heating appliances), the technologies and the fabric of the building, in addition to furnishings and clothing, all make a significant contribution to domestic energy use (Cooper, Huebner & Jones, 2012). Thus, poor insulation and central heating are considered to reduce the elements that can contribute to local thermal discomfort, which in turn can result in a desire for increased warmth accomplished through increased temperatures in the home.

Linked to attaining thermal comfort is a complex set of interrelated factors that are also identified as being influential in increased HECB in the home. For example, how occupants use the building, the number of occupants living in a house and their differing needs for thermal comfort, their differing knowledge and expectations of their home, cultural and lifestyle choices, responses to the existing conditions of their property and psychological factors (as well as those discussed above under 'energy efficiency gap') – these are all acknowledged to have a significant impact on the levels of overall HECB (e.g. Abrahamse & Steg, 2009; Banfi et al. 2008; Kollmuss and Agyeman, 2002). In sum, existing evidence suggests that residential energy consumption is complex and contributes in part to current understandings of HECB; however, very few studies provide a model explanation of the influence of all the interrelated factors (DECC, 2011; Swan et al. 2010; Yao and Steemers, 2005).

4.4.4 Technical versus behaviour interventions

Similar to the technically framed studies discussed earlier, those studies advocating behavioural interventions also face the same problem of the performance gap, which they sometimes refer to as the 'value-action' gap, or 'barriers to action'. In particular, a well-established body of studies asserts that despite holding pro-environmental attitudes and intentions, people may fail to adopt more environmentally friendly behaviours (e.g. Allen, 2008; Barr, Gilg & Shaw, 2006; Blake, 1999; DECC, 2011; Kollmus & Agyeman, 2002; Maller & Horne, 2011). This has been accompanied by those who seek to model and quantify the gap, and identify causes for inaction (through a barriers/drivers framing) and determine how interventions could be redesigned to overcome such a gap (discussed further in Chapter 6).

In particular, and as noted earlier, with behavioural interventions there is the added difficulty of knowing whether the adopted behaviours are durable and become embedded into everyday HECB. The complexity of human behaviours suggests it would be far too difficult to measure accurately the long-term cumulative effect of behaviours on HH level carbon emission reduction contributions (Barr, Gilg & Shaw, 2006; Staats, Harland & Wilke, 2004). Importantly, this analysis demonstrates the limits in terms of understanding people's behaviour in their homes and to what extent they can be changed meaningfully (e.g. Maller & Horne, 2011; Ozaki & Shaw, 2014; Staats, Harland & Wilke, 2004; Sweeney et al. 2013).

4.5 Chapter Summary

This chapter examined understandings of both technical and behavioural interventions in an effort to provide a sociotechnical perspective on the housing EE discourse. This was in recognition of the differing types of environmental behaviour changes needed to reduce HECB (e.g. installing insulation, efficient energy management, micro-generation installation) and contribute to meeting climate change goals. It highlighted the dominant and normative research approaches through a review of existing studies that focus on measuring domestic buildings' technical performance following technical or building specific interventions. It also reviewed empirical studies that have examined the different influences of the HH occupant user (human dimensions). This part of the debate argued that changes in user behaviours are just as important as any technical intervention. It highlighted, e.g. how fuel type, socio-demographic, physical attributes of housing stock, the type of EET, and occupant behaviour amongst other factors are all critical in contributing to overall HECB and the energy performance of a residential building (some of these aspects will be expanded upon in Chapter 5).

The discussion here has focused on the dominant and normative research discourses and on the limitations of a purely technical and behavioural approach to understanding HECB. It demonstrated a fundamental gap between 'predicted' savings and actual performance at the building level, as well the existence of a value-action gap towards environmental goals – where there is often a disconnect between individuals' attitudes and actions, e.g. the rebound effects signify tensions between comfort and environmental performance. Importantly, these facets of the analysis demonstrated that improvements to a building's environmental performance is not guaranteed following 'technical' interventions, but is also reliant upon the 'correct' user behaviour, and therefore both technical and behavioural interventions need to work in tandem: however, in reality they seldom do.

Behavioural intervention studies typically grapple with questions of understanding how people use energy in the home and which behaviours are likely to have the most abatement potentials; these studies also highlight behavioural unpredictability and the risk of its being short lived (as HECB can change overtime). Hence, this provides an explanation for why technical interventions appear to be favoured in policy interventions, although both types of intervention raise questions of whether they can realistically contribute towards the desired policy goals. Overall, this chapter has been able to highlight fundamental disconnections between 'green' aspirations, technology adoption and energy conservation practices

The next chapter will examine another key knowledge area that links with this dominant discourse: although we know which measures can help in reducing HH energy consumption, there remains a reluctance to adopt EET by household. There is an existing body of studies that provide insight into understanding EET adoption decision-making processes from an interdisciplinary perspective. This will be examined further to gain understandings of why people may or may not decide to adopt, implement and use technologies in desirable ways.

Chapter 5 Factors influencing the adoption of energy efficiency technologies

5.1 Introduction

This research is interested in both the adoption decision-making process and use of EET in the HH, as these are considered integral to gaining an understanding of the problem of low adoption of EET. Thus, this section will examine, through an interdisciplinary – largely social and environmental-psychological – perspective, some of the key interrelated factors that have been identified as significant in determining aspects of people's technology adoption decision-making behaviours or those that relate broadly to pro-environmental behaviour (i.e. energy-conserving actions) in the existing literature. These key factors include:

1. Personal and attitudinal factors;
2. Green consumer values;
3. Levels of involvement with technology purchase;
4. Socio-demographics;
5. Role of communication, information and knowledge;
6. Financial aspects – costs;
7. Timing, trigger points and lifecycle events; and
8. Contextual aspects of renovation.

5.2 Personal and Attitudinal Factors

The dominant environmental-psychological literature highlights how broadly an individual's favourable personal attitudes towards environmental issues[37] (Blake, 2001; Kollmuss & Agyeman, 2002), together with contextual forces, personal capabilities and habits (rather than conscious or cognitive decision-making alone) are most influential in adoption decision-making behaviour (Blake, 2001; Kollmuss & Agyeman, 2002; Lorenzoni, Nicholson-Cole & Whitmarsh, 2007; Stern 2000). There is considerable debate and contention over the view that holding strong pro-environmental attitudes necessarily leads to the adoption of EET or 'green' purchases (Defra, 2006). This means there is a discrepancy between what people think and what they do, and sometime they may even do right thing without being environmentally minded (Gram-Hanssen, 2010:185). They may also consume more energy even if they have high environmental concerns (Gill et al, 2011). This reinforces the role of the HH occupant behaviour in the energy performance in housing (discussed in Chapter 4).

Furthermore, Stiess and Dunkelberg's (2013:257–58) study suggests that 'the decisions to install EET or LZC technologies were often the result of a combination of personal and contextual factors and shaped by wants and everyday needs, including comfort, convenience, social status and belonging' and 'motives' which are perceived to be 'widespread amongst homeowners'.

5.3 Type of Consumer: Green Consumer Values

37 Discussed further in Chapter 6.

An alternative approach (Young et al. 2008) suggests conceptualising individuals as 'green consumers', defined as a distinct group holding 'green values' achieved through the adoption of a sustainable lifestyle. For these 'green consumers' each purchase has ethical, resource, waste and community-impact implications; therefore, they are more likely to purchase environmentally friendly products and change their behaviour towards sustainable consumption (Young et al. 2008). The adoption of any given green product results from a complex decision-making process containing trade-offs between conflicting issues – a 'motivational and practical complexity of green consumption' (Moisander, 2007:404 in Young et al. 2008:3).

Furthermore, Peattie (1999 in Young et al. 2008:5) suggests that:

'green consumerism' is consumption behaviour that should be viewed as a series of purchase decisions where individuals or families build up portfolios of purchase (or non-purchase) decisions which may or may not be linked or underpinned by a belief set about sustainable consumption.

These purchase decisions may be interrelated and underpinned by common values or they may be completely unconnected and situational – and thus not necessarily a product of holding green values. However, Keirstead's (2012) examination of UK adopter HH of solar PV technologies, found that nearly all held favourable 'green' values, worldviews, and self-identities, which helped adoption. The results suggested that the solar PV systems represented a symbolic reinforcement of a personal dedication to responsible energy use and environmental values.

5.4 Levels of Involvement with Technology Purchase

In general, Moisander (2007:404 in Young et al. 2008:3) suggests that 'technology-based product' purchasing requires 'high involvement' or 'risk' aspects which distinguish it from low involvement product purchasing, such as buying cleaning products or coffee. Consumers are likely to place less value on the products' environmental performance in the case of purchasing high involvement products compared to frequently purchased products with low involvement (Sriram and Forman 1993 in Young et al. 2008:6).

Linked to purchase decisions is how HH perceive the effort involved in engaging with the EE measure itself. As discussed earlier in Chapter 4, householders can engage with a range of activities (consumption orientated or habitual activity) that may result in either energy saving or efficiency. Thus, habitual efficiency behaviours (e.g. turning off lights) require 'less conscious thought' to execute, and fall into the domains of the 'every day effort rather than every month or year'. This is conceptually considered as different and separate from 'purchase' related (curtailment) behaviour, and in particular, to technology consumption which requires more conscious thought (Barr et al. 2005; Barr & Gilg, 2006).

In a US national online survey, 505 participants reported their perceptions of energy consumption and savings for a variety of HH, transportation and recycling activities. When asked for the most effective strategy they could implement to conserve energy, most participants mentioned curtailment (e.g. turning off lights, driving less) rather than efficiency improvements (e.g. installing more efficient light bulbs and appliances) (Attari et al. 2010). This suggests some people may favour efficiency behaviours over EET purchase.

5.5 Type of Technology and Product Attributes

Evidence from the existing research suggests that specifically in relation to technology, adoption rates can vary according to the different types of measures and their attributes and how people prioritise the EE values or attributes of the product or technology (e.g. EST, 2011; Faiers, Cook & Neame, 2007; Rijnsoever & Farla, 2014; Roy, Caird & Potter, 2007; Roy et al. 1998). For example, policymakers often describe insulation measures such as cavity wall insulation as having a particular functional 'fit and forget' quality which means that once installed they become 'invisible' yet can tangibly help reduce heat loss, raise thermal comfort and save money on energy bills. Other measures such as double glazing installation can serve a number of functions by not only reducing heat loss, but also by being considered aesthetically desirable and a purchase that can increase property values (EST, 2010, 2011; BRE, 2003).

In other domestic products, such as televisions or washing machines, EE may enter purchase decision-making only after other more prioritised factors such as 'value for money' and 'product performance' had been taken into consideration (Roy et al. 1998:268–69). Hence, the technologies' functions, design attributes and user requirements need to be taken into account in adoption decision-making.

Furthermore, instead of goods being categorised against personal attitudes or motivations for purchase (as suggested in individualistic perspectives), the products (as innovations) are the focus of analysis and categorised against five 'characteristics' – where potential adopters or consumers are likely to assess the feasibility of attributes through a step-wise decision-making process (e.g. Gillard, Bailey & Nolan, 2008; Rogers, 1995).

According to Rogers (1995), these attributes are defined as: relative advantage, compatibility, observability, trialability, and complexity. In this context, relative advantage refers to the degree to which an innovation is perceived as better than the idea it supersedes; compatibility is the degree to which an innovation is perceived as being consistent with the existing values, past experiences and needs of potential adopters; complexity is the degree to which an innovation is perceived as difficult to understand and use; trialability is the degree to which a user may experiment with an innovation on a limited basis; and observability is the degree to which the results of an innovation are visible to others (Gillard, Bailey & Nolan, 2008:24). Therefore, the products' characteristics are likely to determine how quickly their adoption will occur. 'Innovative products perceived as being only a small departure from current practices (or products/technologies), as not too complex, that can be tried out before making a major commitment, and as compatible with current thinking are likely to be adopted faster than their counterparts that require more thought or skill and cannot be easily observed' (in Gillard, Bailey & Nolan, 2008:24).

5.6 Socio-Demographic Aspects

Previous studies have shown that socio-demographic factors (e.g. gender, age, personal income, household income, education level, homeownership (housing tenure type), number of household occupants or family size) were often considered to influence people's propensity for pro-environmental behaviours such as energy conservation (e.g. Bergmann, Hanley & Wright, 2006; Diamantopoulos et al. 2003; Gilg, Barr & Ford, 2005 in Rijinsover & Farla, 2014; Keirstead, 2007; 2012; Martinsson et al. 2011; Poortinga et al. 2003; Stiess & Dunkleberg, 2013). However, to date there appears to be little consensus over which aspects of these socio-demographic characteristics is the most salient in this debate.

In particular, some studies have highlighted that those with a higher level of education and income are more likely invest in EET or adopt energy-conserving behaviours (Scott, 1997; Martinsson et al. 2011 in Weiss et al. 2012). Furthermore, Brandon and Lewis (1999:75), from an environmental-psychological perspective, reinforce this view: 'that income and demographic features predicted historic energy consumption' where 'people with positive environmental attitudes, but who had not previously been engaged in many energy conservation actions, were more likely to change their consumption subsequent to the feedback period' (this reinforces the personal attitudinal factors discussed above).

Moreover, a study of solar water heating and domestic photovoltaic systems adopters in Germany found that highly educated professionals were more likely to be interested in technology adoption (Fisher, 2004 in Roy, Caird & Potter, 2007:43). In contrast, adopters of loft or cavity wall insulation were likely to include families/pensioners on low incomes often utilising subsidised energy-saving schemes (Roy, Caird & Potter, 2007). Furthermore, Rochracher (2003:189?) found that early adopter users involved in shaping technological systems were from very specific social groups, e.g.: highly educated, wealthy, with strong environmental values or commitments.

In sum, Nair et al. (2010a, 2010b) propose that a combination of personal and contextual factors such as gender, age, education, income and attitudes and awareness of EE measures, influence adoption of housing specific EET.

5.7 Role of Communication, Information, Knowledge and Learning

Another key influential factor in understanding adoption decision-making processes is perceived to lie in the role of knowledge, information and communication sources people are exposed to or have available to them (Roy, Caird & Potter, 2007:43; Stiess & Dunkleberg, 2013; Rogers, 1995, 2003). According to Fleck (1997) people often tap into five broad forms of knowledge in decision-making, i.e. from 'informative knowledge', 'expert knowledge', 'tacit knowledge', 'experiential knowledge' and 'textual' knowledge. For example, NEF (2014:2–4) in an 'Energy Poll' of 2,058 adults in Britain[38] found that: three in five (58%) felt informed about energy issues; three-quarters (73%) regularly sought information about energy issues; furthermore, 42% identified television and radio, and 32% searching the Internet, as the most important sources of information, compared to 22% who received information from the energy companies directly.

5.7.1 Expert knowledge

Some argue that access to expert knowledge (including specialised information, skills and capacities) is particularly important in the context of retrofitting EET into existing residential buildings. This was considered critical to homeowners who were unlikely to have sufficient levels of knowledge of new technologies systems, as well as relevant aspects of building construction and its potential adaptability (e.g. Nair et al. 2010a, 2010b; Stiess & Dunkleberg, 2013).

Furthermore, Stiess and Dunkelberg's (2013:253) survey of 1000 German homeowners, found that they 'consulted experts for advice on refurbishment but

[38] Representative of all GB adults aged 18+ interviewed online in 2014.

chose differing sets of professionals for information'. Their study found that an energy conscious HH group 'more often turned to a broader range of specialists instead, including heating installers, chimney sweeps, architects, and manufacturers', drew 'on the internet, handbooks, and journals as sources of information on refurbishment' and often sought 'professional energy advice' (Stiess & Dunkelberg, 2013:254) (similar findings were suggested by Nair et al. 2010a). These groups were more likely to participate in open home events to share their knowledge and experience with others and therefore aid diffusion of EET (Berry et al, 2014).

Therefore the 'communication and transfer of knowledge from external sources is thus a crucial prerequisite for successful adoption of low and zero carbon technologies' (Stiess & Dunkleberg, 2013:252). Of particular importance in this respect are the role of builders, other tradespeople, and their 'knowledge of building design and technology; and skills required undertaking high quality work' (Horne & Dalton, 2014:7; also: Nair et al. 2010a, 2010b; Stiess & Dunkleberg, 2013). Other studies (e.g. EST, 2011; *Which?*, 2013) show that homeowners are likely to have poor awareness and knowledge of potential solutions for home EE measures, creating a barrier that could lead to an overestimation of the true cost of measures and the level of disruption involved in adopting such measures.

5.7.2 Interpersonal networks of communication

Weening and Midden (1991 in Staats et al. 2011:345) examined whether 'decisions to adopt energy saving appliances in the home could be stimulated by information spread through social interaction in neighbourhoods'. The research suggested that the decision to adopt new technology is indeed likely to be influenced by the 'informal advice of neighbours who were friends or kin that is persons whose opinions adopters considered relevant and reliable'. The visibility of solar panels could stimulate adopters to discuss the technology and its potentials with friends and neighbours.

Thus, interpersonal communications were vital in decision-making. For example, adopters of solar water heating in the USA were often found in clusters, the result of neighbours observing – the peer effects – and discussing the costs and benefits of installing this technology (Bollinger & Gillingham, 2012; Rogers, 2003:16 in Roy, Caird & Potter, 2007).

5.8 Financial (Economical) Aspects – Costs

Some have suggested that perceived and/or actual costs can play a complex and significant role in people's adoption decision-making (e.g. EST, 2011; Fawcett & Killip, 2014; Hodek, et al. 2013). The question of how much EET will cost to buy and then install can vary from building to building, between HH and between differing technology types. This also relates to questions of whether an upgrade is perceived to be cost-effective over its payback period and/or the potential levels of return on investment are factors likely to influence HH decision-making (Fawcett & Killip, 2014; Hodek, et al. 2013).

The final cost is also likely to vary across differing refurbishment projects: from a single measure installation, a small room-by-room project say, to a large-scale and comprehensive refurbishment project (EST, 2011:12). A relatively large upfront investment cost is likely to deter some more than others, particularly those in lower income groups (EST, 2011; Poortinga et al., 2003). The EST (2011) suggests that there is a mismatch between perceived and actual costs of EE measures regardless of whether they are relatively low-cost[39] (i.e. insulation, new windows or new boilers) or

[39] Sometimes referred to as 'low-hanging fruit' investments for improving energy efficiency in existing buildings (e.g. Chandler and Brown 2009; McKinsey & Company 2009; NRC 2009) – although for numerous reasons many people choose not to take advantage of these supposedly cost-effective measures.

high cost (i.e. wall insulation or solar photovoltaics panels). In addition, often people do not adopt EET rationally (seeking lowest costs) as evidenced by the inconsistencies in what measures are adopted, e.g. overlooking simple and easy to install measures (e.g. loft insulation) for more costly and technical ones (e.g. boilers and photovoltaic systems) (Crosbie & Baker, 2010; DECC, 2010).

In contrast to rationalistic understandings of adoption decisions, Crosbie and Baker (2010) identified lifestyle as a key motivational 'pull' factor in HH technology adoption decisions. They suggest that HH were likely to overlook some well-established technologies for those that *fit in* with their lifestyle, and cite the example of buying an EE fridge-freezer (a tangible technology with a 'positive lifestyle attribute') but not insulation (said to have a negative attribute). Lifestyle, it would seem, can play a more influential role than cost as a deterrent.

Furthermore, studies with an economic and rationalistic perspective of the low consumer adoption of EET suggest it is the result of 'non-market failures' (e.g. highlighting the 'transaction costs of adopting new technology' or the 'use of inaccurate discount rates') as well as 'market failures' (e.g. a lack of transparent information about the benefits of EE (e.g. Brown, 2001; Pelenur & Cruickshank, 2012:3 – discussed in Chapter 4). However, one of the key shortcomings of this perspective[40] is its starting premise that the adoption of EE measures is driven solely as a rational economic investment decision, when in fact there is increasing evidence suggesting that non-economic factors and motives are equally influential in decision-making processes (e.g. Maller & Horne, 2011; Nair et al. 2010a; 2010b; Stiess & Dunkelberg, 2013; Zundel & Stiess 2010).

40 Further discussion of rational approaches is provided in Chapter 6.

5.9 Time, Trigger points and Lifecycle Events

The role of trigger points (EST, 2011a, 2011b), 'occasions' (Stiess & Dunkelberg, 2013) or 'moments of change' (Thompson et al. 2011) have increasingly been highlighted by government as 'opportunities for influencing behaviour' (Fawcett & Killip, 2014; Thompson et al. 2011). These 'opportunities' seek to mobilise personal life events, such as when people are moving homes, having a baby or changing family size in some other way, as well as 'wider macro socio-economic events' (e.g. the 2008–09 'credit crunch') that are likely to trigger HH to undertake building renovation works (Thompson et al. 2011:6). Hence, many of the changes that HH undertake to their buildings – including EET adoption – can occur over time, as one-off events or as something that unfolds over many months and years as a result of specific life events (Fawcett, 2013; Fawcett & Killip, 2014; Hand et al. 2007; Maller & Horne, 2011).

Good practice guidance provided by government suggests that ideally improvements of energy performance to existing housing should be integrated into everyday maintenance and repair works as this makes them cheaper and easier to implement rather than installing them separately later (BRE 2003; EST, 2011b:8). Stiess and Dunkelberg's (2013:253) survey of 1,000 German householders' renovation decision-making reinforces this viewpoint. It found that 'approx. two-thirds of the homeowners agreed strongly or somewhat that refurbishment was carried out because of necessary maintenance work' which 'is linked to the life cycle of the building's technical components'.

5.10 The Role of Home Renovations

Some ‘sociological’ studies have increasingly focused on the established social practice of home renovations as the basis from which to understand how buildings are changed. This body of research stresses examination of residential building renovation activity (including refurbishment, repairs, maintenance) as a context for understanding the adoption of EET in order to enhance its environmental performance of houses (e.g. Achtnicht & Madlener, 2014; Mallaband, Haines & Mitchell, 2012; Maller & Horne, 2011; Stiess & Dunkelberg, 2013).

Maller and Horne, (2011:67), through a qualitative study of 16 homeowners from states across Australia, identified a ‘home improvement spectrum’ and used it to describe the changes people made to their home, ranging from minor changes to windows and light fittings, to major and structurally intrusive changes such as a kitchen and bathroom extensions; they also distinguished between ‘retrofits’ and ‘home improvements’. Maller and Horne found that respondents had more than one reason for the home improvement, the most common reasons cited concerned HH cost reduction (through measures such as installation of EE lightbulbs, insulating roofs/walls, buying EE appliances); this was followed closely by the need to improve the thermal comfort and ‘updating interior aesthetics’ and ‘increasing the interior space’ (2011:68). They suggest home renovations are ‘embedded within HH cultural practices and an integral part of homemaking’ (Maller & Horne, 2011:60).

Wilson, Crane and Chryssochoidis (2013:1), drawing on the results of a nationally representative survey of over 1,000 UK homeowners, described home renovations (including EE measures) as a ‘decision making process that unfolded over time and emerged from within the conditions of everyday domestic life’. In other words, their findings support an overall picture of ‘energy efficient renovations as an adaptive response to competing commitments within the home’ (Wilson, Crane & Chryssochoidis, 2013:1). More specifically, the ‘everyday life’ circumstances leading to home renovation works are often linked to personal factors (e.g. desire for thermal comfort and other aspirations) but also contextual factors, such as the building’s age, design and aesthetics (heritage value), condition, size and its functional potential for its users (Achtnicht & Madlener, 2014; Gram-Hanssen, 2014; Maller & Horne, 2011; Stiess & Dunkelberg, 2013).

5.10.1 Distinction between EE renovations and general renovations

According to Haas et al. (1999) identified a 'conservation chain', in which the adoption of SPV technologies in particular were connected with a series of HH actions in energy-saving investments. Stiess and Dunkelberg (2013) considered whether there was a distinction between 'normal' home renovation decisions and 'energy efficient' refurbishment decisions. The results of their survey suggested some subtle differences between the two groups. For example, the 'standard' group members were mainly driven by aesthetic or functional concerns, their goals being to embellish their home, do necessary maintenance work or maintain and/or increase the value of their home. In contrast, the 'energy' group showed 'a more comprehensive, set of motives for refurbishment', such as 'to save heating energy and reduce energy and operating costs'. In addition, the 'energy' group voiced a desire to 'contribute to climate protection or to become less dependent on fossil fuels', while a desire to install 'up-to-date technology in the home' was also relatively strong amongst the 'energy' group (77%) when compared to the 'standard' group (28%) (2013:253).

Many studies have highlighted how renovation/refurbishment activity is not motivated by a single reason but is a result of an alliance of economic and non-economic factors (e.g. Stiess and Dunkelberg 2013; Wilson et al. 2013). They have also suggested that the adoption of EET technologies can – or should – ideally coincide with major renovations/repairs to the home. Conversely, government is concerned that many homeowners often miss such occasions, and frequently undertake renovations without investing in EET (EST, 2011a). This issue contributes to understandings of the complexity of low adoption rates that government policy seeks to change.

5.11 Occupant Use of Technology

Finally, whilst understanding adoption decision-making is important, it is equally important to understand the factors influencing the use of EET: adoption alone is not enough to reduce and manage HH energy consumption behaviour (see Chapter 4, Section C). Therefore, the existing literature has already suggested that in order to reduce carbon emissions significantly, consumers have not only to choose the right products that use less energy than the ones they replace, but also to then use the products efficiently. There is a body of literature that has highlighted some of the contradictory aspects of occupant use that can reduce the potential of the adopted measures: technologies not being used as intended; lock-in of practices; rejection of technologies; rebound effects and so forth (e.g. Caird & Roy, 2010; Roy et al. 1998). The use dimensions of occupant behaviour suggests people's use of EET in the home also depends on the context of circumstances and constraints, habits, desire, comfort, convenience, owners' information, design of products and systems (e.g. Hand et al. 2007; Pierce, Schiano & Paulos, 2010; Roy et al. 1998; Roy, Caird & Potter, 2007).

5.12 Chapter Summary

Following on from previous chapters, this chapter has outlined how consumer adoption and use of EET and systems is not a straightforward and rational matter of saving money or the environment, but is influenced by a complex network of factors. It highlighted specific key aspects deemed significant in EET adoption decision-making: personal attitudinal values; technological attributes; socio-demographics; the role of communication, information and knowledge; financial aspects; trigger and lifecycle events; and the context in which renovation takes place. The studies also suggest that there is considerable debate over which aspects are most salient, therefore reflecting the complexity in individual decision-making processes and behaviours. Although these factors are not an explicit part of the research theoretical framework, these components are nevertheless taken into consideration in the final thematic analysis undertaken as part of the empirical analysis using the domestication framework (Chapters 10–11).

Chapter 6 will examine some of the dominant theoretical approaches, which are crucial to understanding the determinants of energy consumption behaviours and how these have informed related government intervention strategies.

Chapter 6: Theoretical Models & Government Policy

6.1 Introduction

Complementing previous chapters, Section A of this chapter presents the dominant insights originating from psychology and sociology that offer a range of theoretical models which have been used in studies to understand, predict and change individuals' responses to energy and environmental issues (for example, to promote voluntary pro-environmental behaviour). Additionally, and recognising that there is no single model but rather many overlapping models, this chapter shows how numerous models highlight the different factors that influence behaviour. Although this chapter provides an overview of the dominant perspectives this is by no means a comprehensive review of all the differing approaches emanating from differing disciplines, but is rather an indication of the type of approaches that have been used in relation to energy behaviours

Examining these differing disciplinary approaches and models also allows an opportunity to compare the diverging influences and barriers and their attempts to model such influences. One key purpose is to demonstrate how these two academic disciplines have viewed the same issues, although understanding human behaviour is not, of course, exclusive to these two domains and spans numerous other academic disciplines (POST, 2012:1; Martiskainen, 2007; Wilson & Dowlatabadi, 2007).

Within the dominant theories and models of energy-related behaviour (hereafter referred to as 'behaviour theories'), behaviour is conceptualised and defined in numerous ways, but it can be broadly divided into two distinct groups. The first groups psychological or individualistic approaches, which place the individual at the centre of analysis. These approaches originate from economics and psychology, and are explored in Section A. The second group consist of studies that place the behaviour itself at the centre of analysis; these originate from sociology, human geography, marketing studies and anthropology (Section B). The key distinctions between these two will be further examined. Sections C and D of this chapter examine how these dominant normative approaches shape current government policy interventions[41] for behaviour change, and offer an evaluation of their effectiveness.

Section D briefly introduces Domestication Theory (DT); DT is a research framework appropriate for this study that is able to fill a knowledge gap. Section D also highlights how the use of this particular lens represents a critique of the dominant approaches (discussed in Sections A and B) within energy research discourse. DT offers a middle ground for examining people's interactions with technologies and energy consumption practices in their everyday life. Finally, DT provides an alternative perspective for understanding the complexity of technology adoption processes and lived experiences.

This chapter is divided into the following sub-sections:

- Section A: The dominant individualistic and psychological approaches to energy-related behaviours
- Section B: Sociological approaches to energy-related behaviours
- Section C: The influence of theory in policy practices
- Section D: DT as an alternative perspective

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41 From government departments, i.e. DECC, DEFRA.

6.2 Section A – The Dominant Individualistic and Psychological Approaches

Psychological approaches have traditionally dominated research on energy-related behaviours. They draw on insights from sub-branches of the discipline such as environmental, social, economic and cognitive psychology. These analyses place the individual at the centre of behaviour, putting the influence of individual agency above the influence of wider external societal factors.[42] Nevertheless, behaviour is overall perceived to be a product of individuals either balancing or trading-off competing influences (e.g. Dawnay & Shah, 2005; Faiers, Cook & Neame, 2007; Jackson, 2005; Wilson & Dowlatabadi, 2007).

Typically, environmental behaviour is examined through the lens of individual behaviours in an attempt to explain or predict why people behave in the way they do (Abrahamse et al. 2005; DEFRA, 2008; Gardner & Stern, 1996; Jackson, 2005; Lorenzoni, Nicholson-Cole & Whitmarsh, 2007). Researchers are often preoccupied in trying to identify and model 'which types of interventions' are likely to deliver more favourable environmental behaviour (Abrahamse et al. 2005; Gardner & Stern, 1996; Wilson & Dowlatabadi, 2007). The key influences identified by the environmental psychological literature that are likely to affect an individual's attitudes and behaviour towards environmental issues, include 'past behaviour, knowledge, experiences, feelings, social networks, institutional trust, demographic background' (Kollmuss & Agyeman, 2002 in Lorenzoni, Nicholson-Cole & Whitmarsh, 2007:446). In a comprehensive literature review, Stern (2000) highlights the fact that contextual forces, personal capabilities and habits, in addition to attitudinal factors, influence behaviours.[43]

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[42] These approaches arise from more general psychological theories: for example, the theory of planned behaviour, theory of reasoned action, value belief norm theory, attitude behaviour context model, the Triandis model, etc. (see Ajzen, 1991; Ajzen & Fishbein, 1980; Stern et al. 1999; Stern, 2000).

[43] E.g. Jackson (2005) and Faiers, Cook and Neame (2007) provide detailed reviews of the literature on consumer behaviour, behavioural change and comprehensively review consumer behaviour theories.

Furthermore, in growing recognition of the harmful impact or effects of individual lifestyles on the environment and the urgent need for people to change their behaviour, studies have commonly used the theory of planned behaviour (TPB) to predict environmental behaviour (e.g. Hines et al. 1986–87; Pettifor, Wilson & Chryssochoidis, 2015). Moreover, policymakers to explain, change, manage and develop interventions to encourage pro-environmental behaviour and change behaviour (Cabinet Office, 2011; Darnton et al. 2006; Wilson & Dowlatabadi, 2007) have frequently used it.

Numerous studies have used TPB across a range of energy and environment-related themes. Typically these include: recycling participation, waste management and attitudes thereto (e.g. Chan & Bishop, 2013; Davis et al. 2006; Lowe et al. 2005; Tongleta, Phillips & Read, 2004); domestic energy consumption feedback and monitoring (e.g. Webb, Benn, & Chang, 2014); small-scale renewable energy technology acceptance and purchasing behaviour (e.g. Alam et al. 2014; Allen et al, 2008); the psychological factors affecting commuters' transport mode use (e.g. Bamberg & Schmidt, 2003; Donald, Cooper & Conchie, 2014); and how to optimise consumer-directed EE interventions (e.g. Pettifor, Wilson & Chryssochoidis, 2015).

However, research applications of the TPB model have also acknowledged that in reality, and despite people's best intentions, some people fail to act or change their behaviour. This inaction of intention is often identified as a 'value action gap' (Blake, 1999; Kollmus & Agyeman, 2002). Hence, the model appears to fall short in explanatory power in relation to this problem (Blake, 1999; Kollmus & Agyeman, 2002; Sutton, 2001). The value action gap is a topic of considerable contemporary research debate (see for example, Jaffe & Stavins, 1994; Kollmus & Agyeman, 2002; Rhodes & Bruijn, 2012; Rhodes & Dickau, 2012, etc.); research has tried to quantify the gap and identify the causes, barriers and inactions that give rise to it, in order to determine how policy interventions could be designed to bridge it.

6.2.1 Rational model influences

It has been argued that the weaknesses of the predictive individualistic TPB model may be related to its underlying rationalistic assumptions derived from classical economic theories. Its key assumptions are that individuals act as rational agents through self-interest and future-oriented goals, and weigh up the costs of possible future courses of action in order to maximise benefits.[44] Later modifications to the model have, however, accepted a 'bounded rationality' – that is, people are not always seeking to maximise benefits and/or minimise costs (Chatterton, 2011; Dawnay & Shah, 2005; Jackson, 2005; Martiskainen, 2007).

One manifestation of this rationalistic theoretical approach has been its use in an information deficit model in government energy policy approaches (e.g. Blake, 1999). Here, policy has assumed that consumers do not have access to the relevant information when making decisions or purchases in order to make the most effective or rational choice. However, both research and practice have shown that information alone, in the form of communication campaigns and information leaflets, is generally not enough to change HH' energy-consuming behaviour (see Abrahamse et al. 2005; Blake, 1999; Darby 2006; Geller, 1981). Thus, information sources may need to be combined with measures such as feedback on energy use, which could then contribute to behaviour change (Abrahamse et al. 2005; Darby 2006; Gardner & Stern, 1996). Therefore, there is also policy and research recognition that no single intervention

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44 E.g. rational choice theory is one such micro-economic model focusing on how individual behaviour results from individual preferences, choices and decision-making and in circumstances where individuals are free to act on their intention regardless of the constraints.

alone can deliver change (Martiskainen, 2007; Stephenson et al. 2010; Wilson & Dowlatabadi, 2007).

6.2.2 Key criticisms of psychological and rational approaches

A number of key weaknesses of the individualistic and psychological approaches and models can be identified. Firstly, they have been criticised for offering an overly rational account of how people make decisions. Secondly, for some these approaches offer limited explanations of social complexity, in terms of the occurrence of 'cognitive dissonance'[45] at the individual level. This means that consumers may reject adoption of a good based on emotional or personal preferences (Lorenzoni, Nicholson-Cole & Whitmarsh, 2007; Stoll-Kleemann et al. 2001). Thirdly, these approaches underplay the significance and influence of broader structural factors – economic, environmental and social – that may affect an individual's ability to change their behaviour (Abrahamse et al. 2005; Hansen, 2005 in Faiers, Cook & Neame, 2007; Jackson 2005; Shove, 2010).

In particular, Shove (2010) forwards a critique of the dominant individualistic psychological approaches, which currently underline many contemporary government policies seeking to foster sustainable everyday practices. Such government approaches can be seen in a range of policy strategy documents (e.g. 'Motivating Sustainable Consumption' (Jackson, 2005)), and in a range of models that have been used (e.g. '4 E's' and MINDSPACE). These have been criticised for being too focused on individual consumer decision-making and cognitive processes, with limited recognition of context, and without fully engaging with the socio-structural influences on behaviour. These governmental initiatives and models appear

45 E.g. Dickerson et al. (1992) discuss dissonance in relation to water conservation in showering.

to be ‘deliberative’ policy tools designed to change particular sets of entrenched or habitual unsustainable behaviour (Dolan et al. 2010; Jackson, 2005; Shove, 2010).

Furthermore, Shove (2010), labels these dominant policy initiatives as a ‘rationalistic’ ‘ABC framework’ (attitude-behaviour-choice), which through a narrow focus emphasises individual responsibility to bring about sustainable changes. This, she asserts, detrimentally diverts attention away from the significant influences government and other actors play in ‘sustain[ing] unsustainable economic institutions and ways of life’ (Shove 2010:1274). She proposes that sociological perspectives are better placed to understand the impact of policy frameworks and broader social contexts, as these approaches consider the role and influence played by social conventions, norms, discourses, power relationships and unequal distributions of resources.

Closer inspection of government[46] policies suggests use of both psychology (e.g. the Triandis model) and sociology (social practice theory (SPT)) models (POST, 2012; Chatterton, 2011). This suggests recognition of the limitations of individualistic behaviour models, and hence a move towards a focus on approaches that consider more contextual aspects of behaviour (from sociological approaches) – the following section examines these further.

46 E.g. the Department of Energy and Climate Change (DECC) and the Department for Environment, Food and Rural Affairs (DEFRA).

6.3 Section B – Sociological Approaches to Energy-Related Behaviours

In contrast to the psychological and individualistic approaches discussed above (which emphasised the autonomy of individual choices), sociological approaches (e.g. social practice theory, social studies of technology) emphasise that behaviour is an outcome of complex socially shared practices, interactions and interrelationships (Ropke, 2009; Shove, 2003; Spaargaren, 2011; Southerton, 2006). This approach focuses on manifested behaviour by taking account of the societal context in which it occurs, examining relationships between individuals, their actions and their relationships to the surrounding social, physical, material and environmental context. Hence, social practices are embedded in wider sociotechnical systems of society, which are themselves historically and culturally variable (e.g. Bartiaux, 2008; Shove, 2003; Spaargaren, 2011; Southerton, 2006; Wilhite, 2007).

6.3.1 Social Practice Theory

SPT has been increasingly used in sociological research and policy aimed at tackling environmental and energy consumption issues (e.g. Darnton, 2004; Gram-Hanssen, 2011; Judson & Maller, 2014; Maller & Horne, 2011; Palm & Darby, 2014; Shove, 2003; Spaargaren, 2011; Southerton, 2006). Its specific approach to understanding how people think and act seeks to challenge the dominance of individualistic socio-psychological perspectives of behaviour (rational consumer choices). It switches attention away from individual behaviour to 'systems of practice' as a collective social phenomenon (e.g. Reckwitz, 2002, 2003; Røpke, 2009; Shove, 2009; Shove & Pantzer, 2005; Southerton, 2006; Spaargaren, 2011; Warde, 2005). It specifically moves the debate onto a complex sociotechnical system, incorporating user relations, practices and infrastructures that shape how energy is consumed (e.g. Gram-Hanssen, 2010, 2011; Ozaki & Shaw, 2014; Palm & Darby, 2014).

SPT is useful in its conceptualisation as an umbrella approach (rather than a single unifying theory) from which various theories and approaches have been developed. For example, Shove's three-elements model has defined three interlinked elements or components (material artefacts, meanings and procedures) which come together to comprise a social practice (Chatterton, 2011; Shove, 2003, 2010).

However, there is no unifying definition of the meaning of 'practice', and different scholars make specific characterisations of the concept of practice in different ways (Darnton, 2004; Jackson, 2005; Reckwitz, 2002, 2003; Røpke, 2009; Schatzki, 1996). For Schatzki it is a 'temporally unfolding and spatially dispersed nexus of doings and sayings' (1996:89). For Reckwitz a practice is defined as 'a routinized type of behaviour which consists of several elements, interconnected to one another' (Reckwitz, 2002:249–50). Broadly, these are 'societal everyday practices which people perform, and can be routine, collective and conventional, habitual and even complicated, e.g. showering, cleaning, eating, walking, going to work or shopping' (Schatzki, 1996:98).

One key element of SPT draws on Latour's actor-network theory to incorporate the role of the material world – elements such as the non-human 'actors', artefacts and infrastructures – in constructing, reproducing and shaping practices (Latour, 2005; see also Pantzar & Shove 2010; Shove 2003; Spaargaren 2003). Social practices involve interaction with material artefacts (things) and broader technical infrastructures and systems,[47] which drives both stability and change. Thus, the

[47] E.g. at the HH level the use of computers, mobile phones and electrical appliances; and at a broader level, e.g. how the development of motorway infrastructures led to the dominance of private car use over public transport (see Shove, 2003, 2010).

material world and its related systems of production actively define what society takes to be normal. Through their ‘stabilising’ nature, these systems can sometimes ‘lock-in’ certain social practices, limiting and preventing changes from taking place. The lock-in or stability of some practices can be further perpetuated by social conventions or norms, which determine how people do things (at a conscious and subconscious level). For example, beliefs about what is deemed to be normal behaviour can form the basis of how people go about using energy in their homes; and the social networks that they are part of can either support or supress certain types of practices (Bartiaux, 2008; Gram-Hanssen, 2011; Shove, 2003; 2010).

SPT’s strength and appeal lies in the way it provides new ways to understand and explain behaviour by focusing on the ‘embedded’ nature of certain energy consumption practices. However, some argue that this characteristic can also be its weakness as it remains unclear how these practices can be changed especially when it comes to consumption practices that are difficult to change (e.g. DECC, 2011; Gram-Hanssen, 2011; Southerton et al. 2004:40; Warde, 2005:140), and in particular in light of the introduction of new technology.

Increasingly in response to this criticism, various authors have argued that practices are not static, and that it is possible for social practices to be changed through the flexibility of actors’ meanings and competences and the continuous re-enactment of practices (Pantzar & Shove, 2010; Reckwitz, 2002:255 and 2003:294; Shove, 2003, 2010; Warde 2005). However, they also seem to simultaneously concede that due to the complexity of the differing underlying factors involved in social practice change (e.g. multiple, interrelated and historically specific, across space and time) a simple universal theory of practice change appears unrealistic.

Shove (2003), in her classic study of showering, cleaning, heating and cooling of homes, examined how social norms have changed and shaped our daily routines. She notes how increasingly people require higher internal temperatures – often of over 22 degrees even though only up 18 degrees is required for health – and that changes in notions of cleanliness mean that weekly baths have changed to daily showers – all of which are connected with notions of social norms in modern lifestyles. However, her study also suggested that the introduction of new technologies or innovations could result in the transformation of practices, and yet the approach does not necessarily identify specific causes for change, but rather suggests how change could co-evolve within practices.

6.3.2 Technology and energy practices

Within broader sociological perspectives of the role of technology, its appropriation and use appears to be a wide and disparate area with many differing discursive strands. However, as suggested already within SPT, actors are continually shaping social structures through routine social practices. Within this context, the role and interaction of physical artefacts, technology, infrastructures and institutions are integral to the construction and reproduction of energy-related practices (e.g. Bourdieu, 1977, 1990; Giddens, 1984; Gram-Hanssen, 2011; Reckwitz, 2002, 2003; Schatzki, 1996; Schatzki, 2001).

Technology and related artefacts can be used in energy practices in very different ways from their design for a variety of reasons: people's energy consumption can be contingent upon how they appropriate technology, as well how they use existing infrastructures; it is also likely to be socially conditioned by what is perceived to be 'normal' within their social network or cultural context (e.g. preference for car use over bicycles) (Bartiaux, 2008; Gram-Hanssen, 2011; Jensen, 2005). The replication of social practices is also assumed to result in stable practices, which can also determine the evolution and use of specific technologies (Bartiaux, 2008; Shove, 2010). Hence, technologies are an active component of practices and therefore shape such practices and their interrelated energy consumption dimensions (Ozaki & Shaw, 2014).

At a practical level, sociological perspectives, through their meanings, competences, materials, social structures and environmental contexts, serve as a contextual basis for understanding social practices. They have been used by policymakers to help analysis and to then design 'purposive interventions' to tackle undesirable components of social practices, thus intervening in their social reproduction (Darnton, 2005; DECC, 2011; Jackson, 2005; Lorenzoni, Nicholson-Cole & Whitmarsh, 2007).

Furthermore, given interest in promoting behaviour change in environmental and energy policy, government has (in addition to psychological models) begun using sociological approaches such as SPT in policy formulations. For example, DECC has used SPT in order to reconceptualise the way it views energy-consuming practices (such as cooking and showering) as social phenomenon beyond their conceptions as individual actions or choices (POST, 2012:2). From an SPT viewpoint, change in energy consumption behaviour must come from a societal level and not necessarily from individual actions alone (POST, 2012).

6.4 Section C – Influence of Theory in Policy Interventions

Notwithstanding their varying strengths and weaknesses, the differing insights offered in this analysis have informed public policymaking. They have been used to improve understandings of energy-related behaviours which no single approach can exclusively claim to do. Firstly, psychological approaches can help policymakers identify the factors that influence behaviour and understand the conflicting nature of people's intentions and actions when it comes to energy use and saving behaviours. Secondly, sociological approaches reveal the social embeddedness of consumption patterns over time and their resistance to change. Collectively, these multidisciplinary insights contribute towards helping to unravel the complexity of energy-related behaviours (which sometimes interact paradoxically with each other) and the multitude of factors that shape them, thereby highlighting that there are no one-size fits all interventions (Abrahamse et al. 2005; DECC, 2011; Jackson, 2005; POST, 2014).

6.4.1 Intervention strategies

In recognition of the complexity and unpredictability of people's energy intensive consumption practices, over time a number a number of behaviour change focused policy interventions have been deployed (e.g. Cabinet Office, 2011; DECC, 2010; DEFRA, 2006; HM Government, 2009). These interventions have included a mix of regulatory and non-regulatory mechanisms, e.g. providing information or awareness raising campaigns; taxation and/or legislation; so-called 'nudge' interventions, etc. (STSC, 2012).

Furthermore, non-regulatory interventions, such as the use of social norms marketing and the nudge approach (Cialdini & Goldstein, 2004; Thaler & Sustein, 2008) have increasingly been endorsed by the UK government in many policy agendas (Cabinet Office, 2011; STSC, 2012), but particularly in electricity consumption reduction (Allcott, 2011; Ayres et al. 2009). Moreover, other strategies include feedback mechanisms (e.g. Brandon & Lewis, 1999; Darby 2006; Fischer, 2008); financial or fiscal incentives (e.g. the Green Deal and Feed-in Tariffs) and the more recently proposed use of smart meters (with customer displays) to manage habitual energy use (Gifford, Kormos & Mcintyre, 2011; POST, 2012). Further adaptations combine online checking of heating costs (via energy suppliers), with prompts, goal-setting, social comparisons, real-time personalised feedback, etc. (e.g. Brandon & Lewis, 1999; Garay & Lindblom, 1995).[48]

Based on the types of interventions promoted, it seems that government policy advocates that individuals take responsibility for reducing HECB through 'rationalistic' consumer choice and the take-up of financial incentives and tailored information and so on. These are underpinned by economic approaches and accompanied by feedback and personalised advice strategies, which originate from sub-areas of psychological approaches. Recently, more sociological approaches have underlined interventions such as social comparisons and collective pledges or community actions. Moreover, SPT has been applied in understanding sustainable behaviours around domestic energy use, transport, waste and recycling, etc. (DECC, 2011; POST, 2012). However, these strategies have been criticised for failing to foster large-scale 'mainstream' behaviour change, reflecting their failure to provide a clear framework for how behaviour could change and through which means (Lorenzoni, Nicholson-Cole & Whitmarsh, 2007; Janda, 2011; Wilson & Dowalatabadi, 2007).

[48] There is an established body of research that has reviewed and evaluated the merits of the various interventions cited here (see e.g. Abrahamse et al. 2005).

6.4.2 Problems with interventions

One of the most commonly deployed interventions has been in the use of information communication (e.g. the Energy Saving Trust[49]) or awareness raising media campaigns (e.g. Act on CO_2), which are accompanied by market segmentation of HH types that allow the delivery of tailored information. Such interventions are often pursued, as they are perceived to be the most efficient and cost-effective to implement; yet they have proven to be relatively ineffective in delivering behaviour change (Cabinet Office, 2011; Janda, 2011). This approach originates from policy assumptions based on an 'information deficit model', which has tended to dominate energy policy and research discourses (e.g. Owens & Driffill, 2008 in Janda, 2011; Wilson & Dowalatabadi, 2007). Hence, the awareness raising and education aspects of such interventions have become the main ways to 'overcome' this deficit. This is underlined by the premise that 'more and better information' may result in more efficient energy use or 'correct' behaviours (Janda, 2011). Additionally, despite its potential merits the evidence (e.g. Janda, 2011; Jackson, 2005; Wilson & Dowalatabadi, 2007) suggests that this strategy alone does not work.[50]

This information approach holds particular implications for how people use their buildings in relation to curtailing energy consumption (e.g. not leaving lights on standby and insulating homes). For instance, despite national marketing of the Green Deal the rate of its adoption had been deemed low; and even where people have adopted domestic EET it cannot be assumed that it will result in the automatic 'correct' and efficient use of such technologies, and nor does it guarantee spill-over benefits of changing existing energy practices (e.g. Jackson, 2005; Roy, Caird & Potter, 2007; Wilson & Dowalatabadi, 2007). In this context, evaluations of EE

49 This is a government endorsed intermediary body designed to provide the public with impartial advice and information on home energy efficiency.

50 The application of energy information with feedback connected to the HH EET own behaviour has shown evidence to lower residential energy use in some studies (e.g. Gardner & Stern, 1996). Also, the evidence suggests that non-regulatory interventions used in isolation, such as nudges, are ineffectual (STSC, 2012).

intervention outcomes need to not only take account of the potential savings but also consider the potential for rebound effects (discussed in Chapter 4).

Finally, there remains considerable debate within this ‘energy’ discourse over understandings of what influences human behaviour, which interventions work and their application at a population level (POST, 2012; STSC, 2012). This is largely attributed to the complexity of factors that shape people’s energy use in buildings,[51] which is often idiosyncratic and unpredictable, and which no single approach can adequately explain (Janda, 2011; Kierstead, 2006; Wilson & Dowalatabadi, 2007). Therefore, effective policies will inevitably need to use a range of interventions if they are to succeed (Cabinet Office, 2011; STSC, 2012). There are calls to develop a stronger evidence-base for evaluating and monitoring the design and impact of policy interventions beyond the lifespan of the intervention – all of which continue to create challenges for policymakers (POST, 2012; STSC, 2012).

6.4.3 Evaluation of theoretical approaches and policy practices

My analysis has so far provided an overview of the most dominant theoretical perspectives and models of behaviour and behaviour change. Whether the approach is individualistic or sociologically focused, they appear to offer a specific position in the problem of understanding people’s behaviour. For instance, whilst individualistic psychological theories are often criticised for their simplistic behavioural assumptions – missing or devaluing the impact of social context (i.e. overlooking the embeddedness of everyday consumption practices and escalating consumption demands; or that energy use is often grounded in norms and habitual routines) – they nevertheless provide invaluable insight into the strong role of individual agency.

[51] They can leave windows and doors open when the heating is on; their practices such as cooking and body temperature can generate heat issues; they may consume large numbers of heat-generating and energy-consuming technologies, etc. (e.g. DECC, 2012; EST, 2011; Janda, 2011).

Arguably, the sociological contexts appear more fragmented, diffuse and less tangible, which is largely attributable to the complexity of measuring social factors. Equally, whilst previous studies and theories have contributed to our understanding of HECB, there is no single model that can claim to be inclusive of all these factors.

In addition to government recognition of the social and behavioural dimension, the technological – material – dimension needs examination, given that many of the policy interventions promote technology adoption as a solution to energy demand reduction (Ozaki & Shaw, 2014; Ravetze, 2008). Furthermore, the former two approaches do not adequately explain people's specific interactions with EET. Due to this study's interests in both adoption and use of technology (as a process not a single event) and their implications for energy-related consumption practices, DT has been identified as providing a middle ground that offers scope for examining a gap between the two dominant approaches.

Thus, the next section briefly introduces the concept of DT – the research framework, and why this represents an alternative perspective to understanding technology adoption processes.

6.6. Section D – Domestication Theory as an Alternative Perspective

6.6.1 Overview of Domestication Theory

DT is a sociotechnical theory. The concept is used to describe and analyse the interactions between people and technological artefacts (Berker et al. 2006; Hynes & Richardson, 2009). It provides a conceptual framework for analysing and describing the processes by which technological artefacts are accepted, rejected and/or used to become part of everyday life in the domestic sphere. In particular, it identifies four non-discrete phases though which this is achieved: appropriation, objectification, incorporation and conversion (Berker et al. 2006; Hynes & Richardson, 2009; Silverstone, Hirsch & Morley, 1992).

DT focuses on 'individual agency over the technology', and places the emphasis on the role played by the user, their experiences, their adoption of a technological artefact and the way they define its 'nature, scope and functions' (Lee, Smith-Jackson & Kwon, 2009; MacKenzie & Wajcman, 1999, 2006). Therefore, unlike the individualistic psychological cognitive models of behaviour, DT uniquely offers both a practical and symbolic perspective on the processes of adoption and use of a given technology by HH.

Additionally, its usefulness lies with the fact that it provides an 'analytical framework for describing and understanding complex user experiences' at the HH level in relation to the adoption of specific domestic EET. However, it could also be argued that this model seems to underplay the significance and influence of 'cognitive' factors and also broader social and structural contexts, such as economic, environmental and even material technical infrastructure dimensions, that may or may not affect individual behaviour and the ability to change (Berker et al. 2006; Hynes & Richardson, 2009).

Furthermore, unlike the individualistic models and their over-reliance on quantitative methods and/or search for causality and generalities, DT methodologically has tended to be qualitative – undertaking more descriptive and case study analyses to provide in-depth explorations of the complexity of social relations in the various research topics where it has been applied (Haddon, 2006). The nature and origins of DT as a research framework will be presented fully in Chapter 7. It has been introduced here briefly to illustrate its contrasting approach in relation to the dominant normative approaches discussed in Sections A, B and C.

6.6.2 DT as a critique of government policy

It is argued that the domestication approach by its very nature seeks to challenge industry, research and policy presumptions of rationality and efficiency in the processes of technology adoption and use. Therefore, DT represents a 'critical paradigm that aims to critique the status quo and expose deep-seated structural contradictions within social systems. It involves a critical stance against "taken-for-granted" assumptions' and 'reveals the historical and ideological contradictions within social practices' (Hynes & Richardson, 2009:489).

As already discussed, concerns over low uptake of EET have given rise to the prevalence of research and policy interest in a 'barriers/drivers' and technology-driven framing of the problem (e.g. Crosbie & Baker, 2010; Lorenzoni et al. 2007; Technomar, 2005). This has meant a focus on how to remove such barriers and incentivise take-up – through for example incentives, rebates, grants and promoting money saving dimensions e.g. FiT, RHI, smart meters). It relies heavily on adoption and ‘correct’ use of new and established technologies, designed to aid HH ‘take control’ to reduce and manage energy consumption in the home (Hargreaves, Wilson & Hauxwell-Baldwin, 2014; Roy, Caird & Potter, 2007).

There are many (e.g. Crosbie & Baker, 2010; Islam & Meade, 2013; Roy, Caird & Potter, 2007) who suggest that the weaknesses of the overall energy policy dimension relates to its prioritisation of technological solutions, misunderstandings of HH preferences and how people live. These dominant approaches are often referred to as ‘techno-rational’ or ‘techno-economic’ (e.g. Hargreaves, Wilson & Hauxwell-Baldwin, 2014; Ozaki & Shaw, 2014; Roy, Caird & Potter, 2007; Shove, 1998). These approaches assume that the adoption of technology is sufficient to achieve a reduction in energy consumption, but place insufficient emphasis on the need to address occupant behaviour. It is not surprising therefore; that this approach often fails to explain what happens in practice (see Chapter 4).

In this context, then, the approach of domestication theorists (e.g. Berker et al. 2006; Silverstone et al. 1992) represents an alternative lens and critique to the dominant techno-economic models embodied in current policy approaches. In particular, a focus on domestication emphasises the co-evolution of technologies with their users and use-environments; and improved understandings of the social shaping of technology within the home. Nevertheless, this concept is also not free from criticism, mainly from those outside the science and technology studies paradigm from where DT originates (discussed in Chapter 7).

6.6.3 Key conceptual criticisms of DT

Firstly, it has been argued that DT places too much 'emphasis upon the trajectories of single artefacts and neglects the importance of suites of technologies or how technologies are always part of, and indeed only valuable as part of, wider "configurations"' (e.g. Suchman et al. 1999, in Hargreaves, Wilson & Hauxwell-Baldwin, 2014:3). Existing domestication research (e.g. Jensen et al. 2009; Lehtonen, 2003) shows that over time the focus has moved to analysis of a multiple and diverse range of technologies beyond media and ICTs used in the home. For example, Juntunen (2014) examines the domestication of a range of housing renewable technologies, and Aune's (2007) research shows how the home is domesticated through a range of renovation activities. Both effectively demonstrated the scope for the concept's application beyond the analysis of single discrete artefacts and as part of wider technological systems. Here, DT is used to examine a suite of EET as systems within the sociotechnical system of the house.

Secondly, it has been argued 'that analyses of domestication are incomplete in that they tend towards a form of "stability" once a technology has been domesticated and fail, therefore, to recognize the multiple and always ongoing sources of change and disruption that can lead to de- and re-domestication' (Hargreaves, Wilson & Hauxwell-Baldwin, 2014:3). From an examination of existing studies (to be reviewed in Chapter 7) using the domestication approach, this critique appears to provide an unfounded and narrow interpretation of the approach. Whilst DT seeks out evidence of 'stability' in everyday HH practices following new technology adoption, the approach also maintains that adoption of new technologies can serve to both change and perpetuate existing patterns of practices. For example, Juntunen's (2014) research concludes there is no stable final point in the domestication of renewable technologies; rather, he proposes that it is a 'continuous cycle'. Again, this view is reinforced in Aune's (2007) research, suggesting that once a home has been domesticated through renovation activities, the process starts over again.

Thirdly, Shove et al. (2012, in Hargreaves, Wilson & Hauxwell-Baldwin, 2014:3) – advocates of SPT – argue that the key weakness of DT is its focus on technologies and how they are taken up within, or rejected from, everyday life. They argue that the focus should be on everyday practices and how they evolve and change; in this context, technologies should be understood as one important 'material' element amongst many elements contained within everyday practices; DT, in contrast, focuses on technology as a core unit of analysis and emphasises the co-evolution of technology with its users and use-environments. This is its key distinctive component.

Furthermore, a comparison of SPT and DT approaches suggests that there are some areas of common ground despite their relatively subtle differing philosophical positions. For example, both approaches argue that technology never determines actions, but rather that it is open to individual and social interpretations or domestication (Gram-Hanssen, 2010). One of its key weaknesses of SPT is that it has not been effective at explaining change, particularly in relation to the introduction of new technologies. Thus, in SPT, the role and influence of technology is unresolved and still open to debate (Gram-Hanssen, 2010). This appears to be a theoretical weakness or gap that DT can fill. Nevertheless, these two seemingly differing approaches appear to be two sides of the same coin, and what the focus of analysis is, is a matter of one's philosophical position.

This research addresses and represents a counter-response to these three key areas of criticisms: by moving research analyses away from single artefacts to a suite of technologies which operate as part of a wider socio-technological configuration of the home it examines both stability and instability in technology domestication (as evolutionary) processes; it also considers the co-evolution of technology within everyday practices of HH.

6.7 Chapter Summary

This chapter has provided an overview of the dominant theoretical perspectives and models of behaviour, and offered a specific position on the problem of understanding people's behaviour. It also highlighted how these have informed government policymaking and interventions. However, none of the dominant approaches explains the key aspects of adoption and lived experiences, and so DT was applied and taken forward. Firstly, as a research framework in order to fill this conceptual knowledge gap, and secondly, as an alternative perspective, which offered a middle ground for examining user interactions with technologies in their everyday life beyond dominant rational techno-economic approaches.

The following chapter will provide fuller details of DT as both a conceptual and theoretical framework.

Chapter 7 Domestication Theory – Research Framework

7.1 Introduction

Chapters 2–5 have highlighted the importance of both technical and non-technical factors as critical influences upon the energy performance of buildings, and stressed how low adoption is a sociotechnical problem. This has provided the justification for the adoption of a sociotechnical perspective in this research as one which enables recognition of the complex dynamic interactions between both human (social) and non-human (technological artefacts) elements (as highlighted by Bijker, 1993; Bijker & Law, 1992). The domestication concept represents a sociotechnical theory and an alternative theoretical perspective on technology-society relationships.

The previous chapters also highlighted some of the deficiencies of overly individualistic and technically framed understandings of the research problem; these overlook the social, cultural, material and specifically the user dimensions of technology adoption and use (Chapter 5). The discussion also touched upon the potentials and limitations of the dominant and normative theoretical approaches[52] and models used to understand individual energy consumption and technology adoption behaviour in the scholarly research (Chapter 6). In general, these approaches provide only a partial understanding because of the way they underplay the complexity of why people adopt and how they then live with and experience technologies in everyday life.

52 Dominant in the housing sustainability and household energy efficiency literature.

Furthermore, there are suggestions[53] that in addition to examining how 'people react to and what they do with technologies' it is also pertinent to ask 'why change has occurred' and 'what has changed in people's lives'. DT proposes to tackle such questions. This chapter forwards a sociotechnical perspective through DT as a theoretical and analytical framework appropriate for this study. It is used as a framework to understand the complex process of adoption, use, embedding and sometimes disuse of technology in everyday life through a qualitative methodological approach.

This research takes forward a British strand of DT due to its greater focus at the HH level (e.g. Silverstone, Hirsch & Morley, 1992) and relevance to the aims of this research (Silverstone, Hirsch & Morley, 1992). To date, domestication researchers have been interested in understanding how particular discrete technologies, such as televisions, telephones and computers, are integrated into the everyday contexts – this has been done by entering people's homes to examine media and technology use *in situ*. However, this research unconventionally develops this idea further by moving analysis away from the traditional focus on particular discrete technologies to a more unconventional focus on examining people's relationships and interactions with building-specific, systemic and non-discrete technologies.

The chapter is sub-divided into the following sections:

Section A – outlines the key features of DT and how it has developed from Silverstone, Hirsch and Morley's (1992) original conceptions;

Section B – outlines the background and origins of DT and the theoretical context for its development;

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53 Broadly based on the literature reviewed in this study.

Section C – outlines some of the existing studies that have used DT in relation to HH energy consumption practices;

Section D – sets out the research conceptual framework used in this study.

7.2 Section A – What is Domestication Theory?

7.2.1 An overview

DT emerged as a concept in the 1990s and was mainly used within the fields of anthropology, media and communications studies, consumption studies and the sociology of technology (Berker et al. 2006:1; Haddon, 2006). The conceptual development of DT (sometimes also referred to as the domestication of technology) draws on several approaches and concepts that fall under the umbrella of science and technology studies (STS) and which are interlinked to actor network theory (ANT), social construction of technology and of particular significance the social shaping of technology (SST) approaches (Sawyer & Jarrahi, 2014).

The main purpose of DT to date has been in its use as a conceptual framework for analysing and describing the processes by which technological artefacts are accepted, rejected and/or used to become part of everyday life in the domestic sphere through four non-discrete phases: appropriation, objectification, incorporation and conversion (Silverstone, Hirsch & Morley, 1992). Later versions of the theory have modified the phases: six phases have now been suggested, with commodification and imagination occurring before the appropriation phase (Silverstone, Hirsch & Morley, 1994). Commodification refers to how the material and symbolic components are created and brought into the consumer market for sale; and imagination refers to the way advertising is used to create the social meaning of an artefact making it a desirable product to purchase. However, the original four-phase conception is used here as it offers the most relevance in relation to the research aims in this study.

In the early days of its development, two distinct strands of the domestication concept emerged: the British and Scandinavian versions. The British strand (developed by Silverstone, Hirsch & Morley, 1992; Silverstone, 1994; and Silverstone & Haddon, 1996 in Haddon, 2006) mainly focused on families, HH settings and on consumption of media technologies – early studies were concerned with televisions and computers. In contrast, the Scandinavian version (developed by Lie & Sorenson, 1996; Sorenson et al. 1996) focused on wider contexts beyond the home (e.g. cars) (Haddon, 2006; Hynes & Richardson, 2009).

In particular, the Norwegian-led Scandinavian version of DT (Sorenson, 2006 in Berker et al. 2006:10–11) – often called the technology studies version – builds on 'social studies on science and technology rather than on a media and communications studies framework' (2006:10). It borrows both from ANT[54] and draws inspiration from industrial sociology. It essentially argues against the idea that science and technology are driving and forcing social change, instead highlighting the role of social learning as part of technology adoption through an analysis of motorcar and mobile phone use in Norway (Berker et al. 2006:10–11).

The domestication concept is used as a metaphor to describe a 'taming' process in which 'novel' or 'alien' technologies or artefacts are given a place in everyday life. It is a concept where the definition of consumption encompasses mutual adaptations of

54 E.g. Bruno Latour, 2005.

social structures, processes and meanings which seek to go beyond perceiving technology adoption as a single event by rather considering it as a process. This process takes account of how people bring meaning to artefacts and how they learn to live with them and where technologies and people adjust to each other and find (or do not find) a way to co-exist (Hynes & Richardson, 2009; Sawyer & Jarrahi, 2014). They have also tended to examine how technologies can change everyday practices and yet are rarely used exactly as intended by their designers (Haddon, 2006; Lee, Smith-Jackson & Kwon, 2009; Sorenson, 1996). In this process, the 'biography' of things is important, e.g. how technologies live their lives as part of the domestic routine practices of everyday life. It suggests that technologies have a lifecycle from its production - its birth – to its maturity and end of cycle (Norman, 1999); and where it is constantly evolving resulting in its acquisition of new characteristics (Peteri, 2006)

The theory highlights the influence of 'individual agency over technology' (Berker et al. 2006; Hynes & Richardson, 2009). Technology adoption requires a mutual adjustment between both the users and the technology (Haddon, 2006; Hynes & Richardson, 2009:487). Therefore, key aspects of the concept are concerned with the 'social shaping of technology' and refer to a mutually reinforcing relationship between society and technology (Haddon, 2006; Lee, Smith-Jackson & Kwon, 2009; Silverstone, Hirsch & Morley, 1992); this is discussed further in Section B. Introducing new technologies into the HH context highlights the need to review both everyday life and the technology, in which everyday life is not stable nor is technology revolutionary. It may change but also reinforce existing routines of everyday life (Aune, 2007; Juntunen, 2014). The concept seeks to capture the 'practical, temporal, and spatial' underlined by cultural 'expressions of lifestyles and values' (Hynes & Richardson, 2009:483).

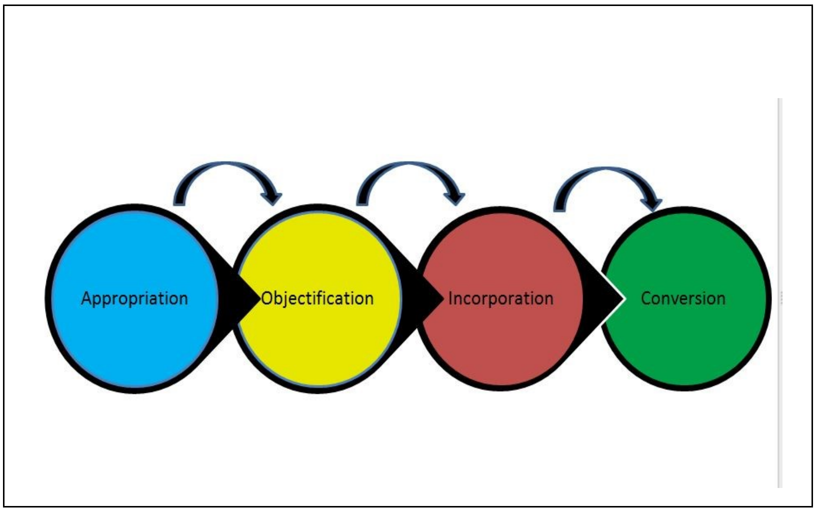
Thus, the domestication of technology is defined as a process, which takes place within the moral economy of the HH, by passing through four predefined phases – appropriation, objectification, incorporation and conversion (Silverstone, Hirsch & Morley, 1992). These key elements will be examined in further detail in the next section through Silverstone, Hirsch and Morley's original (1992) conceptualisation only.

7.2.2 The four phases of domestication

DT is utilised here as a conceptual and analytical framework to examine the process by which EETs are adopted and given a place in the everyday domestic life and practices of users. A detailed analysis of Silverstone, Hirsch and Morley's original conception is provided as a basis for the development of this conceptual framework. Silverstone, Hirsch and Morley (1992:2) identified four non-discrete phases (see Figure 2) in the complex dynamics of HH domestication of technologies; these are often referred to as the 'taming' process, and include:

1. **Appropriation,**
2. **Objectification,**
3. **Incorporation,** and
4. **Conversion** (Silverstone, Hirsch & Morley, 1992:21).

Figure 2 The 'classic' four phases of the domestication process



It should be noted that the original authors do not provide a visual representation of their concept and there appear to be currently no other visual diagrams in the existing research that is available. Figure 2 attempts to visualise DT based on Silverstone, Hirsch and Morley's original conceptions from 1992. It shows four non-discrete (signified by each circular shape) yet distinct phases (signified by their differing colours), as overlapping phases (signified by how each phase sits against another). Although there is a sequence of progression through the phases (as indicated by the arrows), it is nevertheless emphasised by the originators that this is by no means a linear process. Furthermore, key domestication theorists[55] have previously asserted that the stages of domestication are non-linear and non-discrete in nature, and that user interactions can blur the boundaries between them to the point where they seem indistinct and may even merge, indicating a more imprecise process than indicated here. This premise is taken into consideration in the proposed research framework development and application.

55 Silverstone & Hirsch, 1992; Silverstone, 1994; Sorensen, 1994 in Ward, 2006:152.

7.2.3 Moral economy of the household

In its original conception (outlined below), the four phases of the domestication process were seen as four non-discrete elements which played out in the 'moral economy of the household'. This idea is central to where the domestication process is to unfold. The term is described as a 'moral economy because it is both an economic unit, which is involved, in the productive and consumptive activities of its members in the public economy, and at the same time it is a complex economic unit in its own terms' (Pahl, 1990 in Silverstone, Hirsch & Morley, 1992:18). This is where 'the household is a part of a transactional system, dynamically involved in a public world of the production and exchange of commodities', where their 'involvement is not simply a passive one' (19). Furthermore:

The moral economy of the household is therefore grounded in the creation of the home which may or may not be a family home but which will certainly be gendered, and which itself is multiply structured both spatially and temporarily. (Giddens, 1984:119 in Silverstone, Hirsch & Morley, 1992:19)

In brief, the appropriation phase centres on the process of possession and/or ownership of an artefact, marking its movement from the public to the private domestic sphere (in other words, its entry into the moral economy of the household). It is through objectification that an artefact is given its meaning and place in users' lives and homes (such things as the timetable of use, its physical location or display). The incorporation phase describes how established practices emerge, and outlines whether or not an artefact fits into the routines of the users' everyday lives. Finally, the conversion phase commences when an artefact reaches a 'taken-for-granted' status to become a part of the user's life. This final phase also defines the relationship between the HH and the outside world, and focuses on how the technology's meaning is shared with others. These components describe a complex process of how we accept technology, normalise its use in our daily domestic lives and activities, and then speed (or hinder) its adoption in wider society (Silverstone, Hirsch & Morley, 1992). Each phase is explored in depth in the following section.

7.2.4 Appropriation (possession and ownership)

The appropriation phase describes the 'process of possession or ownership of an artefact' by a HH or individual, and its transportation into the domestic 'household' spheres – 'the moral economy of the household' (Silverstone, Hirsch & Morley, 1992:18). The appropriated artefact can be either a material or non-material 'object', such as 'a technology' or 'a message'. It is 'appropriated at the point at which it is sold', and 'is taken possession of by an individual or household and owned' (1992:21).

Therefore, appropriation encompasses the 'whole process of consumption', including the 'moment at which an object crosses the threshold between the formal and the moral economies' (1994:22). It marks the movement of the artefact 'from the world of commodity' to an object in the owner's 'possession', a process by which the artefact or commodity objects gain new 'significance' and 'status' (1992:22). This aspect of the process can be central to an individual or household's 'self-creation' or self-identity constructions, for instance by 'defining and distinguishing themselves from, and allying themselves to each other' (1992:22).

Importantly, there are two key distinguishing components of appropriation. Firstly, it is not confined to the appropriation of material objects only and can be applicable to the ownership of non-material things, e.g. media services such as buying computer software, subscribing to telecom software, etc. Secondly, Miller (1998 in Silverstone, Hirsch & Morley, 1992:22) argues that 'there are different strategies available to HH in the appropriation of a commodity' and in transforming 'the meaning of potentially alienating commodities'. Miller suggests that the 'key criteria for judging the utility of contemporary objects is the degree to which they may or may not be appropriated from the forces which created them'. Thus, users' responses can be either non-reactive – passive acceptance – or reactive, i.e. adaptive, or rejecting, to some extent depending on the strength of the sense of 'alienation' they may or may not feel towards a commodity. Miller argues that this should be read as a sign of proactive participation of a household in the process of social self-creation (Miller, 1998 in Silverstone, Hirsch & Morley, 1992:22).

7.2.5 Objectification (display and location)

It is through the objectification phase that users seek to ascribe their cognitive values and aesthetics to technology (Silverstone, Hirsch & Morley, 1992). Thus:

[I]f appropriation reveals itself in possession and ownership, objectification reveals itself in display and in turn reveals the classificatory principles that inform a household's sense of itself and its place in the world... these classificatory principles will draw on perceptions of, and claims for status, and will express and in turn define differences of gender and age as these categories are constructed within each household culture. (Silverstone, Hirsch & Morley, 1992:22)

Importantly in this phase of objectification, a range of artefacts including information and communication technology are given new meaning and placed in the users' lives:

Objectification is expressed in usage... but also in the physical dispositions of objects in the spatial environment of the home (or in extensions of the home). It is expressed in the construction of that environment... An understanding of the dynamics of objectification in the household would also throw into strong relief the pattern of spatial differentiation (Private, shared, contested; adult, child; mail, female, etc.) that provides the basis for the geography of the home. (22–23)

Furthermore:

All technologies have the potential to be appropriated into an aesthetic environment (and all environments have, in some sense, an aesthetic). And many are purchased as much for their appearance and their compatibility with the dominant aesthetic rationality of the home as for their functional significance. (23)

Thus, the call is to examine holistically the spaces technologies occupy through the order of their significance in relation to other domestic objects and the meanings they acquire in the 'symbolic universe' of the home (Leal, 1990:25 in Silverstone, Hirsch & Morley, 1992:23).

A central feature of objectification occurs when 'objects appear, and are displayed, in an already constructed (and always reconstructable) meaningful spatial environment' (23). This may refer to the rearrangement of a room on the arrival of a new technology, making things visible to outsiders and/or influencing the arrangement and decoration of rooms. In this context, appropriation and objectification together signify 'an expression of the systemic quality of a domestic aesthetic which in turn reveals, with varying degrees of coherence (and contradiction), the evaluative and cognitive universe of the household' (23).

Silverstone, Hirsch and Morley (1992) raise the question of whether or not the non-material objects or semi-material artefacts (e.g. television programmes, computer software, videos, etc.) could be objectified in the same way. They argued that these should be taken as 'commodities for consumption in the same way as material artefacts; that they are subject to similar kinds of appropriation as material objects, and their meanings are not fixed in production' (23). These items could be articulated into the moral economy of the HH not through physical display but more through their incorporation into the temporal structure or fabric of the HH. However, these authors also suggest that 'the content of the media is objectified in the talk of the household', e.g. through the way the occupants talked about 'television programmes' or 'events in the news', which together could 'provide a basis for identification and self-representation' (24).

7.2.6 Incorporation

Incorporation is the phase during which an artefact is used in everyday life; the level of functionality depends on 'how it is incorporated into everyday life' (24). It attempts to move the focus primarily on to the functions fulfilled by the artefacts used. In particular, incorporation can help to highlight the unintended uses or functions that technologies may acquire from the one intended by its designers. A number of changes in this respect can be identified: a technology can become multifunctional, or the function may change or disappear altogether. Thus, it can be said that 'to become functional a technology has to find a place within the moral economy of the household, especially in terms of its incorporation into the routines of daily life' (Gershuny, 1982 in Silverstone, Hirsch & Morley, 1992:24).

The key differences identified between objectification and incorporation is that 'objectification principally identifies the spatial aspects of the moral economy of the household, whilst incorporation focuses on the temporalities' (24). Furthermore, when technologies are incorporated into the moral economy of the household it highlights aspects of the 'visibility or invisibility of technologies'. Technologies are also incorporated into the household as 'articulations of gender' (Gray, 1987 in

Silverstone, Hirsch & Morley, 1992:25) ‘and age differentiation, as well as reinforcement or assertions of status and identity’ (25).

Furthermore, the ‘incorporation of artefacts, technologies and text together with their objectification, provides, therefore, a basis for the constant work of differentiation and identification within and between households’, and which is, ‘in turn, sustained through display and use’. This is where ‘spatial and temporal boundaries are created and defended within and around the household’. Therefore, in this phase ‘where technology is located and when and how it is used (and of course by whom) become crucial elements in the moral economy of the household as a whole’ (25).

7.2.7 Conversion

In addition to the material utility of technology, the emergence of a symbolic aspect to any technology provides a sign of its successful HH integration. In conversion, emphasis is on the following:

Whereas objectification and incorporation are, principally, aspects of the internal structure of the household, conversion, like appropriation, defines the relationship between the household and the outside world – the boundary across which artefacts and meanings, texts and technologies, pass as the household defines and claims for itself and its members a status in neighbourhood, work and peer groups in the ‘wider’ society. (25)

Furthermore, a number of facets underline the unfolding of the conversion process. Firstly, communication of meanings to the outside world:

[A] household's moral economy provides the basis for the negotiation and transformation of the meaning of potentially alienating commodities but, without the display and without the acceptance of those meanings outside the home, that work of mediation remains private: inaccessible and irrelevant in the public realm. The work of appropriation must be matched by this current work of conversion if the first is to have any significance outside the home... (25)[56]

The second facet is the importance of verbal communication of HH experiences to others outside the home:

... telephone conversations are as important as face-to-face communication as a means of transmission. Discussions about a recent or future purchase, a purchase prompted by television advertising perhaps or by the particular culture of neighbourhood or class, are similarly ubiquitous. So once again we can point to the ways in which information and communication technologies are doubly articulated: facilitating conversion (and conversation) as well as being the objects of conversion (and conversation). (26)

7.2.8 'Double articulation' concept

Conversion can highlight the importance of the 'double articulation' concept. This refers to the 'ways in which public and private meanings of media or IC technologies are mutually negotiated through its consumption' (26). The third facet highlights the importance of the display of the symbolic and material components in conversion:

... the appropriation of an object is of no public consequence unless it is displayed symbolically as well as materially, for through that display a household's (or household member's) criteria of judgement and taste, as well as the strength of his or

[56] Influenced by the work of Douglas & Isherwood, 1980; Bourdieu, 1984.

her material resources, will be asserted and confirmed ... some households, of course will resist (or not acknowledge) this aspect of the transactional system,... the conversion of the experience of the appropriation of meanings...is an indication of membership and competence in a public culture, to whose construction it actively contributes. (26)

The final facet suggests that this is where conversion can provide a mechanism for the individual to become a member of a peer group (e.g. through the exchange of information, ideas and conversations about the technology). In the conversion process 'the boundary of the moral economy of the [private] household is extended and blended into the public economy through these exchanges' (26).

The domestication approach outlined above provides a framework for 'understanding of the complex interrelationships of cultures and technologies as they emerge in the practices of institutions and individuals, and through the unequal but never totally determining or determined relations of public and private spheres' (26). Over time, the concept of domestication has been built upon, updated and adapted by the contributions of other theorists, who have provided insights into its meanings and scope – their work is discussed further here too.

7.2.9 Biography of things

Once an artefact is placed within the moral economy, one key component of the domestication process is in the potential career, or 'biography', of the artefact. This concerns how technological artefacts live their lives, so to speak, as part of the domestic routine practices of everyday life, and how their meanings and functions may change over time (Silverstone, Hirsch & Morley, 1992).[57] According to Kopytoff (1986), 'things have biographies in the same way as individuals do' (17). Furthermore:

> [T]he life of an object can be traced in all its forms from certainty and uncertainty, from invention to production, to marketing to use and disuse, and uniqueness of that life can be used as a tracer of the social and cultural context of his continuous creation and recreation ... they too pass through a succession of phases and stages in their life cycle and as they reveal, in their passage, the containing cultures and environment which helped define their particular meanings. (Silverstone, Hirsch & Morley, 1992:18)

Therefore, an artefact is likely to have more than one biography, which will differ between users and their varying social and cultural backdrops (Kopytoff, 1986:18). Hence, it is that the domestication of an artefact is conceived as a process rather than a single event; it is constantly evolving, acquiring new characteristics and has no clear-cut beginning and end.

7.2.10 Other key elements of the domestication concept

The moral economy of the household is suggested to be multi-structured both spatially and temporarily (Silverstone, Hirsch & Morley, 1992:19). The salience of space and time within DT has been a focus of debate. For example, Haddon (2006) suggests that within the incorporation phase, 'usage (even non-adoption) has to be understood within the time structures as well as time constraints people operate' (2006:3). These include factors such as 'social commitments; free disposable time to use technology;

57 Silverstone, Hirsch & Morley, 1992 incorporate Kopytoff's concept of the 'biography' of artefacts.

how time is organised; and how people experience the quality of their time, which is often of a “subjective” nature’ (2006:3).

In relation to space or the spatial dimensions within the objectification phase, the location of technologies can be determined by aesthetic factors rather than notions of a best location. Additionally, the choice of location will also be influenced by the location of other pre-existing technologies, their functions within the chosen space, and whether or not they occupy public or peripheral locations in the home (Haddon, 2006:3; Juntunen, 2014). However, both ‘time and space constraints can change’, and the changing needs of a household could mean the place of the technologies could change (Haddon, 2006:4).

Domestication is, in particular, perceived as process of consumption that is active not passive (Silverstone, 2006). Haddon (1992:128) highlights the importance of paying attention to ‘who’ decides which EET is to be ‘appropriated’, and considers the role of the family/household as a unit as well as the differing positions of various family members. Furthermore, Haddon (2006:6) suggests examining the way people talk about (in the phases of incorporation and conversion) and display technologies in their homes – this goes beyond considerations of pure use. He uses the examples of how teleworkers convey and control particular images of what they do in order to portray a more convivial impression of their working conditions. He highlights that this ‘desire to control the image given out to the outside world’ can also result in non-adoption in some cases (Haddon, 2006:6).

SST is another key theoretical element underpinning DT, which will be examined in detail in the next section.

7.3 Section B – Theoretical Underpinnings of Domestication Theory

As has already been stated, DT was adopted in this research in order to provide a sociotechnical perspective. As a theory, it has many conceptual and theoretical roots; in particular, DT draws on the contributions of STS, which are interlinked with SST and the social construction of technology and ANT (Sawyer & Jarrahi, 2014). All of these approaches have contributed to the conceptual development of DT, and are thus examined further in the following section. Figure 3 provides an overview of the hierarchy of the differing theoretical contributions in the development of DT.

7.3.1 The sociotechnical foundations of domestication

It is particularly important to briefly define here what the sociotechnical perspective is and what it provides to the underpinnings of DT. Firstly, the sociotechnical perspective is defined as a research perspective and a subject matter that is concerned with the 'phenomena that emerges from the interactions between both social and technological systems' (Lees, 2001 in Sawyer & Jarrahi, 2014:3). This mutual constitution of the social and technological is the basis of the term sociotechnical; mutual constitution directs scholars to consider phenomena without making *a priori* judgements regarding the relative importance or significance of social or technological factors (e.g. Bijker 1987, 1995 in Sawyer & Jarrahi, 2014:3–4; Latour 1999).

In particular, 'mutual constitution implies (1) that both humans and technologies may have some sort of agency – some ability to act – in a given situation and (2) these actions are not deterministic – actions are not independent of surrounding events. It seeks to "stand apart" from specific social and technological deterministic viewpoints of social and technological aspects of society as independent variables rather than looking for simplified causal agency' (Sawyer & Jarrahi, 2014:4–5). Therefore, an underlying premise of mutual constitution is co-evolution and the interdependency between technology and humans. This provides an opportunity to explore the 'contextual influences, processes of development, adoption, adaptation, and use of new and established technologies in people's social worlds' (Jones & Orlikowski, 2007 in Sawyer & Jarrahi, 2014:4).

Importantly, sociotechnical approaches have developed in contrast to those that focus too much on either socially or technologically deterministic views.[58] The former focus attention on 'the heterogeneous networks of institutions, people and technological artefacts that together play roles in the design, development, deployment, take-up and use of any technologies' (Kling, McKim & King 2003 in Sawyer & Jarrahi, 2014:7).

The sociotechnical perspective provides the basis for the qualitative methodological approach adopted in this research. For example, through semi-structured interviews with people it draws on firstly, their expert knowledge as users in their everyday life; and secondly, it draws on their memories, reflections, observations and meanings which provide a multidimensional in-depth picture of the lived experiences and interactions with technologies. Therefore, the sociotechnical perspective does not specifically set out to find cause–effect relationships (Sawyer & Jarrahi, 2014).

7.3.2 The role of science and technology studies

58 Socially deterministic views focus on behavioural dimensions: they regard how we create and use technologies as important, and underplay the agency of technology itself; technological determinism is seen as an independent and material force that can determine human behaviour of individuals and social organisations (Sawyer & Jarrahi, 2014:4).

The sociotechnical perspective is associated with the contributions of STS. These highlight an interdisciplinary research approach focusing on the 'reciprocal relationships between social, political and cultural structures, science/scientific research and technological innovation' (Sawyer & Jarrahi, 2014:18–19; Hackett el al. 2008). STS also contests social and technological determinism by highlighting the need to examine the reciprocal relationships between technology and society (Smith & Marx, 1994 in Sawyer & Jarrahi, 2014).

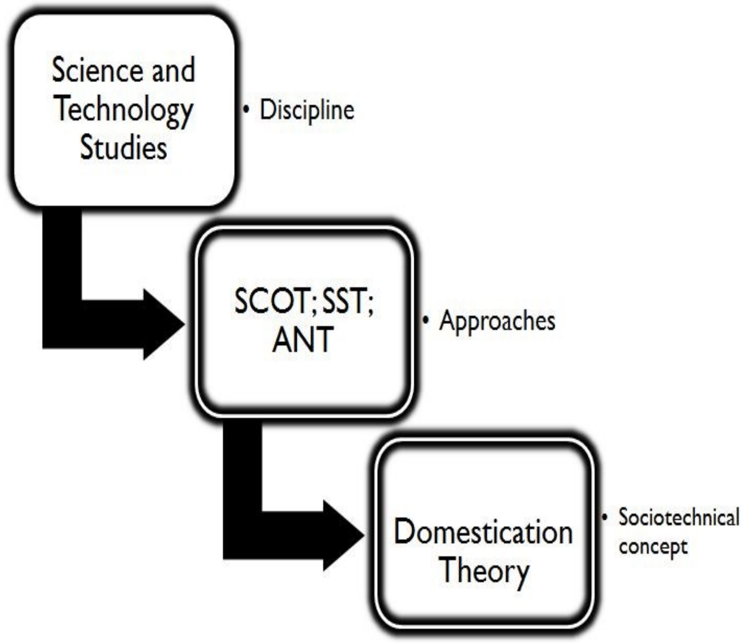
Additionally, STS appear to build upon a number of other theories, concepts, methodologies and empirical works (Smith & Marx, 1994; Sorensen, 2006:40 in Sawyer & Jarrahi, 2014; Williams & Edge, 1996). This diverse make-up gives rise to a number of 'conceptual ambiguities' (particularly within the field of technology studies) which widens its conceptual boundaries. In this case it provides an opportunity to examine housing EET through its lens.

Two key seminal approaches informing STS are: the SST approach (MacKenzie & Wajcman, 1985), which emphasises mutual shaping and co-evolution in the relationships between technological and social systems; and the social construction of technological systems (SCOT) approach (Bijker, 1997; Pinch & Bijker 1987), which focuses on the concepts of interpretive flexibility and relevant actors.

A third and contrasting dimension within the discourse of technology-society relationships is developed through ANT, which has introduced concepts such as 'actants' 'networks', 'enrolment' and 'translation' (Latour, 1987, 1999 in Sawyer & Jarrahi, 2014). Fundamentally, its starting premise makes no a priori 'distinctions between social and technological entities' as 'actants' that only acquire meaning through 'their relations with other entities' (Latour 1999; Latour 1999 in Sawyer & Jarrahi, 2014:21).

All three dimensions have developed in contestation of technologically deterministic perspectives, emphasising a more complex relationship between society and technologies (Sawyer & Jarrahi, 2014). As SST and SCOT are approaches that appear to have played a key role in the development of DT they are examined further in the following sections.

Figure 3 Hierarchy of the differing theoretical contributions in the development of Domestication Theory.



7.3.4 Social shaping of technology origins

Domestication theorists assert that one of its key elements is its SST dimension (Berker et al. 2006; Hirsch & Morley, 1992; Silverstone, Haddon, 2006). SST suggests that this is a 'two-way process' which involves a mutually reinforcing relationship between people's everyday lives and technology (Lee, Smith-Jackson & Kwon, 2009; Silverstone, Hirsch & Morley, 1992), where 'people shape the place and use of technology, where in turn the technology can influence how they are then experienced' (Silverstone, 2005 in Haddon, 2006:6). It asserts that society decides what technology is needed, produced and then used (or not used); hence, technology is not only shaped by the social context but also shapes it (MacKenzie & Wajcman, 2006).

Significant emphasis is placed on the role played by the user, their experiences, their adoption of an innovation or technology and the way they define its 'nature, scope and functions' (Lee, Smith-Jackson & Kwon, 2009; MacKenzie & Wajcman, 1999). Implicit in this relationship is a need to examine the 'social consequences' of such technologies (Bakardjieva, 2005 in Haddon, 2006:6). The SST approach – also seen as a social constructivist stance – is concerned with the agency of both social and technological actors, their effects and implications – the 'dynamics of technologically mediated consumption' (Hynes & Richardson, 2009).

7.3.5 The meanings of technology

Furthermore, it is worth briefly considering here how technology may be conceived or defined in STS approaches. In general, a broad range of meanings ascribed to technology' and definitional choices emerge, often depending on the disciplinary and philosophical perspectives taken within science and technology studies. Broadly, technology is perceived as a complex term embracing the physical artefact, including how it is designed and configured; it forms part of a set of human activities and also incorporates what people know as well as what they do (Hynes & Richardson, 2009; MacKenzie & Wajcman 1985, 2006).

Additionally, from a domestication viewpoint 'technology should be seen not only as a piece of hardware but also as a process of work and a kind of knowledge' (Mackenzie & Wajcman in Silverstone, Hirsch & Morley, 1992:35). In this context, 'technologies come not in the form of separate, isolated devices but as part of a whole, as part of a system' in which the 'existing sociotechnical systems provide a template and precondition for the introduction and integration of new technologies' (Murphie & Potts, 2003:9). For example, 'an automatic washing machine can work only if it is integrated into systems of electric supply, water supply and drainage' (MacKenzie & Wajcman, 2006:9–11). This highlights a relatively broad definition of technology, incorporating both systems and individual, discrete technologies under this broad umbrella of the term technology – it is thus applicable to scrutiny under DT. Thus, they serve as an active shaping force in further technological development. According to SST perspectives, these existing preconditions provide the 'basis of devices and techniques to be modified, and [are] a rich set of intellectual resources available for imaginative use in new settings' (MacKenzie & Wajcman, 2006:9).

Within the SST approach technology is also perceived as 'a product of social interaction' (Wajcman, 2004 in Hynes & Richardson, 2009:483) and 'understood as part of the social fabric that holds society together; it is never merely technical or social'. Rather, technology is always a sociotechnical product, 'a seamless web or network combining artefacts, people, organizations artefacts, people, organizations, cultural meanings and knowledge' (Wajcman, 2004:106 in Hynes & Richardson, 2009:483–84).

The SST perspective sits on one side of a broad debate between a technological determinist position and a social and cultural materialist one (MacKenzie & Wajcman, 2006:11). Hence, an SST approach seeks to move away from essentialist and technologically determinist conceptualisations by rejecting notions of technological innovation leading a one-sided transformative power in social and economic relationships (MacKenzie & Wajcman, 2006).

In particular, SST and DT challenge the most contentious assumption of technological deterministic concepts, namely that 'technology alone can fix social problems' without the 'active involvement of its users' (Hynes & Richardson, 2009). It takes the perspective that the most fruitful analysis can be gained from situating technologies in their social and cultural context.[59] It argues that the characteristics of a society play a major part in deciding which technologies are adopted and how they are implemented, controlled and used (Hynes & Richardson, 2009; MacKenzie & Wajcman, 2006). SST and domestication theorists point towards the fact that historically technologies emerged from specific socio-economic, cultural and political processes and from the active involvement of their users, through their acceptance and use of technological innovations as socially conditioned products (Hynes & Richardson, 2009; Sawyer & Jarrahi, 2014).

7.3.6 Social construction of technology

SCOT developed initially through the theoretical work of Bijker, Pinch and others.[60] Both SST and SCOT appear to share common themes, particularly in their seeking to move away from technological determinisms yet still offering their distinctive perspective on technology-society relationships. Distinct from SST, SCOT focuses on how humans socially construct technologies, and moves beyond questions of

[60] E.g. Bijker, 1995; Bijker et al. 1987; Pinch & Kline, 1987, 1999.

technology use to aspects of design and content through its emphasis on two key stages – the 'interpretive flexibility' of a technological artefact, and the role of 'relevant actors' (Hynes & Richardson, 2009; MacKenzie & Wajcman, 2006:21).

Firstly, the interpretive flexibility aspect of SCOT distinguishes it from other social constructivist approaches, and focuses attention on 'what counts as a viable working artefact' through its 'testing and workability'. It also rejects the taken-for-granted assumptions and fixed and uniformity of meanings of the technical realm by highlighting how the meanings of artefacts will differ across 'spaces, times and communities' (Kline & Pinch, 2006:114). Secondly, actors who play a role in the development of a technological artefact are defined as 'relevant social groups' who share meanings and other properties which give them their group characteristics. Particular shared interpretations of technologies can be analysed to explain the shaping of a technological artefact's development path.

The notion of interpretive flexibility means that the same artefact can enact different meanings to different social groups. In the development phase, such meanings can become embedded in new artefacts, and subsequent development paths are described which may reinforce this meaning. However, 'interpretive flexibility does not continue forever, "closure" and stabilisation occur, and … some artefacts appear to have fewer problems and become increasingly the dominant form of the technology'. In practice this could 'result in rivals disappearing or sometimes two very different technologies can [co]exist side by side'. New problems can emerge at any time and interpretive flexibility may reappear (Kline & Pinch, 2006:113–14).

SCOT is underlined by the premise that 'technology can't exist without action'. Therefore, 'user actions determine the degree of interpretive flexibility' – when attempting to integrate new technology into domestic life. This means artefacts are ascribed with meanings and functionality, which are bound up with relationships, HH changing needs and circumstances (e.g. retirement, divorce, etc.). Thus, the influence of interpretive flexibility in the domestication process means that it may not lead into a harmonious process and may need to accommodate the new and sometimes conflicting needs of HH (MacKenzie & Wajcman, 2006; Ward, 2006).

7.3.7 Section B – Summary

Whilst these approaches have contributed to the development of the domestication concept in their distinct ways, they are not without criticism, however. In particular, their move away from technological determinism has meant they can distance themselves too far from considerations of the agency of technology. This signifies a socially deterministic bias, which overemphasises 'social choice over technological considerations' (Sawyer & Jarrahi, 2014:21). Despite their differences, both, SST and SCOT highlight a dynamic and complex process of interactions between technology and society: close examination of these approaches provides greater interpretive meanings and insight into the theoretical make-up of the domestication concept.

7.4 SECTION C – Existing Domestication Studies

7.4.1 Traditional themes of domestication studies

DT emerged as a theoretical and analytical tool largely used to study a range of media and ICTs (e.g. Haddon, 2006; Lie & Sorenson, 1996; Silverstone et al. 1992; Silverstone & Haddon, 1996, etc.). These studies encompass both a diverse range of target groups (e.g. nuclear families, single parents, teleworkers, etc.) and a range of specific technologies (e.g. home computers, cable television, the Internet, computer software and computer learning courses, home telephones, mobile telephones, I-Pads, etc.). However, early studies predominantly used DT in relation to ICTs and understanding their 'double articulations', drawing distinctions between their 'un-inert' and 'inert' qualities (Silverstone, 2006:240). Shifts in research foci have either examined single artefacts or an ensemble of artefacts, varying over time and reflecting the 'goals of the researchers' (Haddon, 2006:2–3[61]).

Whilst there have been some been studies of individuals (Berg, 1997 in Haddon, 2006), most studies had until recently focused on the HH or families as the unit of analysis – thus while 'some of the earliest British research stressed the collective identity of HH or families (Hirsch, 1992), others have focused on ICTs in relation to an individual's sense of identity' (Hartmann, 2005a in Haddon, 2006:2–3). These studies have raised questions of whether the home or the HH level provides a more effective focus of analyses (Haddon, 2006:2–3). This research seeks to take forward both contexts as the basis from which to understand the unfolding of the domestication process of EET.

61 These various studies are summarised in Haddon, 2006:2–6.

In recent years, the fast pace of technological developments has moved to areas such as robot vacuum cleaners (Frennert & Ostlund, 2014), mobile phones (Lee, Smith-Jackson & Kwon, 2009) and I-Pads (Luomanen & Peteri, 2013). Nevertheless, understanding new 'media technology use in the complex structures of everyday life settings, with attention to interpersonal relationships, social background, changes and continuities' remains ever pertinent (Hynes & Richardson, 2009:486).

7.4.2 Research gaps within domestication and housing energy studies

Researchers working with the domestication framework have discussed ways in which the approach has been, or could be, extended (Silverstone, 2005a; Haddon, 2004), or whether, indeed, some of its elements and goals could be challenged. In particular, an expansion of DT into new arenas is reflected through its emerging interest in the field of housing sustainability and EE technology discourses. Although there has been an abundance of studies on housing sustainability, energy efficiency and HH energy consumption reduction, very few scholarly works appear to have utilised the domestication approach as a theoretical framework in relation to questions of adoption and use of 'building' EET and the user lived experiences.

However, a few examples (e.g. Aune, 2002, 2007; Behar & Chui, 2013; Juntunen, 2014; Isaksson, 2009; Lees & Sexton, 2012) that have emerged recently appear to challenge the dominant use of DT in relation to media and ICT analysis. These studies have pioneered its use in the broad theme of housing EE issues, and although relatively small and disparate, they deserve further examination. However, it should be stated at the outset that none examine the domestication process of housing EET amongst home-owning occupants of existing housing and within a UK context – this is a gap that this thesis seeks to address. The next section examines a number of key studies for their application of DT to the theme of EE in the home.

7.5 Empirical Studies: Domestication and Housing Energy and Technology Themes

7.5.1 Domestication strategies for homes

Firstly, Aune's (2007) study highlights 'domestication strategies for homes' by focusing on HH level practices and experiences. She loosely applies the domestication framework to the analysis of home renovations and private energy consumption in two Norwegian case studies of homeowner HH. Through qualitative interview data analysis, Aune takes the 'home' as a unit of analysis; this is because 'private energy consumption is part of a complex network and the home was regarded as an entry point into the network' (Aune, 2007:5457).

Moreover, for Aune 'domestication strategies influence the way the house is shaped as a material frame and as a symbolic image'. These strategies are shaped by the 'norms and values and material frames' which 'seem to contribute to various everyday life routines and changes in these routines. The resulting energy consumption depends on the various combinations of these factors' (2007:5463).

In particular, Aune focuses on material changes represented through the renovation process. She identifies three different classifications of how people domesticate their house through how they interact with it through their lifestyles, routines and differing consumption of goods:

(1) **'Home as haven' –** highlights the importance of the symbolic aspects of the home, i.e. 'cosiness', 'unity and privacy' through 'a simple lifestyle'; this group does not continually remodel their home;

(2) **‘Home as project’** – ‘where rebuilding, redecorating and appropriation of artefacts are central’ and where once domesticated the process can start all over again; and where ‘environmental concerns do not seem to be essential motives behind the activities’; and

(3) **‘Home as arena for activities’** – highlights the ‘unity of people and activities’; ‘this group does not highly value style and material good, where environmental aspects have to be practical and not something to show off with; and where using less technology is encouraged’ (Aune, 2007:5462–63).

For Aune, the three different categories of home illustrate the various ways of domesticating a house and turning it into a home by ‘constructing and negotiating a network of occupants, activities, technologies and values’. Moreover, these groupings hold implications for energy policy interventions.

Aune justifies her ‘simplistic categories’ on the basis that they represent ‘analytical constructions and not the complete picture of variation’ and because they help ‘convey an understanding of a complexity that is far from the “rational consumer”...’ (5464). Aune’s different domestication classifications suggest that examining the process of change – through home renovations – at the whole house level provides a more holistic picture of HH practices. This is taken forward in the empirical research framework for this study outlined further below.

7.5.2 The symbolic, utility and materiality aspects

In an earlier study that sought to understand the interactions between everyday technology and everyday life, Aune (2002) examined through user perspectives the domestication of Ebox in Norwegian HH. The Ebox ‘is a technology for monitoring and administering electrical equipment in private houses through the internet'. The Ebox project involved HH interviews in 17 apartments in a housing co-operative in Oslo. The HH, while varied in terms of age, income and education, all lived in the same type of apartment. The Ebox project 'mainly dealt with how this device was used and integrated into a household'. In particular, her study examines the two-way process of interaction between HH and their Ebox.

In this study, the concepts of *domestication* were chosen as an analytical perspective in order to understand the integration and use of the Ebox as a process with practical and symbolic content, the meaning of design, and a potential network. Aune suggests that the insights into 'different domestication strategies are important to avoid deterministic perspectives towards technological development. Users do not passively adapt to technological changes. Small changes on the micro-level of society can be important both as indicators of, and as reflections on changes on a macro level' (Aune, 2002:13).

For Aune, the signs of a successful integration of technology in the HH sector are demonstrated through a product's symbolical aspect in addition to its utility aspect. The role of the symbolic, utility, materiality and other aspects of the user (in terms of passive or active adopter) will be further examined.

7.5.3 Domesticating ICT and related energy consumption

Jensen et al.'s study (2009) of households' use of ICT focuses on how the dynamics of consumption influence levels of HH energy use. The research project combines data gathered through mixed methods. Of particular interest to this research are the 14 interviews with families examining 'how users domesticate and use technologies in many different ways' and 'the practices related to them'. Although 'energy use was not a central theme', the participants 'were asked about their experiences and practices in relation to energy consumption and the ICT equipment'[62] (Jensen et al. 2009:3). The interviews revealed a variety of practices and dynamics in different aspects of everyday life, including sport, shopping, entertainment and different hobbies. Rising electricity consumption related to ICT use is thus as dependent on the consumers' use and domestication of the technologies as on the EE of the appliances – an issue of great concern to policymakers seeking to limit energy consumption (Jensen et al. 2009:1).

The domestication framework applied to analysis of interview data adopted a 'three key themes' framework, rather than the classic four phases. These three key themes of domestication were: (1) 'evolution not revolution'; (2) 'personal meaning and creativity'; and (3) 'non-adoption'. The process of domestication includes 'user driven innovations' (e.g. designing intelligent homes to manage energy use via ICTs) as well as comprising 'social, spatial, and temporal changes' observed in existing 'traditional ICT consumption practices' (e.g. watching TV on the Internet). Due to their development in relation to ICT, these classifications are not relevant for an examination of the domestication of the multiple and disparate suite of EET considered in this study. However, the suggested evolutionary nature of domestication is taken forward as an underlying principle of the adopted research framework.

62 It defined ICTs as including computers, laptops and monitors, as well as consumer technologies such as TVs and DVDs.

7.5.4 Domestication as a set of trials

A study of new technologies by Lehtonen (2003) suggests that domestication unfolds as a ‘flexible’ ‘set of trials’, which directs attention to the tensions and dynamics of relationships, e.g. ‘compatibility between things and people’. Ultimately, the ‘criteria for judging the success of a technology can change and vary from case to case’ (381). This aspect resonates with the notions of interpretive flexibility discussed earlier. Although it does not explicitly have a housing energy dimension, Lehtonen’s study does exemplify how the classic domestication framework has been applied and extends the domestication concept further.

The data was derived from recurrent interview discussions with 14 people (seven females and seven males from southern Finland), that took place within the participants’ homes and involved demonstrations of their use of everyday digital technologies. Its key aim was to ‘comprehend the way these became adopted in everyday life, and to understand the technoscape of the home as a whole, and to follow biographies of things and people as they emerge’ (Lehtonen (2003:363). Lehtonen argues that:

instead of technology determining the forms of use or rational atomistic individuals simply deciding what is useful to them, there is a middle ground of compromises, of negotiations between different types of influences – negotiations that result in more or less stable attachments between new technology and its users. (Lehtonen, 2003:362–83).

‘Importantly, trials produce knowledge’, a ‘process where new things are learned’. ‘The interviews reveal the variety of different types of knowledge that people need when they are acquiring devices: placing them, using them properly, and fitting them in with other technologies and other people'. Hence, conceptually the domestication process of new technologies should be viewed more as a 'set of trials' where 'new user knowledge is created and the moral order of the HH is negotiated recurrently' (Lehtonen, 2003:363). The idea of domestication resulting in trials producing a process of learning and knowledge creation is taken further within the research framework for this study.

7.5.5 Domesticating ventilation technology

In a small exploratory study, Behar and Chui (2009) 'investigate the processes by which residents in the UK embed energy efficient ventilation systems into their lives'. They present the 'findings of the first stage of a case study in which they examine how people engage with new ventilation technologies' through a 'qualitative case study methodology using in-depth interviews (complemented by home visit, analysis of design and construction documentation of building) with residents in three new-build social housing developments in the UK'. The data was analysed using the four-phase framework of the domestication lens in order to explore the interactions between ventilation systems and their users (2009:2389).

The findings suggest that successful adoption and adaptation does not occur in isolation and solely within the boundaries of the private sphere as proposed by DT. In the case of the social housing example, successful adaptation relies on opportunities for support and learning offered by the social landlord and other stakeholders. Behar and Chui propose that negative experience of a new technology may lead residents to reject the system outright, whereas an engaged user would take an active approach to adapting to the new ventilation technology. They argue that 'it is not enough to simply design, specify, and install an innovative technology and expect the residents to use it correctly. People often need a careful, and more engaged handover process to make sense of the new technologies that they have to live with' (2009:2398).

This research has served to highlight one of the limitations of DT's application. In particular, it has highlighted the challenge of applying the appropriation stage to social housing tenants who appear as passive recipients (or reluctant adoptees), and in cases where technology adoption decisions are made by others. It suggested that understandings of the domestication process within this context would represent an incomplete picture – appropriation encompasses the symbolic and material components of acquisition, and the motivations underpinning the entry of technologies into the home. This issue raises the question of whether DT can still offer conceptually valid insights in the case of social housing; whether it strictly represents a 'challenge to the assumptions of the four phase domestication model', or whether it is an inappropriate or flexible use of the framework. The prominence and/or absence of phases in DT are a theme that will be further examined in due course.

7.5.6 Domestication and low and zero carbon technologies

A further small-scale study by Lees and Sexton (2012) uses the four-phase domestication lens to examine the use of solar thermal technologies in new build homes through two case study HH, again in social housing (comprising four tenants of a housing association). Unusually, this research applies Silverstone's later model (1994) which identifies six phases to the consumption of technology in order to establish the occupants' understanding and use (or non-use) of the technologies contained within their homes: commodification, imagination, appropriation, objectification, incorporation and conversion.

Their results suggested that the HH had little knowledge of, or interest in, the technology prior to moving into the houses, and appeared to be passive recipients of technology. However, 'once in the houses, the meaning ascribed to the technology and the household practices emerging from user-technology interaction were significantly different in each of the two households'. They highlight that 'low and zero carbon technologies are not uniformly and homogeneously absorbed and used by households', thereby contesting the inherent technical rationality of policy (Lees & Sexton, 2012:1389). Like Behar and Chui's study, the application of the appropriation stage to social tenants in new build housing holds similar implications. The domestication framework is not itself developed further but is used purely as an analytical framework for the qualitative interview data. Importantly, their work highlights the need for research that treats low and zero carbon technologies not as discrete entities but as integrated into the sociotechnical system of the home – an aspect that is taken forward in this research framework.

7.5.7 Domestication pathways of multiple renewable technologies

The only study, which demonstrates parallels to this work, is a Finnish study by Juntunen (2014). Juntunen applies the domestication framework to an examination of a range of diverse renewable and decentralised technologies (e.g. wood burning boilers and fireplaces, air source heat pumps, ground source heat pumps, wind turbines, solar PV and solar thermal collectors, etc.). The author utilises interview data and 'internet material' of private homeowner occupiers in detached dwellings, including second home occupiers of summer cottages, as well as those using renewable technologies for more than a year (2014:7).

Juntunen examines 'how renewable energy technologies are adapted in local conditions' where 'multiple domestications are linked and lead to the increasing use of new technologies without a stable final point', a process he conceptualises as ‘domestication pathways’ (2014:4). In his analysis of data, Juntunen does not apply the classic four-phase framework, but instead opts for a broader ‘pathways’ understanding of the domestication process. This, he suggests, is because the earlier four-phase framework approach implied that ‘new technology adaptation processes have clear starting and ending points with a new “normal,” where new technology has become part of everyday life’ (2014:12)

Juntunen suggests that domestication pathways form as a ‘result of cognitive processes related to learning through practice, where acquired experience and knowledge increase trust in renewable technologies’. Moreover, pathway development occurs in an ‘evolutionary way in the energy systems of houses and within the existing housing stock over a long period and through general renovations in houses, which contribute, to its overall energy-system improvements’ – thus the pathway development is an ongoing process (Juntunen, 2014:14).

The pathway approach undertaken by Juntunen represents a very holistic and retrospective view of the technology domestication process and is a concept that has been useful here. For example, Juntunen collectively examined domestication of multiple technologies, which have differing pathways, varying degrees of integration into the everyday life of HH. In a way similar to Juntunen’s approach, one aspect of the current research data analysis will be to focus on how differing technologies are domesticated over time (as discussed in Chapter 11).

7.5.8 Section summary: Key themes from existing studies

Based upon the key studies and their findings reviewed in this section, the existing conceptions of domestication process mean that it:

1. Unfolds as a ‘whole’ house process not a single event (Aune, 2007);

2. Appears as an evolutionary rather that revolutionary process event (Aune, 2007; Juntunen, 2014);

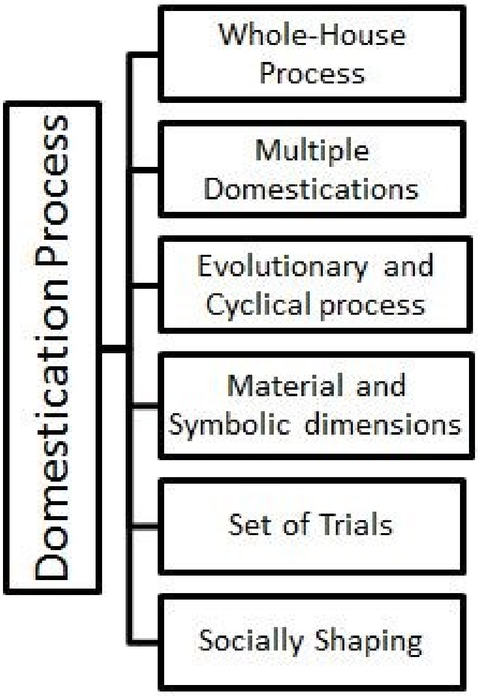
3. Contains multiple domestications – where multiple and disparate technologies can be integrated into the sociotechnical system of the house; and where disparate technologies are not uniformly and homogeneously absorbed and used by HH (Aune, 2002; Behar & Chui, 2009; Jensen et al. 2009; Juntunen, 2014; Lee & Sexton, 2014);

4. Highlights the importance of the symbolical and material aspects – the signs of a successful integration of technology in the HH sector is demonstrated through a product’s symbolical and utility aspects; these may foster social, spatial and temporal changes within everyday consumption practices (Aune, 2002, 2007; Juntunen, 2014);

5. Occurs as a set of trials – where ‘new user knowledge is created and the moral order of the HH is negotiated recurrently’ (Lehtonen, 2003:363); and

6. Is socially shaping – where technologies are socially shaped, and in which the social is shaped by technologies (Berker et al. 2006; MacKenzie & Wajcman, 2006).

Figure 4 Summary of the multifaceted nature of the domestication process.



These particular studies were specifically selected for detailed analysis because they use DT in relation to understanding householder and technology relationships, and tackle questions of HECB in response to the introduction of new technologies (beyond media and ICTs). Although this body of literature is relatively small, it captures a broad range of themes that highlight the multifaceted nature of the domestication process – as shown in Figure 4.

The desire to unpack this multifaceted nature has informed the research design for this study, specifically its adoption of two-tiered analysis for the empirical study (described in Chapter 1). This meant using the four-phase framework for analysis: firstly, through a broader whole house level of analysis where multiple EET were integrated into the house (findings in Chapter 10); and secondly, using 'single technology' as a unit of analysis, examining the domestication of a selection of individual non-discrete EET (findings in Chapter 11).

7.6. Section E – Research Framework

7.6.1 Domestication as an analytical framework

This research primarily seeks to use Silverstone, Hirsch and Morley's (1992) original conception of domestication and its four phases as a conceptual and analytical framework to understand the process of EET adoption, use and integration into everyday life. Furthermore, key domestication theorists[63] have already asserted that the stages of domestication can be non-linear and non-discrete, and that user interactions can blur the boundaries between them. This premise is taken into consideration in the proposed research framework.

There are currently no standard sets of questions that can identify when each phase has been reached. This research has thus developed a number of proxy questions based on existing conceptions of such phases from the other domestications studies reviewed in this chapter. In order to apply the theory, the following questions are raised for each phase:

7.6.2 Appropriation phase

Firstly, the appropriation phase is primarily concerned with the acquisition, purchase and ownership of a technological artefact and its entry into the private sphere. It consists of a material and symbolic appropriation concerned with the 'motivations and reasons associated with acquiring the technology' (Juntunen, 2014). In this research, the appropriation phase will explore questions relating to this area: see Table 4.

[63] Silverstone & Hirsch, 1992; Silverstone, 1994; Sorensen, 1994 in Ward, 2006:152.

Table 4 Appropriation phase questions

Key Questions
• **What are the reasons and motivations for purchase, and/or the reasons for selecting some EET whilst rejecting others?** • **How does the purchase of EET take place?** • **What does the installation process look like?** • **Who in the HH makes the decision to have the technology installed?** • **What significance or status do EET acquire once installed?** • **What benefits are sought and experienced?** • **What past changes to the home were undertaken and their timescales**

7.6.3 Objectification phase

Objectification focuses on how the HH physically locates and fits technology materially into the home, but also symbolically fitting into the minds of the owners/users. It comprises both a 'spatial' dimension (finding a physical location for it in the home) as well as a 'temporal' dimension (how it is fitted into the time structures of HH practices), yet the spatial aspects are emphasised more in this phase (Hynes & Richardson, 2009). For the key questions relating to this phase see Table 5.

Table 5 Objectification phase questions

Key Questions
• **What does the process of installation and integration into the building look like?** • **Who installs the product?** • **How long does it take to install?** • **What does physical location and display mean?** • **What was the experience of installing the product?**

7.6.4 Incorporation phase

The key aspect of incorporation is established by technology use in which the 'temporal' dimensions are emphasised (Silverstone, Hirsch & Morley, 1992). Incorporation is evident when established practices emerge and become embedded into the everyday routines of HH life (Juntunen, 2014). However, the technology in question has to be 'actively used e.g. through the performance of a task' (Hynes & Richardson, 2009). The key questions relating to this area are summarised in Table 6.

Table 6 Incorporation phase questions

Key Questions
• **How do HH interact and operationalise the technologies?**

• **Do the technologies serve their intended use? Are the intended functions or user expectations satisfied?** • **Are there any new ways that technology is being used (i.e. are there any unintended uses)?** • **Does the technology interact with other HH activities?** • **How are personal values, tastes and styles expressed in the symbolic aspects through everyday use?**

7.6.5 Conversion phase

Conversion focuses primarily focuses on symbolic communication, i.e. on how technology takes on a taken-for-granted status, and how the meanings of technology are shared with others and communicated to the outside world (Hynes & Richardson, 2009; Juntunen, 2014). Successful domestication is signified through HH integration of technology where the artefact displays symbolic, material and utility components (Juntunen, 2014). It is concerned with how individuals use the technology in various ways, for instance using it to gain symbolic meanings to enhance their social status, to share their knowledge and exchange their ideas with the outside world. For the key questions relating to this see Table 7.

Table 7 Conversion phase questions

Key Questions
• **Do HH tell others about the changes made to their home?**

- **Do HH feel a sense of ease with the adopted new EET? Have they taken them for granted?**
- **What meanings do people seek from EET or from a more energy-efficient home?**
- **How do HH visually, orally and symbolically display the meanings?**
- **What other symbolic meanings are associated with making the home more energy efficient?**

Although the four-phase framework is designed to be broad and abstract, this thesis seeks to extend this conceptual framework further, in particular to test the applicability of understanding the process of voluntary uptake of EET in the private home-owning sector. Interpreting the domestication process of housing EET in existing housing is an under-researched topic – a matter that will be further examined in this thesis. The full set of research questions asked are found in the 'Interview Topic Guide' in Appendix 1.

7.7 Chapter Summary

This chapter introduced in full the concept of domestication and its theoretical underpinnings. It explained why DT represents both a sociotechnical perspective and forms an analytical framework for understanding technology-society relationships. A small yet important body of domestication literature that has developed around the field of EET adoption, housing and energy consumption practices was thoroughly reviewed. This highlighted how existing studies have applied DT, and how they have provided insight into domestication processes. The review also helped develop a research framework based on the use of Silverstone, Hirsch and Morley's (1992) original conception of domestication and its four phases of appropriation, objectification, incorporation and conversion to understand the process of EET adoption, use and integration into everyday life. The next chapter sets out the research strategy and methodologies to be used in the empirical investigation.

Chapter 8 Methodology

8.1 Introduction

This chapter sets out the methodology used to respond to the research question, aims and objectives identified in Chapter 1. Given the complexity of the research problem and the interest in uncovering in-depth meanings and experiences of homeowner adopters in relation to domesticating EET, a qualitative and inductive methodological approach was considered appropriate. In particular, the empirical investigation sought to provide a homeowner perspective primarily through semi-structured in-depth interviews. Participants were recruited through purposive sampling (via voluntary self-selection) from England and encompassing a relatively diverse socio-demographic profile. The four-phase domestication theoretical framework was utilised for its explanatory power and as an analytical tool for data analysis. Thus, transcribed data was analysed using the domestication lens as a prime thematic framework for analysis combining both an interpretive and inductive approach. The methodology is summarised in Table 9. Further in-depth details of the research methodology are provided through the following key subheadings:

- **Philosophical assumptions**
- **Qualitative research**
- **Interviews**
- **Data collection**
- **Household interview data analysis**
- **Research validity: ethics and bias**
- **Chapter conclusion**

Table 8 Key primary and secondary data collection methods utilised.

Primary Data generated	
Methods used	**Key purpose**
1. Semi-structured interviews	Primary research data Interviews conducted face-to-face and were tape recorded and transcribed verbatim; Thematically analysed using the four phases of domestication: appropriation, objectification, incorporation, and conversion (information) - to capture attitudes/end-user lived experiences towards the use of specific EET (e.g. solar PV), etc.).
2. Background Questionnaire	To capture descriptive and contextual background of each householder, this gathered three types of information: (1) socio-demographics; (2) building characteristics and types of EET implemented; (3) types of energy practices undertaken (either as self-completion or researcher-completion survey)
3. House observation	walk-through the house and/or photographs taken where feasible (Optional information gathered where available).
Secondary and supplementary data	
4. Online internet websites	Web-based textual information about the house and local area was collected (within the public domain and freely accessible to the researcher), e.g.: Planning history, EPC record; planning permission information, etc. (Optional information gathered where available).
5. Other 'personal' documentary sources	Personal information on energy usage (numeric information) or textual information e.g. gas/electricity bill or other sources (optional information); and/or other personally generated textual written information provided by the participant (e.g. list measures they had implemented in their home) (Optional information gathered where available).

8.2 Philosophical Assumptions

The methodological position adopted here is rooted in the social sciences and is underlined by a particular research paradigm (Creswell, 2007, 2009). A paradigm is defined as a set of 'basic beliefs that guide action' (Guba, 1990:17 in Creswell, 2007:6). In part, this approach straddles a social constructivist and pragmatic philosophical position. Research paradigms are often considered as inhabiting different positions within a spectrum, arguably going from positivism at one end, through to critical realism and then social-constructivism at the other end (Creswell, 2009; Guba & Lincoln, 1994 in Reeves, 2009).

In brief, on the one hand, ontological assumptions in social-constructivism emphasise the subjective nature of reality, and view the construction of meaning as being situation- and context-specific. The world and reality is understood as being subjective, and socially constructed by individuals interacting with others. Epistemologically, knowledge claims are based on the discovery of meaning in the social constructions of phenomena. This is a paradigm typically found in social science research favouring various qualitative methods (inductive and interpretative). In contrast, and on the other end of the spectrum, sits the positivist paradigm, which views the world and reality mainly through universal laws governing existence and through a belief in an objective reality. Epistemological knowledge claims are typically based on the observable statistical measurement of causality of phenomena, using quantitative methods (hypo-deductive) and often testing prior hypotheses (Creswell, 2007, 2009).

8.2.1 A pragmatic approach

A further distinct paradigm, often described as a ‘third paradigm’ (Hammersley, 2013), arguably sits between positivism and constructivism (Creswell, 2007). This third paradigm seeks to break away from the traditional nexus between worldview and methodology. It takes on the perspective that a methodology should be selected first and foremost based upon the specific research questions and objectives rather than any philosophical orientation (Creswell, 2007, 2009). Therefore, it employs the appropriate techniques or tools to address the research objectives. This approach allows data collection to be both positivist and interpretivist, and enables triangulation of evidence delivering a multidimensional investigation. The pragmatic research approach commonly champions the use of a variety of research methods typical of mixed-method studies that integrate both qualitative and quantitative methods (Creswell, 2007).

This research combines both a social-constructivist position within a pragmatic knowledge claim to guide the empirical investigation. The pragmatic approach enables the researcher to employ any complementary quantitative or qualitative methods whilst acknowledging that every method has its limitations. This could also mean using different techniques at the same time or one after the other (e.g. surveys to scope the issues/attitudes, and then interviews to probe for further details, or vice versa, and in some cases being able to turn qualitative data into quantitative data for statistical analysis). This approach has particular relevance to this research, which seeks to bring together data from a variety of sources (Creswell, 2009; Maxwell, 2005).

Finally, the key research aim for this investigation contains two epistemological orientations: firstly, aiming for explanation, interpretation and understanding of a given problem; and secondly, seeking real-life practical implications of findings that could foster social change by feeding into policy. Hence, this aim is located mostly within an interpretive stance yet corresponds with a pragmatic approach (Braa & Vidgen, 1999).

The 'interpretive view of knowledge' seeks to challenge positive perspectives through its reliance on an understanding of 'social process by getting inside the world of those generating it' (Rosen, 1991 in Orlikowski & Baroudi, 1991:14). Hence, the research adopted a pragmatic knowledge claim by applying a predominantly inductive approach using a qualitative method – HH interviews –, which provided important in-depth knowledge of the research topic.

8.3 Qualitative Research

The qualitative research adopted was considered appropriate given it sought 'to address research questions that required explanation or understanding of social phenomenon and their contexts'. Through its qualitative stance the investigation provided insights into various stages contained in a process (i.e. the four phases of the domestication process) that have been previously overlooked in housing EE discourses. This assists the researcher to create rich descriptions of people's experiences, and enables them to interpret and/or build theories about how and why a social process occurs. According to Wilhelm Dilthey,

Social research should explore lived experiences in order to reveal the connections between the social, cultural and historical aspects of people's lives and to see the context in which particular actions take place. (Dilthey in Ritchie & Lewis, 2003:7)

Additionally, qualitative research is 'particularly well suited to exploring issues that hold some complexity and to studying processes that occur over time' (Ritchie & Lewis, 2003:5). For example, one of the objectives of the study was to understand individual perspectives and experiences of those who adopt and use EET through the process of domestication. Therefore, by its nature it does not seek any overarching predictive generalisation(s) and explanations, which often call for the use of quantitative methods. Historically, qualitative research methods were developed to overcome some of the perceived limitations associated with quantitative – positivist – paradigms in studying human behaviour, and hence they have critically developed in contrasting ways (Ritchie & Lewis, 2003:5).

8.3.1 An interpretative view

‘[Q]ualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them’ (Denzin & Lincoln, 1998:3 in Ritchie & Lewis, 2003).[64] An interpretative view of ‘knowing the world’ places importance on the investigator’s own interpretations and understandings of the phenomenon being studied. Again, these ties in with the pragmatic approach adopted and is considered ‘problem-driven’ rather than ‘method-driven’ (Mottier, 2005: para. 2). This is widely accepted practice in social and behavioural sciences (Creswell, 2007; Ritchie & Lewis, 2003), and these tenets are a central foundation of this research design.

Finally, the qualitative approach is well suited to this study not only due to its emphasis on understanding people’s ‘lived experiences’ and everyday practices but also in connecting them with the social world around them. It also borrowed the idea of an insider perspective in studying the practices of homeowners *in situ*. Moreover, it enables in-depth analysis and assessment of the complexities and subtleties of social context, cultural process and the socio-cultural meaning in relation to user adoption interactions, and embedding of energy-saving technologies in homes. Thus, the ultimate goal is to acquire an understanding of human behaviour in relation to the context.

8.3.2 Types of qualitative data gathered

Furthermore, the qualitative data collection undertaken here relied primarily on HH interview data which is ‘generated data’ from the research activity itself, and which was supplemented by either a range of ‘naturally occurring data’ which provided the

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[64] Following authors such as Levi-Strauss (1963), Becker (1989) or Denzin and Lincoln (1998) in Moittier, 2005: para. 2.

contextual basis for each ‘householder’ case, or other personal information provided by the householder.

Methods employing observations, documentary analysis, discourse analysis, conversation analysis and so forth are all approaches that study phenomena in their naturally occurring settings (Ritchie & Lewis, 2003:35). Conversely, ‘generated data’ – e.g. biographical methods, individual interviews, focus groups, etc. – provide insight into people's own perspectives, beliefs and behaviours, and importantly an ‘understanding of the meaning that they attach to them’.

This approach yielded two levels of data: firstly, it provided explanations from the participants for their actions in response to questions; and secondly, explanations collected by the researcher through interviews and other sources were dissected and analysed and then tested against each other. Hence, it triangulated both secondary and primary data in the final analysis of the whole sample as well as examining individual components.

Both primary ‘generated’ data and ‘naturally’ occurring ‘supplementary’ data in the public domain were used:

- documentary web-based information about specific EET (including statistics contained in documents);
- informal, unstructured telephone and face-to-face interviews with some key householder informants during the pilot phase for general scoping issues;
- self-completion questionnaires to capture socio-demographic and descriptive information about the householders;
- some direct observation of physical and technical artefacts *in situ*; and

- other information sources where available.

This enabled the researcher to cover a wide range of phenomena and use different sources of data for cross-validation to supplement the HH participants' background context.

This eclectic form of data collection provides a more in-depth and holistic knowledge about the HH. This approach was considered appropriate given that no single method would be sufficient to investigate the key aim.

Furthermore, through the accounts of householder 'adopters' the research sought to capture multiple HH and 'homeowner' experiences and perspectives. For example,

multiple perspectives may come from multiple data collection methods, but they may also derive from multiple accounts – collected using a single method (e.g. in this case semi-structured householder interviews) from people with different perspectives on what is being observed. (Lewis & Ritchie, 2003:52)

In most instances, 'the sample design is structured around context (e.g. homeowners and those that had adopted a range of EET) rather than around a series of individual participants'. Additionally, 'the integration of different perspectives on the context can result in detailed in-depth understanding' and 'used when no single perspective can provide a full account or explanation of the research issue, and where understanding needs to be holistic, comprehensive and contextualised' (Lewis & Ritchie, 2003:52).

8.4 Interviews

Interviews were a key method in this research and are, of course, an important technique in the qualitative tradition. To capture the key actor's perspective semi-structured interviews were undertaken as the main method for primary data collection. The main advantages of this method are that it provides rich in-depth and detailed data, even though interviews can be time consuming and resource intensive and, some argue, lack the same degree of explanatory rigour when compared to positivist approaches. However, their perceived weaknesses are argued to be outweighed by increased interpretive power (Bryman, 2004; McNeill, 1990; Ritchie & Lewis, 2003).

The interview method was chosen over the quantitative survey method because the latter was considered too numeric (statistical) and sterile in terms of the limited details it offered. This is one of the key weaknesses of surveys in social research, although surveys do have merits and relevant functions for certain types of investigations, particularly ones that focus on hypothesis testing and for predictive data results and representativeness (Bryman, 2004; McNeill, 1990). However, a survey was not considered appropriate for this research given its focus on the qualitative dimensions – examining people's experiences and perceptions – which required a more subjective or interpretative view of the research problem.

8.4.1 Semi-structured interviews

Semi-structured face-to-face interviews with open-ended questions were undertaken rather than a structured style of interviewing. It was considered that structured interviewing was too formal and inflexible, e.g. with its pre-defined set framework prior to interviewing and its interpretation undertaken only after interviewing. The main advantage offered by the use of a semi-structured and sometimes informal interview is that it allowed the researcher the freedom to ask open and probing questions in the appropriate directions (before, during and after); hence it became part of the learning process for the researcher. For example, the flexibility of a less structured approach offered many specific advantages: the order and wording of the questions and the way they were asked could be varied depending on the respondent's needs and understanding; it was possible to probe and elaborate unexpected issues as they emerged; and things could be explained more fluently to the respondent (Bryman, 2004; Ritchie & Lewis, 2003).

8.4.2 Application of interview method

'Household' interviews were conducted using a topic and questions checklist (for the research interview guide, see Appendix 1) as a guide, although it was designed with some built-in sequence or order for its execution. In contrast to a completely unstructured approach, the semi-structural and open-ended nature meant that the data could be collected in a more focused and systematic way while still allowing scope for people to elaborate on their answers and even digress into new and unanticipated areas. The semi-structured approach also allowed the comparability of interview data across the selected sample of HH being interviewed.

For the piloting of questions, three unstructured conversational interviews were carried out with homeowner occupiers living in single-dwelling residential houses. These interviews were carried out to test the overall sequence and wording of questions for the main interviews later, and to get an overview of the key issues that needed to be covered.

8.4.3 Interview questions covered

Whilst the interviews sought information from the key decision-maker in the home (those who owned the property and/or paid bills), they were worded to mainly capture the 'household' perspective, rather than just an 'individual' viewpoint (both were nevertheless used interchangeably in the final analysis). Often the questions were deliberately phrased in a way so that the results would not only demonstrate individual behaviours, but also provide insights about how HH relationships between family members affected consumption behaviour and so on.

The HH interview covered specific questions around a number of issues: previous experience and perceptions of home improvements and technology adoption; the reasons and motivations behind the need to carry out the work; what was involved in getting the work done, and how people felt about the works and what was achieved at the end of a project. One key question asked homeowners to recount all the changes made to their building since moving in, and their experiences of each stage. In addition, information about background socio-demographics and brief descriptions of the house/building were captured through a self-fill tick-box questionnaire.

All interviews were recorded and transcribed word-for-word and thematically analysed using NVivo software. This involved systematically coding each interview transcript; first thematically, and then by reorganising themes and recoding using the domestication four-phase research framework (as described in Chapter 7). In summary, each HH interview included the instruments shown in Table 10.

Table 9 Summary of household interview tools utilised.

1) Interview 'topic guide' – see Appendix 1
2) A tape recorder for recording interviews, lasting between 1-2 hours maximum.
3) A short structured questionnaire for HH background information (containing closed ended tick box elements) – see Appendix 2
4) A one sided sheet containing a list of environmentally friendly actions - participants were asked which ones they had implemented in their home (containing a closed ended tick box element) – see Appendix 3
5) A research participation consent form (see Appendix 4)
6) Photograph of the outside and inside of the house (supplementary and optional)
7) Energy bills (gas and/or electricity bills (supplementary and optional)
8) Other information sources provided by participant (where available) (supplementary and optional)

8.5 Data Collection

The HH interviews provided the primary data for the empirical investigation, and therefore an explanation of the HH sample and participant selection will be explained further. HH participants were selected using a combination of snowballing and purposive sampling. Thus, the overall approach is considered to be interpretive, and providing an in-depth snapshot of the problem under study which is not statistically valid or applicable across a larger population of HH.

8.5.1 Household sampling – purposive sampling

The population refers to the 'universe of units' from which the sample was selected (Hedges, 1978 in Hoinville et al. 1978; Sapsford & Jupp, 1998). Given the focus was on gaining the householder perspective, the main population under study is homeowners occupying private housing – living in single occupancy dwelling houses in England only – typically built before 1945. The literature review underlined the rationale for studying homeowners and this type of older traditional housing.

Due to the small-scale and qualitative nature of the research, the sample was selected using purposive (non-probability) sampling, which by its nature did not specifically aim to obtain a representative sample. This is suitable where the purpose of the research is to explore ideas and develop theoretical understanding (Hedges, 1978 in Hoinville et al. 1978; Sapsford & Jupp, 1998). Through the purposive approach, the HH participant sample was selected with a range of characteristics of interest – falling under two categories, namely housing stock and socio-demographics. These participants were considered to be typical of homeowner occupiers, and encompass issues/features that could be relevant to the wider population.

Purposive sampling is synonymous with qualitative research,

where the sample units are chosen because they have particular features or characteristics which would enable detailed exploration and understanding of the central themes and puzzles which the researcher wishes to study. These may be socio-demographic characteristics or may relate to specific experiences, behaviours, roles, etc. (Ritchie & Lewis, 2003:78)

Arguably, there are two principal aims of this technique:

The first is to ensure that all the key constituencies of relevance to the subject matter are covered...second is to ensure that, within each of the key criteria, some diversity is included so that the impact of the characteristics can be explored. (Ritchie & Lewis, 2003:79)

Furthermore, this diversity is important for two key reasons:

First it may help optimise the chances of identifying a full range of factors or characteristics that are associated with a phenomenon. The greater the diversity of characteristics or circumstances, the more opportunity there is to identify their different contributory elements or influences. Second it can allow some investigation of interdependency between variables such as those that are most relevant or those of lesser import can be disengaged from. (Ritchie & Lewis, 2003:83)

Therefore, the requirement for 'symbolic representation and diversity' in the sampling units have to meet prescribed criteria in order to be selected for the sample (Ritchie & Lewis, 2003:83).

8.5.2 Snowball sampling

Snowball sampling was also used, albeit mainly in the pilot study. Snowballing is 'often used to obtain a sample where there is no adequate list which could be used as a sample frame', or is used when the target group may be difficult to locate by normal means. This approach seemed appropriate for the selection of a 'numerically small group' in this research, particularly during piloting. Snowballing involves 'asking a member of the population of interest whether they know anyone else with the required characteristics (e.g. to identify someone they know who may have had renovated their home recently or put in PVs on their roof, etc.). Once those people have been interviewed, they are also asked to identify other people and so on 'until no further sample is obtained'. The process is resumed with another member of the population of interest, preferably with differing characteristics and asking them again to identify people, they know with the required characteristics again (Gilbert, 2001:74).

Of particular relevance to this study is the fact that snowball sampling helped target specific individuals, some of whom may be involved in 'some kind of network with others who share the characteristics of interest' (Gilbert, 2001:74). However, whist this is considered, on the one hand, to be an advantage – as it 'reveals a network of contacts which can itself be studied' – it can also be a limiting factor as it only includes those within a connected network of individuals. Snowballing could, therefore, result in a biased perspective if it is not carefully implemented (Gilbert, 2001:74–75). Nevertheless, it is considered a valid approach where 'the researcher's primary goal was an understanding of social processes and relationships between variables rather than obtaining a representative sample nor establishing causal connections' (Gilbert, 2001:73-74.

8.5.3 Application of sampling method

In response to the research objectives, the sample was selected to reflect EET adopter HH experiences. The sample was also chosen using both 'typical case sampling' and to some extent 'extreme and critical case sampling' (Ritchie & Lewis, 2003:83). The former is selected to represent the 'normal' or 'average' through detailed profiling (e.g. typical of private homeowner tenure). The latter was chosen on the basis that they represent exceptions within the typical case and which are unusual or special to expose 'implicit assumptions and norms' (Ritchie & Lewis, 2003:83); e.g. one HH living in a retrofitted Passivhaus house (ENERPHiT standard) was selected. The sample reflected a snapshot of different domestic situations to be explored and was not intended to be a statistically representative sample. The sample reflected a snapshot of different domestic situations to be explored and was not intended to be a statistically representative sample.

Finally, a so-called point of 'saturation' determined the sample size. In other words, sampling stopped when theoretical saturation was deemed to have been satisfied: 'when no new analytical insights were forthcoming from a given situation' (Gilbert, 2001:74). The researcher supported the premise that the actual size of the interview group is a secondary issue, as the researcher was not trying to achieve a target number of interviews. Hence, in this way the researcher was alert for the stage when the whole range of realistic responses was explored. Thus, the sample size comprised a total of 23 HH (although 30 were initially recruited). Wherever possible, more than one adult member of a HH was interviewed to explore different viewpoints within a family and the dynamics of decision-making in relation to home EET retrofitting.

The sample in this research was determined by the fact that the HH was the unit of analysis. However, the HH unit was divided into two sub-branches: the house and the people occupying it. Specific characteristics of the 'house' were selected using the following criteria:

- the age of the building (only houses built before 2006 were included);
- form of the building (single-dwelling houses only such as terraced, semi-detached and detached, but not flats or apartments);
- those that had adopted some form of EET to their home (i.e. from basic, intermediate to advanced technological measures);
- different size HH;
- different socio-demographic backgrounds; and
- different geographies and urban situations (e.g. inner-city and suburban locations).

The existing housing stock included pre-, post-war, and more recent builds prior to 2006. Some housing cases were located in conservation areas, but none had listed buildings status. In terms of geography, participants were selected in three cities/towns: London (including parts of Greater London), Birmingham and Salisbury. All housing was located in suburban or inner-city locations and in areas that represented diverse geographic, political, economic and infrastructure composition. They contained houses typical of the whole of the UK.

Participants with a variety of social and demographic backgrounds were also selected. This helped capture the 'heterogeneity of the population' under study (Bryman, 2004: 99). For example, the sample comprised HH (occupants of an existing house, not new build or those sharing or living in a flat or maisonette), including those that have undertaken a diverse range of changes to their homes since moving in. This included measures which the participant broadly defined as EE-related and any measure that was put in with the express purpose of reducing energy use and improving thermal comfort in the home either in the past or planned within the next 12 months.

8.5.4 Criteria for participant selection

The following provides a step-wise process in the selection criteria for the proposed participants in the study:

1. HH participants were selected on the basis that they met the criteria that defined them as 'homeowner occupiers'. This meant selecting only those that lived in the house they owned (freeholders/leaseholders) within a single occupancy dwelling house – this deliberately excluded houses in multiple occupancy, sub-tenancy HH, sub-divided houses, flats and maisonettes, and those who were in social housing.

2. The homeowner occupier participants were recruited for the study through a combined strategy of 'self-selection' through various forms of area-based 'targeting'. In practice, this meant a relatively reflexive approach.

3. Specific boroughs in London (e.g. Ealing, Camden, Hackney, Tower Hamlets, Haringey and Greenwich) were targeted because they had some form of a legacy of efforts to help promote HH EE. Information from borough websites and informal telephone calls with each borough's energy team officers helped to identify relevant local initiatives; glean information about an area's socio-demographics and housing profile; confirm any local policies and interventions to increase private householder EE; and identify community stakeholders engaged in relevant activities that could be contacted in order to promote the research study.

4. Once this existing local context was established, contacts were made by email and telephones calls with various community groups and individuals, highlighting the

importance of the study and asking for their help in recruiting local homeowner participants through posters and leaflets to be circulated or forwarded to homeowners they had contact with. The researcher also attended various community events that were helping to promote HH EE. During these events potential participants were approached directly by the researcher (prior permission to approach event attendees was required from the event's organisers). It was at these events that the vast majority of homeowner participants were recruited.[65]

5. In most cases, participants were self-selecting from the events held in London. This means that they volunteered to take part as a result of either receiving publicity material in the post or after seeing the posters advertised locally in their area, and/or being approached in a public venue or event (e.g. at community centres, libraries, churches, cafes, etc.) and/or being contacted directly by community organisers, etc.

6. In some cases, participants recruited were residents from outside London; these were recruited because either they attended an event in London, or through snowballing where a participant had recommended someone they thought could be eligible to take part. The full breakdown of the geographical location of the participants, their housing and socio-demographic profiles are provided in Appendix 5. The inclusion of these participants served to illustrate a more balanced perspective and suggested that the phenomenon observed in London is also evident elsewhere in England. The sample was chosen mainly from London because it has the diversity of socio-demographics and housing characteristics to be found across the country.

7. In all cases, homeowner participants underwent a pre-participation screening process before selection through either a telephone call or email. This involved asking them about their HH background, i.e. whether they owned their property and the

[65] E.g. the Camden Green Festival; 21st Century Homes – Green Open Homes in Haringey; the St Paul's Way Community Festival – Tower Hamlets; and others.

nature of the changes made to the home; an explanation of the purpose of the study, an explanation of what would happen during interviews, and completion of participation consent forms and so on were also discussed. This strategy allowed for the selection of the desired ‘character’ of the homeowner ‘adoptee’ group in terms or age and income ranges and so on.

8. After a group of potential homeowner volunteers had been screened, mutually agreed dates were set for interviews at their homes. HH interviews were undertaken with an adult member of the HH who was either: one of the owners of the house; the bill-payer; in charge of the main purchasing decisions for the HH, especially in relation to repairs and improvements. In some cases where it was feasible (and where joint decisions were made about home changes), more than one adult member was interviewed.

9. In most cases, face-to-face interviews with homeowners were carried out indoors, in the privacy of the participant’s home; the interviews were tape recorded, and only interview participant(s) were present in the room. During the interview slot, some home walk-through observations were noted and photographs taken. In all cases, participants were asked to fill in the participant background survey and energy behaviours survey and a participation consent form. Following interviews, some follow-up questions were obtained where required by either telephone or email. Each interview recording was transcribed verbatim and collated and analysed together with all the other materials about the participant’s home.

8.5.5 Pilot phase

A pilot study is a small-scale trial undertaken before the main investigation (Sapsford & Jupp, 1998:103). For this research, the pilot study started with a development stage that involved examination of existing research literature and consultation with key 'householder' stakeholders and some practitioners – such as local government officers – to examine existing views and concerns and to assess the priorities for the research. This stage was followed by three unstructured interviews with homeowners. This multifaceted approach allowed for a range of perspectives on the issues. It ensured that questions were understandable and could be completed within the allotted time, thus delivering reliable responses. All participants interviewed were also asked to provide written or verbal feedback, which was in due course used to modify the survey design; their responses from this stage were not included in the final data analysis.

8.6 Household Interview Data Analysis

The semi-structured nature of the interviews predetermined the nature of the data collected in terms of answers given, and in turn influenced how these would then be analysed. In particular, tape recording standardises responses from each participant and secures accuracy for analysing people's accounts later. Following a standardised format allowed comparison of HH, which then meant that the variables influencing findings could potentially be isolated. The types of question selected are based on themes identified in the literature review chapters, and the domestication framework is used in data analysis (see Table 10). Thus, the final thematic analysis – using all interview data and related background supplementary data – used the four-phase domestication framework as a key strategy to organise the data set.

Table 10 Summary of domestication framework used for interview data thematic analysis.

Key Phases	Broad Themes covered
1 **Appropriation**	Purchase; ownership; acquisition process; how do people find out and why do they acquire
2 **Objectification**	Spatial display, physical location; geographical location in the home
3 **Incorporation**	Use; fitting around everyday life; meanings acquired
4 **Conversion**	Feeling comfortable, taking for granted Telling others

Although there are many different approaches to qualitative data analysis, thematic analysis (sometimes known as 'thematic coding') of some form is a common feature in most. The act of 'coding' is perceived as a 'process' of analysis which emphasises analysis of 'what is said rather than how it is said' (Bryman, 2004:412). It 'is a method for identifying, analysing, and reporting patterns (themes) within data' and which goes beyond just 'organising and describing the data set in (rich) detail' to 'interpretation of various aspects of the research topic' (Boyatzis, 1998 in Braun & Clarke, 2005:6). Despite the many advantages of the flexibility offered by the coding process (e.g. it can be used by any discipline and from any theoretical position, etc.) it has been sometimes criticised for 'fragmenting and decontextualizing text' (Bryman, 2004:415).

Arguably, thematic analysis could be considered a ‘method in its own right’ which is ‘essentially independent of theory and epistemology, and can be applied across a range of theoretical and epistemological approaches’ (Braun & Clarke, 2005:4). Braun and Clarke argue that there is no ‘one ideal theoretical framework for conducting qualitative research’, nor indeed one ideal method. What is important is that the ‘theoretical framework and methods match what the researcher wants to know, and that they acknowledge these decisions, and recognise them as decisions’ (Braun & Clarke, 2005:7).

Furthermore, any underpinning theoretical framework (whether explicit or not) in a research investigation is likely to ‘carry with it a number of assumptions about the nature of the data, what they represent in terms of the “the world”, “reality”, and so forth’. Thus, ‘a good thematic analysis will make this transparent’, although ‘thematic analysis is not wedded to any pre-existing theoretical framework’ and it is useful to any number of theoretical or philosophical positions. Therefore, thematic analysis as a method ‘works both to reflect reality, and also to unpick or unravel the surface of “reality”’. Ultimately, it is important for the researcher to make transparent the theoretical position of a thematic analysis prior to analysis (Braun & Clarke, 2005:9).

8.6.1 Thematic and analytical framework utilised

The thematic framework for data analysis was underpinned by the domestication framework set out in Chapter 7, section 7.6. This analysis involved the following criteria:

1) It was a method to search for certain themes or patterns across the (entire) data set, rather than just within an individual data item such as an individual interview or interviews from one person only;

2) In order for an item to be counted as a theme it must ‘capture something important about the data in relation to the research question, and/or represents some level of patterned response or meaning within the data set’;

3) There must be some form of ‘prevalence both in terms of space within each data item and prevalence across the entire data set’.

Therefore, it is considered an ‘active’ process that the researcher actively engages in, ‘identifying patterns and themes, selecting which are of interest, and reporting them to the readers’. Additionally, themes or patterns within data can be identified in one of two ways: ‘in an inductive or “bottom up” way or in a theoretical or deductive or “top down” way’ (Braun & Clarke, 2005).

All the interviews were tape recorded and transcribed verbatim; they were then ‘thematically’ analysed and coded using Nvivo computer software. All the supplementary data were used to support thematic analysis and helped to build contextual knowledge of each HH or house occupied.

8.7 Research Validity: Ethics and Bias

8.7.1 Applicability and validity

In contrast to a scientific approach, one of the key weaknesses of a largely qualitative approach is arguably related to the question of its validity. This validity is on the one hand about its 'internal validity'. First, this can be to do with whether the findings could be justified by the research approach and the effects of researcher bias. Second, the notion of 'external validity' raises questions of whether the findings could be generalised, and therefore whether they are of limited or no scientific value (Braun & Clarke, 2005; Bryman, 2004). Hence, the largely qualitative nature of this research means that concern over its validity needs to be addressed.

Qualitative approaches are often criticised in contrast to a more scientific approach. Those supporting qualitative approaches recognise that they fill particular knowledge gaps not met by causal research design. Thus, in applied research it is not enough to know that X can cause Y; in order to apply that knowledge, we need to know how and why it works; and therefore something which this type of research approach taps into. Nonetheless, the 'how' and 'why' questions are more explanatory and likely to lead to the use of case studies, interviews and so forth as the preferred research methods. This is because such questions deal with operational links needing to be traced over time, rather than mere frequencies or incidents (Yin, 1989). Therefore:

[U]nlike statistical research, qualitative research does not set out to estimate the incidence of phenomena in the wider population. Qualitative sampling therefore requires a different logic to quantitative enquiry, one in which neither statistical representation nor scale are key considerations… A qualitative research sample is defined by its ability to represent salient characteristics…more crucially the principles of probability sampling can work against the requirements of sound qualitative sampling… (Ritchie and Lewis, 2003:81–82)

8.7.2 Validity of purposive sampling

Second, and more specifically in relation the use and validity of using a purposive sampling approach, the researcher subscribes to the following principle that although purposive selection involves quite deliberate choices, this should not suggest any bias in the nature of the choices made. The process of purposive sampling requires clear objectivity so that the sample stands up to independent scrutiny. (Ritchie & Lewis, 2003:80)

In particular:

[Q]ualitative samples are often criticised for not holding features of quantitative samples (for examples scale, national coverage, distribution or representation) when these would do nothing to enhance the robustness of the sample for its qualitative purposes. It is crucial that those who want to assess the strength of a qualitative sample apply the appropriate criteria, not one that belongs to a quite different research paradigm. (Ritchie & Lewis, 2003:81–82)

8.7.3 Triangulation

One of the central ways of addressing the validity of qualitative research is through the 'triangulation' of data in analysis. Hence, 'triangulation involves the use of different methods and sources to cross-check the integrity of, or extend, inferences drawn from the other data sources' (i.e. documentary, interview and conversational – whether formal or informal – data). For example, 'with a qualitative approach, the threats to validity arise from, e.g.: inadequacies of the measuring instruments, researcher subjectivity and bias and misinterpretation of accounts, etc. These threats are addressed through triangulation approach' (Desai, 2012).

However, ‘there is much debate about whether the value of triangulation is to validate qualitative evidence or lies in extending understanding through the use of multiple perspectives for different types of “readings”, often termed as multiple method research’ (Ritchie & Lewis, 2003:46). In this research, it has been used as a technique to obtain the validity of measurement derived from specific data and where other sources were used to check the integrity of that data. It is widely used in qualitative research as a way of investigating the ‘convergence’ of the data and the conclusions derived from them. Despite criticisms of it on ontological and epistemological grounds there is some consensus that the value of triangulation is ‘in extending understanding – or adding breadth or depth to analysis’, providing a fuller ‘holistic’ picture of phenomena but not necessarily a predictive one (Ritchie & Lewis, 2003:43–44).

This research deliberately addressed the potential weaknesses of a qualitative approach. For example, the threat from ‘reactivity’ was kept to a minimum because the involvement of the researcher was limited to only a short period of time (1–2 hours per interviewee); during this period the researcher did not attempt to change the personal situation of the respondent, and only discussed the changes which had occurred or were planned for and only those they were willing to discuss. The issue of researcher bias was addressed by discussing the overall observations with a senior research colleague.

8.7.4 Ethics

Most research studies undoubtedly raise ethical issues in some form. As this research is qualitative research, focusing on ‘people, and their relationships to each other and to the world’, it needed to be mindful of situations that raise ethical issues – in terms of respecting the rights of others, avoiding harm and dealing with unexpected issues (Walliman, 2005:340). The research involved ‘working with human participants’ and so ethical approval from the researcher’s university was gained prior to commencing work. Further details of the how ethical aspects were considered are provided in Appendix 6.

8.7.5 Researcher bias

Whilst every effort was made to reduce researcher bias, the author accepts that it may not have been completely eradicated given the author's position as an academic researcher. However, whilst the research outlined above provided clear justifications for each approach, the author's background, gender, age, education and occupation will undoubtedly have affected the broader rationale for this research and the methods used. For example, researcher subjectivity may have inevitably entered into the analysis of qualitative data, e.g. the interpretation of the interview data and/or choices made in the type of analysis relied heavily upon personal judgements. However, the researcher also asserts that the research benefited from this positionality as it enabled better access to people and resources.

8.8 Chapter Summary

This chapter set out the key rationale for the selection of the qualitative research approach. This research adopted a pragmatic knowledge claim via a predominantly inductive approach and through the use of a qualitative methodology – semi structured HH interviews – which will provide important in-depth knowledge of the research topic. Through this approach it aims to provide both explanation (but not predictive), interpretation and understanding of the research problem, while at the same time also seeking real-life practical implications of findings that could foster social and policy change.

The following chapters will set out the findings from data analysis of homeowner adoptees of EET in England. Chapter 9 reports on the key contextual background for each HH and their house provided by the supplementary data collected. The results of the primary data derived from the householder interviews were used to provide a two tier analysis set out over two chapters (Chapters 10 and 11) which present two contrasting approaches of analysis using the four-phase domestication framework. Analysis in Chapter 10 utilises the entire HH data set and presents a top down 'whole-house' level of analysis, while Chapter 11 provides a 'technology' focused bottom-up analysis which draws on a more restricted householder group that had implemented particular EET. This two-tiered approach seeks to demonstrate how the differing application of the domestication lens can provide multidimensional layers and a holistic insight into the same phenomenon. The insights from the interviews provide important knowledge for understanding the process of domestication of EET in the home.

Chapter 9 Findings for Participant and Housing Profile

9.1 Introduction

This chapter presents the first stage of analysis of the empirical data primarily derived from semi-structured householder interviews. The research findings are divided and presented in three parts. This chapter sets out key descriptive data about HH and the housing they live in, and provides an overview of the characteristics of the research sample captured in this study.

This chapter sets the scene for the subsequent chapters, which present the main data analysis using the domestication lens but further split between two differing scales of analysis. Chapter 10 focuses on presenting analysis of the domestication of a selection of 'individual EET', while Chapter 11 explores a broader domestication process of EET at the 'house' or 'building' level.

As outlined earlier in Chapter 7, the research proposed to use the domestication lens as a conceptual framework and analytical tool and heuristic device - as outlined by Gigerenzer, Todd & Null (1999) - for the analysis of the qualitative data. The empirical investigation gathered qualitative data derived primarily from semi-structured interviews with homeowners. The empirical findings were analysed through a two-tiered approach:

- Firstly, using a broader HH level of analysis where a suite of EET were integrated into the house contributing to its holistic energy efficient sociotechnical re-construction (outlined in Chapter 10); and
- Secondly, using technology as a unit of analysis, examining the domestication of a selection of individual non-discrete EET (outlined in Chapter 11).

This two-tiered approach sought to demonstrate whether the application of the domestication lens could provide holistic and multidimensional layers of insights into the same phenomenon. The deployment of this theory has enabled scrutiny of its usefulness and contemporary relevance – these aspects will be discussed further in this and the next chapters.

9.2 Sample Overview

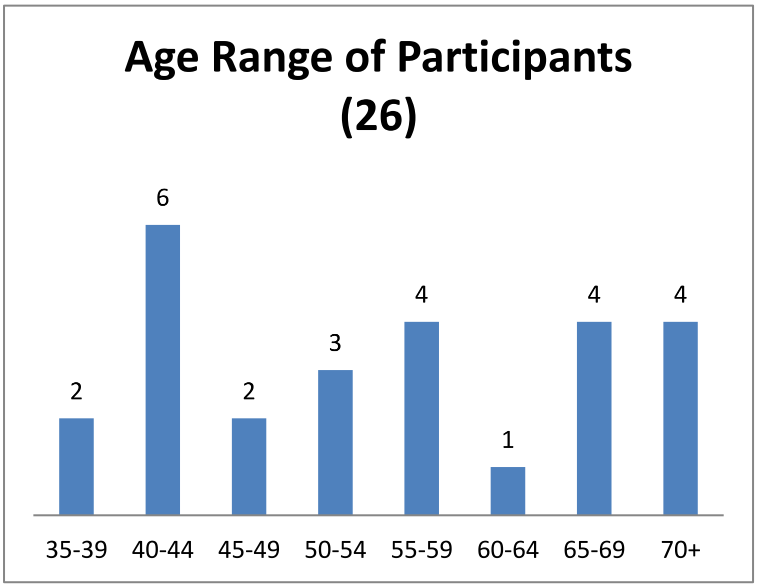
A total of 23 households were recruited through voluntary self-selection, from England: most (17) came from across London boroughs with a smaller proportion from either the south-east of England (Kent (two), Essex (two)) or the south-west (Wiltshire (two)). The recruitment and selection strategy was explained in Chapter 8. The 23 'householder' interviews were all conducted face-to-face, usually with one individual decision-maker in the participant's home. In three cases, a married couple (husband and wife) participated, contributing jointly to the interview discussion. The analysis of interview data therefore represented the combined viewpoints of 26 participants. The following section provides a breakdown through key descriptive statistics on the participants' profiles and aspects of their housing. Aspects of the participants' profiles included the following areas of analysis: gender, age, HH size, ethnicity, education, employment and income.

9.3 Participant – Socio-Demographic Profile

9.3.1 Gender and age

The 26 individual participants comprised 14 females and 12 males. The youngest age range was 35–39 (two) and the oldest over 70 (four) – approximately a third were aged 35–44; another third were between 45–59; and another third were above 60 years of age (see Figure 5).

Figure 5 Overview of participant age groups.



9.3.2 Household size

The HH size includes the following: one single-person HH; parents with dependent children (either one to three children under 17); parents with adult children; and retired couples (empty nesters) over 55 years old. The HH size can be broken down in the following way:

- 1 = single-person HH;
- 10 = two-person HH (living with partner or spouse);
- 3 = three adults as a HH;
- 9 = three or more (a couple living with partner or spouse) with children or other HH grouping.

9.3.3 Ethnicity

In terms of ethnic background,[66] all participants described themselves as 'British'. Those describing themselves as white British (77%) were the dominant group. A closer examination of the British 'white' group showed greater diversity within it, comprising Irish (three), Polish (one), Hungarian (one) and American (one). A small BME (Black & Minority Ethnic) group (five participants) comprised those that described themselves as British Asian or British with mixed ethnic heritage backgrounds.

9.3.4 Education

In terms of education levels, 20 participants stated that they had a degree level or equivalent educational background, and in almost all cases (20) the participants had at least one partner that was degree level educated.

9.3.5 Employment

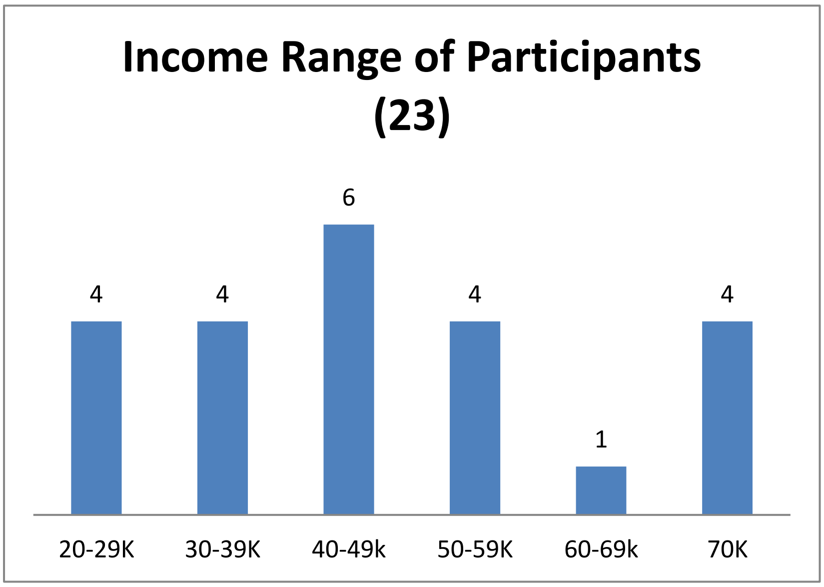
A significant proportion of the sample either was in full-time employment (nine) or retired (nine). The sample is therefore split almost in half between those that were in work (including both full-time and part-time workers) and those that were not (including the retired and homemakers).

66 The ethnic background categories were adapted from the 2011 Census and a tick-box short list compiled for this study – see Appendix 2 for example.

9.3.6 Income

The income ranges suggested a high proportion of people earning an income of over £40K or above annually. Those in the lowest income range £20–£29K per annum were all retired participants (four). Therefore, most of the HH represented in this research had a relatively high income and can be considered as affluent homeowners (see Figure 6).

Figure 6 Overview of the income ranges of participants.



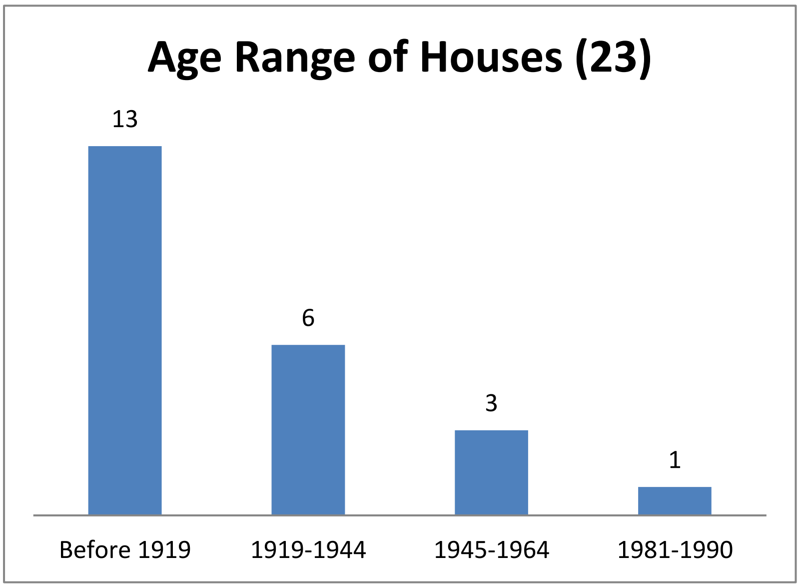
9.4 Housing Background

This section provides analysis of the housing characteristics (age of house, wall construction of house, number of bedrooms, etc.) as well as length of time in occupation by participants.

9.4.1 Age range of houses

A large proportion of HH (13) lived in a house built either before 1919; followed secondly by those (six) living in housing built from 1919–44. A smaller proportion (three) lived in houses built from 1945–64; one participant occupied the most recently built house represented – built in 1982. Of those houses built before 1944, nearly all were either end- or mid-terraces (13), with a small proportion (six) of semi-detached houses (see Figure 7). Nearly all the houses represented (20) were solid walled houses and the remaining were either concrete (one) or cavity walls (two). All the houses represented were large houses containing three or more bedrooms – the largest contained six bedrooms (one) and a further two were five-bedroom houses.

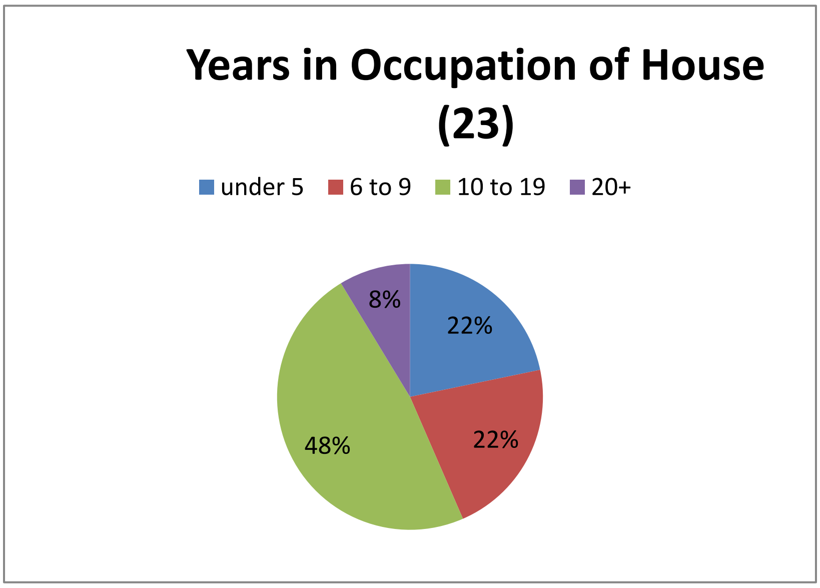
Figure 7 Overview of the age ranges of housing.



9.4.2 Length of time in home

Most of the participants had lived in their house for at least five years. Almost half of the participants had occupied their home between 10 to 20 years; and most of these were older couples (mainly retired) with either adult children who once lived with them but no longer do, or older teens potentially leaving home in the near future (see Figure 8).

Figure 8 Overview – the length of occupation of home.



9.5 EET Installed in the House

The 23 HH were asked to provide details of what changes they had made to their home since moving in, and which measures they themselves had installed for EE. 151 EE measures were adopted across the 23 HH. Most had installed at least six of the different measures listed below. The most frequently adopted measures were wall insulation of varying forms, followed by loft, roof and floor insulation and improved glazing. Table 12 provides a detailed breakdown of the most common EE measures adopted.

Table 11 EE measures adopted by the 23 households.

	Each Measure Installed	**Total**	**%**
1	Cavity wall insulation	**20**	**13%**
2	External wall insulation (EWI)	**17**	**11%**
3	Internal wall insulation (IWI)	**14**	**9%**
4	Loft/roof/floor insulation	**13**	**9%**
5	Double glazing	**12**	**8%**
6	Triple glazing/equivalent	**10**	**7%**
7	Secondary glazing	**9**	**6%**
8	Biomass burner (BB)	**8**	**5%**
9	Solar PV (SPV)	**8**	**5%**
	Solar thermal hot water (STHW)	**8**	**5%**
	Air source heat pump (ASHP)	**6**	**4%**
	EE boiler system	2	1%

	Mechanical Heat Recovery Ventilation (MHRV)	2	1%
	Total	**151**	**100%**

9.6 Home Change Strategy

9.6.1 'Whole-house' versus 'incremental' home change strategy

The research specifically sought to understand the timing, planning and installation of all building level changes. The results suggested that some EET were retrofitted as part of a planned holistic strategy for making the whole house energy efficient, and would be largely undertaken 'in one go'. However, in a small number of cases this did also materialise incrementally in phases over time. In both these instances, the final outcome would lead to a more energy-efficient house. However, frequently these EET retrofits were integrated alongside planned renovation projects, and often required building works, planning permission and/or building control consent.

A further broad category that was identified was those people that had undertaken some EE retrofits, but had stated no deliberated strategy or goal to make the whole house EE –Therefore the results (see Table 13) indicated that over half of the participants (13) had undertaken a 'whole-house strategy' for making their home energy efficient, while the remainder of participants (10) had no overarching strategy for achieving an energy-efficient home and most of their changes were undertaken incrementally. Of those with a 'whole-house strategy', participants could be split between those that implemented measures in 'one go' (six), or those where changes to the home emerged incrementally over time (seven).

Table 12 Summary of home changes.

	Strategy	Changes
1	Whole-house strategy = 13	One go = 6
		Incremental changes = 7
2	No strategy = 10	Incremental changes = 10

9.6.2 Socio-demographic and home change strategy

A further socio-demographic comparative breakdown of the two groups ('whole-house strategy' and 'no strategy'), suggested that there were no significant differences between them in terms of income, education, house type, HH size or stage in their life. As suggested earlier, most of the participants captured in this sample were relatively older, middle-aged, middle-class and affluent homeowners. The sample size was too small to make any further generalisations.

9.6.3 Home renovations

Many of the housing EE retrofits were often undertaken alongside other larger renovations to the house. Table 14 provides a breakdown by each participant, their strategy and other works carried out to their houses.

Table 13 Summary of the key changes made to the home.

		Length of time resident in home (years)	Changes in one go	Changes in phases	Planned whole-house strategy	major renovations/refurbishment of house
1	Neil	6	X		Yes	Kitchen/bathroom upgrade/Boiler/EWI
2	Steve	17		X	Yes	Internal upgrade
3	Lena	4	X		Yes	Kitchen extension and single-storey rear extension/Internal upgrade
4	Molly	23		X	No	Internal upgrade
5	Dawn	5	X		Yes	Single-storey/side and rear two-storey extension/Kitchen/bathroom extension/Internal upgrade
6	Pete	12	X		Yes	Rear two-storey extension/Kitchen/bathroom extension/EWI
7	Anne	18		X	Yes	Internal upgrade
8	Miles	3		X	Yes	EWI/Internal upgrade
9	Lilly	17		X	Yes	Loft conversion
10	Dan	5	X		Yes	Internal upgrade
11	Rita	18		X	No	Internal upgrade

12	Jim	13	X		No	Internal upgrade
13	Jill	12		X	No	Loft conversion/Internal upgrade
14	Nina	7		X	No	Internal upgrade
15	Kate	17		X	No	Kitchen extension and single-/side storey extension
16	Kelly	6		X	No	Internal refurbishments
17	Dean	18		X	Yes	Internal refurbishments
18	Billy	30	X		Yes	Kitchen extension and single-/two- storey extension
19	Jenny	15		X	Yes	Internal upgrade/Kitchen extension
20	Amanda	7	X		No	Internal upgrade
21	Yanis	11		X	No	Internal upgrade
22	Keira	10	X		No	Kitchen extension and single-/two- storey extension
23	Amy	1		X	No	In the planning stages of renovating whole house

9.6.4 Timing: when changes occurred and how long the works took

The length of time for actual implementation of building level changes seemed to happen at different times in the occupation of a house, occurring over some months or many years where a whole-house strategy was being implemented. Most EET retrofits were stated to have coincided with other building level changes or renovation works, e.g. building a kitchen extension, extending the rear of the house, implementing a complete bathroom refit, repairing floors/walls/roofs resulting in additional insulation, etc. One significant finding was that when retrofitting EET alongside other housing renovations most participants stated that this took between six months and a year. However, those that implemented a single measure by itself took anything from a few days to a few weeks, with the exception of solar energy technologies, which could be installed within either one day or less than a week depending on how many panels were being installed. Therefore, the length of time seems to vary for each individual technology being installed, and this time increases exponentially when combined with other renovation works.

9.7 Environmental Concerns, Everyday Purchases and Practices

9.7.1 Technologies purchased by householders

A series of closed-ended 'survey style' tick-box questions sought to identify whether participants were already engaging with other actions in their everyday life that could be termed as environmentally friendly (beyond installing EET). From this, it was possible to identify major energy-consuming technological products that were bought as one-off high-cost purchases by each participant. The five major purchases are identified in Table 15.

Table 14 Key technologies purchased by householders.

EE Measures	Frequency	%
Insulation	20	25%
Renewables	13	16%
Lighting	19	24%
Appliances	20	25%
Efficient car	7	9%
Total	**79**	100%

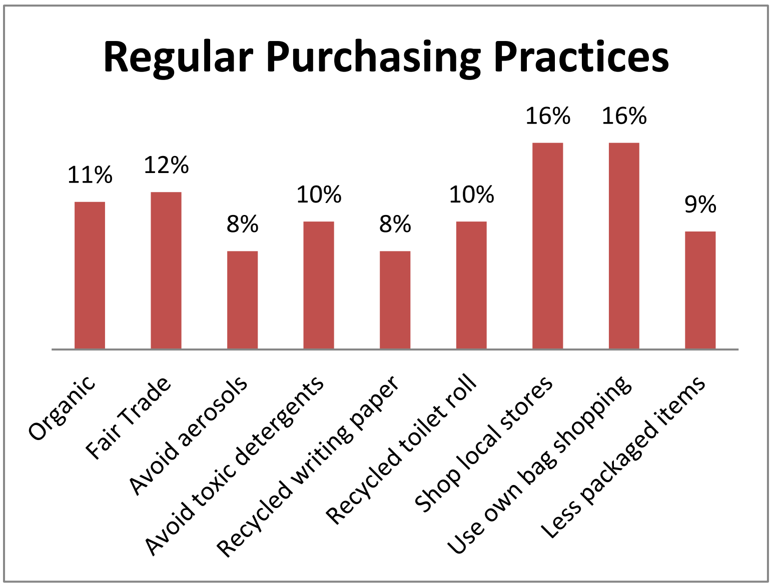
The findings suggested that 79 key technologies were adopted across the 23 HH. The most popular technologies involved buying insulation followed by EE kitchen appliances, while the least popular measure appeared to be buying an EE car.

Therefore, what is observable is that nearly all HH had installed some form of insulation, whether it was a single measure or a group of insulating measures for the entire house. Secondly, buying EE appliances and EE lighting were also fairly well established practices similar to insulation, and most had been implemented at some point. The purchase of renewables was slightly lower (13 HH had implemented this) and potentially linked to its relative novelty and higher upfront costs (as indicated in the existing literature). Interestingly, of the 17 participants owning a car, only seven had actively purchased an EE model.

9.7.2 Other environmentally friendly practices

In examining other purchase-related and environmentally friendly activities the participants regularly undertook, the following could be observed. The most popular and well-established purchasing practices entailed people 'shopping locally' and 'using their own shopping bag'; and the least popular practices were 'avoiding aerosols', 'buying recycled writing paper' and 'less packaged items'.

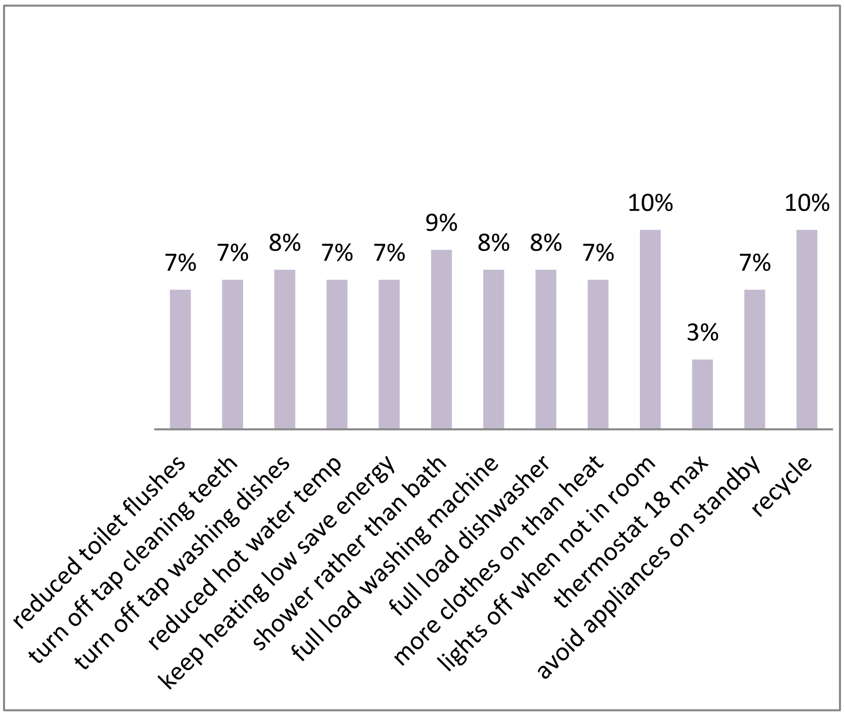
Figure 9 Regular environmentally friendly purchasing.



9.7.3 Environmentally friendly daily habitual practices

In terms of environmentally friendly daily habitual activities, most participants appeared to be relatively well engaged in many of these. For example, all participants stated that they undertook 'recycling' activities, followed closely by 'putting on more clothes rather than increasing or turning on heating when cold'; the least popular activity was 'heating rooms up to 18 degrees as a maximum room temperature' (see Figure 10).

Figure 10 Summary of everyday environmentally friendly practices.



9.7.4 Stated energy performance achieved in house

Participants were asked whether they knew what EE level, they had achieved in their home either in terms of EPC ratings (before and after changes) or carbon savings achieved. Of the 23 HH, only four participants (they had also adopted a 'whole-house strategy') stated that they knew they had achieved over 60% in carbon savings in their home (verified by an energy advisor); only three could estimate their current EPC rating – one participant who had installed external wall insulation (EWI) stated that his home now came close to or equivalent to the former 'Code for Sustainable Homes – Code 3 Level'; and only one participant stated that she had achieved a retrofit Passive House Standard (ENERPHiT); other participants talked about meeting current Building Regulations Part L – largely through extensive renovation works carried out. Furthermore, nearly all participants had either formally or informally consulted an energy expert or received home energy advice from an acquaintance.

9.7.5 Potential EE levels achieved

As this research did not set out to objectively measure the technical performance of the EE interventions undertaken in the house, it was difficult to accurately indicate the EE performance levels achieved. Two proxy approaches would have been to first examine EPC ratings prior and post EET retrofits and to then examine the standard building EE ratings, and/or secondly compare fuel bills prior and post EET retrofit to examine whether energy usage had changed. However, in both cases the participants could not supply this level of information. However, as a substitute this analysis sought to re-categorise the participant's houses according to the measures they had installed into three groups. Those that had:

(1) **'Basic'** measures – typically included the installation of well-established measures such as double-glazing, loft/roof insulation, EE boilers, draught proofing, etc. These were measures that would bring the house equivalent to or above the 'decent homes' standards;

(2) **'Intermediate'** measures – typically included the installation of nearly all of the 'basic' measures as well a few of the other more costly measures, e.g. underfloor insulation, secondary glazing, solar energy, partial wall insulation; and

(3) **'Advanced'** measures – typically included the installation of all of the 'basic' and 'intermediate' measures and more – addressing the EE of the entire building fabric holistically. Table 16 shows that most participants in this sample had gone beyond implementing the 'basic' measures and had embraced more costly, novel, and non-conventional technologies. Significantly, the advanced measures group were also the same 13 that had implemented a whole-house strategy.

Table 15 Summary of the three categories of EE interventions in homes.

Groups of measures	Frequency	%
Advanced	13	57%
Intermediate	8	35%
Basic	2	9%
Total	23	100%

9.8 Discussion of the HH sample characteristics

This research has sought to capture ‘adopter’ HH experiences. HH were selected on the basis that they met the criteria that defined them as ‘homeowner occupiers’ of an existing single dwelling house (not new build housing) and recruited only those that had implemented building-specific technological change for improving the energy efficiency of their house. More specifically, they were selected on basis that they had implemented not only the conventional and basic level measures (i.e. loft insulation) in their homes but also some of the intermediate or advanced measures, which are more costly, and novel and non-conventional technologies (set out in Table 12 and Table 16). It is on this basis that the sample was defined as an adopter HH group.

Moreover, there appeared to be no significant differences between adopter HH in terms of income, education, house type, HH size or stage in their life. However, deeper analysis of the characteristics of what seemed on the surface to be a pre-selected homogenous adopter group (set out in this chapter) highlighted a clear internal distinction within it. This was reflected in the symbolic and material dimensions of the changes they had chosen. This distinction suggested that these adopters and their home changes could be further subdivided into two groups, between first, those seeking merely a more energy efficient house and those seeking not just energy efficiency but also a greener and ‘eco’ house as an extension of a desired greener lifestyle. Therefore, for purposes of comparative analysis the former was classified as an EE group whilst the latter group - the Eco group. For example, the Eco group (13 participants) had stated they had deliberately undertaken a ‘whole-house strategy’ for making their home energy efficient and greener, while the remainder of participants (10) classified into the EE group stated that they did not have a clearly deliberated overarching strategy but mainly sought improvements in thermal comfort and achieving greater energy efficiency in their home (this is similar to groups identified by Stiess & Dunkleberg, 2013).

In particular, the Eco group showed more difference in relation purchase-related and environmentally friendly activities than the EE group. For example, the purchase of renewables was slightly higher (all 13 HH had installed renewables) and all expressed that they undertook environmentally purchasing and saving behaviours in their everyday life. Table 16 shows that most of this group had gone beyond implementing the 'basic' measures and had embraced more costly and novel and non-conventional technologies. Significantly, the advanced measures group were also the same 13 – the Eco group - that had implemented a whole-house strategy.

A further difference between the two groups was in the way they were involved in domestication process where some subtle differences become more apparent in the four phases. For example, the Eco group appeared to be more pro-active in the conversion of technologies. Despite the differences in the way these two groups domesticate technologies into their homes they nevertheless were all likely to be considered 'converters' of technology. This is based on the observation that they all seem actively engaged in conversing with others of their home changes. Further key aspects of HH technology domestication processes and comparative differences between these two groups are detailed in Chapter 10, section 10.6. It was difficult to fully judge from HH verbal accounts (as users) the extent to which their values, taste or styles expressed were quantifiably different from each other and where the boundaries were. The sample size and qualitative nature of this research meant that it was difficult to compare and contrast these differences more definitely, and therefore these groups are noted here more as an emergent theme.

9.9 Chapter Summary

This study relied heavily on voluntary participation of EET 'adopters', and therefore captured a greater proportion of relatively affluent, highly educated, middle-aged (40+ years) homeowners identifying themselves as ethnically 'White British' in the sample. It also captured a high proportion of 'traditional' two-person households (14) living either as a couple or couples with children, and less 'non-traditional' HH groupings, which includes one single-person HH, and two three-person HH where one person was a friend/lodger. Most homeowners occupied on average three-bedroom houses or more, which were more likely to be older solid walled historic houses in affluent urban metropolitan neighbourhoods (mainly in London). Hence, this particular demographic and the identified housing characteristics were tentatively considered more representative of a segment of those that currently do adopt EET.

The overall impression is that EET were either adopted as an intrinsic part of renovating and improving/upgrading the whole house, or incrementally in phases. Most participants appeared to have also adjusted many aspects of their lifestyle and consumption activities by incorporating numerous activities that could be considered environmentally friendly and aimed at reducing HH energy consumption (alongside adopting EET in their home). These characteristics of the participant socio-demographics and housing profile expose a very distinct homogeneity to the identity of the research sample. The following chapters will examine the way these characteristics influence and manifest themselves in participants' everyday lived experiences in domesticating EET.

Chapter 10 Findings of the 'Whole-House' Analysis (based on entire dataset)

10.1 Introduction

The preceding chapter described the HH participants and their housing background; in this chapter, the analysis draws on the viewpoints from the entire data set (26 participants) to provide a detailed overview using the domestication lens. As discussed, the empirical findings were analysed through a two-tiered approach, and this chapter presents the first part of that analysis. Therefore, it presents a broader HH level of analysis where a multiple EET were adopted, integrated and used in the house contributing to its energy-efficient sociotechnical reconfiguration.

The main rationale of this analysis was twofold: to identify factors that supported EE adoption through multiple EET being integrated into the sociotechnical system of the house; and to expand the analysis beyond questions which either support or illuminate each of the four phases of the domestication lens. For example, it sought specifically to examine emergent themes that did not fit neatly into the four phases, but were identified in the wider literature review. This approach was taken in order to highlight the complexity associated with human decision-making processes and experiences in relation to interactions with non-discrete (and not stand-alone) technologies that are designed to be integrated into the sociotechnical system of the house.

This chapter presents findings from questions about: how EET were introduced into homes and how they became part of everyday life; what the processes of technological domestication looks like; why certain technologies were chosen over others; how technologies are used and incorporated into everyday HH routines, what were the HH experiences of this process (for more on the questions see Appendix 1). The data analysis will be thematically and sequentially presented using the four phases of domestication – appropriation; objectification, incorporation and conversion (a full explanation of the research framework and questions was set out in Chapter 7).

Extensive illustrative quotes are used to exemplify key points or issues raised. Particular focus is placed on specific questions, which help reinforce and illuminate each of the four phases of domestication, thus this section is divided into:

- Appropriation
- Objectification
- Incorporation
- Conversion

10.2 Appropriation (acquisition)

The analysis of the findings for the appropriation phase reveals, on the one hand key aspects of this acquisition phase but also a pre-existing sociotechnical context that shapes not only this phase but also goes to shape the whole domestication process. Importantly this phase reveals itself as a key decision-making process for HH. In particular, as the process unfolds it reveals aspects of its complexity which are related to issues such as: the multiple motivations and reasons underpinning the desired changes and solutions, consideration of the existing sociotechnical legacy – a desire to preserve the existing heritage; the selection or rejection of specific EET interventions; accessing information and knowledge of solutions; and the role of government incentives. These are some of the issues that will be discussed further in this section.

In order to understand appropriation fully, the following related issues were examined. Firstly, the 'pre-purchase' rationale or motivation underpinning the purchase decisions for EET adoption. This identified a multifaceted nature broadly falling between social, personal, economic, environmental, technical and structural (including the physical legacy of the house) reasons. Some of the key reasons are discussed below.

10.2.1 Thermal comfort and existing physical legacy of the house

Most participants highlighted *'feeling cold'* as one of the key reasons, which helped kick-start the process of seeking EE solutions for the home. In particular, they correctly linked feeling cold with the poor pre-existing building condition or the legacy of their homes:

Summary of Theme	Example Quote
Feeling cold in uninsulated home	*Steve: "I think the main driver for making the changes was that we felt cold in the house, and especially at that point we had refurbished house but not eco-refurbished it... we were just cold in the house always... well I thought about it: I'm cold and I need to do something about it..."*
	Neil: "Well it was cold and uncomfortable and the windows rattled and we had to put stuffed newspaper between the sashes just to cut some of the draught, it was freezing and the heating was old and didn't work..."

Hence, a desire to improve thermal comfort in most cases meant trying to eradicate unwanted draughts in leaky windows and floors, prevent heat loss, etc. Increasingly, this meant evaluating the overall condition of the house – its physical legacy – and seeking a permanent solution for the whole house, i.e. insulation or draught proofing. This is largely due to most participants in the sample choosing to live in old pre-war built housing[67] (an age breakdown is provided in Chapter 9). Therefore, '*feeling cold'* provided the key trigger for seeking changes that would eventually not only increase thermal performance and comfort levels, but also improve other functional and aesthetical components of 'making a house a home'.

67 None of the HH sample lived in listed buildings although some would have been located in conservation areas.

10.2.2 Desire for heritage preservation

Despite the poor conditions of the participants' houses at the point of purchase, they were bought because participants wanted what they could offer – heritage, traditional and old aesthetical qualities that newly built housing could not provide. There was added scope for renovation and heritage preservation whilst offering adaptability for the occupant's functional need for space. Therefore, many participants in these relatively old houses often preferred EE technical solutions that would support heritage preservation in terms of being sympathetic to the original brickwork, chimneys, bay windows and doors, and internal features such as covings, skirting boards and fireplaces. In relation to keeping the brickwork, many had favoured internal wall insulation for some walls of the house whilst partial external wall insulation for others.[68] Linked to this was a desire to retain the original sash windows where participants often opted for secondary glazing to reduce heat loss:

Summary of Theme	Example Quote
Preserve brickwork, cost deters	*Steve: "... no we wanted to keep the brick... with the external stuff has to marry in with all your windows on your doors... also you see where you have the original coving... the Semtax runs up to it and therefore you can keep your coving... you can see how thick it is."* [Internal wall insulation and secondary glazing installed throughout house.]

[68] The domestication of internal and external wall insulation is discussed in detail in Chapter 11.

Preserve stained-glass window	*Molly: "I was worried about spoiling the stained-glass window... they were draughty old windows* [secondary glazing installed].*"*
Keeping coving, skirting and sash windows	*Jenny: "We have been careful not to remove any coving in the ceiling; originally the architects had that removed (in the plans) and I said not to remove that because that's original, because if somebody wanted to buy the house ... there's a reason to get rid of it so we've kept it and the high skirting boards we've kept and a sash windows but not everything the fire places are all boarded up the banisters are all original ... so to a certain extent original features are important."*
Secondary glazing solution to keep original sash	*Interviewer: "Why did you go for secondary glazing?"* *Rita: "We wanted to keep the original decorations and at that stage Ecodom wasn't able to replicate that... and then there was our bathroom upstairs that had that ... the top three panes of double glazed glass (replacement) we could do that because they were plain and another builder did that ... well because Ecodom could not do that and it would have meant contracting from*

	elsewhere and it would have been costly... it was a company called 'City Sound' for the double glazing who were very good and we recommended them to other people who wanted secondary glazing."

One of the key observations here is that as a result of the participants' desire to keep specific aspects of the houses' original features they very deliberately and pragmatically sought EE solutions that would help them either to keep, renew and modify the existing legacy of the house. Thus, in all cases, adopting such measures inadvertently improved environmental performance and was also found to be set within an underlying context of a wider HH project of 'making a house a home' through renovations – an emergent cross-cutting theme found throughout the data.

10.2.3 Multiple motivations

Most participants offered a mixture of interrelated yet practical and qualitative reasons for seeking EE measures, which went beyond simply feeling cold:

Summary of Theme	Example Quote
Enjoyment of walking barefooted on wooden floors and not feeling cold	*Steve: "... if you have wooden floors and you don't insulate under the floors you'll get cold... the driver for me was I wanted to walk around barefoot on my wood floors and now I can even in the winter, it's not really cold but then you also get rid of all the draughts. When we moved to the house we had carpets and I got rid of that and then I started to feel cold and then I thought I'd got to do something about it... I didn't want to be cold and I wanted floorboards... I know other people who have done..."*
Saving energy and comfort	*Jenny: "I would say saving energy was the first thing and improve comfort in the home..."*
Comfort in specific room and whole house and helping the environment	*Anne: "... we wanted the attic to be a nice warm room and wanted the rest of the house to be warm and we were concerned about the environment and the planet."*

Convenience of having adequate hot water and reducing energy costs	*Pete: "Well I save my gas bills and I get hot water constantly and never ever not have hot water... reduction in bills and cosy life main benefit..."*

The above examples demonstrate a number of key points: a desire for improving thermal comfort is wrapped up in a desire to have a warmer and more comfortable home all year round, and to be able to appreciate its aesthetical aspects; preventing heat loss would help reduce energy costs and have environmental benefits. Therefore, no single reason alone drives people's decisions towards EET adoption, something that also suggests a complex and less rationalistic view for EET acquisition.

10.2.4 Micro-generation installation reasons

In relation to adopting micro-generation technology a wide range of reasons were provided to do with '*cutting costs'*, '*saving money', 'self-sufficiency'* and *'income generation'*. These emerged alongside a desire to help '*the environment'* by '*cutting carbon emissions'*. The priority given to these differing reasons was difficult to determine:

Summary of Theme	Example Quote
Personal benefit and environmental reasons	Steve: *"Partly for personal benefit and for environmental reasons both reasons were strong."*
Cost and environmental reasons	*Interviewer: "What made you decide to do that?* *Billy: "Cost and sustainability ... reduce my environmental impact."* *Interviewer: "Have you always been concerned about environmental impact?"* *Billy: "Yes, slowly grown over last 20–30 years... I pity next generation."*
Cut carbon emissions	*Peter: "Well the reason why we did it was to cut our carbon emissions ... you'll be amazed how many people ask how much do you save in terms of money, but our main reason was to reduce carbon*

	emissions – that was the main reason that was our primary reason...”
Cut carbon emissions, environmental reasons	*Neil: “I suppose it was mainly about cutting my carbon emissions. I am very concerned about the environment it was something practical I could do and also feeling competitive to do better than other people in this area so I was one of the first people.”*

The following examples illustrate further the complex intermingling of financial and environmental meanings associated with the decision to install renewable technologies:

Summary of Theme	Example Quote
Generate own electricity	*Neil: “I wanted us to generate my own electricity and also having the solar hot water would be financially beneficial...”*
Income generation	*Amanda: “The amount of electricity we would generate and income long term ... it is a no-brainer if you work it out you get roughly around £1000 pa* *...You pay £11,000 for it and after 11 years, it is paid for, then you have*

	another 14 years of the government paying you this money. So if John dies first, part of his pension goes with him so this would help me with income."
Environment and income	*Dawn: "Well it is to do with the environment ... yes we like to be financially independent me and my husband, we have a lot of loans and a mortgage and we want to pay it back..."*
Environment and feel-good factor	*Dean: "... it's also quite environmentally sustainable and they're much more efficient than normal coal fires, much more about 90% more efficient... The payback made the extra incentive... so you can do it too reduce your energy cost ... there's environmental benefits of doing that ... because you're generating your own electricity so there's a feel-good factor there ... so we could say the electricity we use in our house and generated by ourselves we also actually generate surplus electricity which will be solar and we can sell that back and get money back and that will be completely zero*

	carbon and environmentally friendly too..."

For most participants personal, financial and environmental benefits seemed to be intrinsically linked generally to EET adoption. Chapter 9, section 9.7, examined participants' other environmental actions already undertaken as part of their everyday HH life. In particular, the Eco group expressed high levels of environmental concerns and desire to attain over time a greener lifestyle. This seemed to translate into actions in their purchasing and habitual everyday practices. Therefore, strong environmental values underpinned their decisions to buy micro-generation renewables.

10.2.5 The desired outcomes from the reconfiguration of the house

In the process of undertaking home renovations and adopting EET, there was one clear comparative distinction observable. This was reflected in the motivations and strategies for home changes that could be observed between the Eco group and EE group. The Eco group stated they had planned a relatively holistic strategy for making all aspects of their house energy efficient as well as matching that with lifestyle changes (that had occurred prior to or in tandem with the EE interventions). The key distinctive feature of this group was that they had conceptualised their overall change activities as something that would lead to an 'eco-house' in tune with their desire/vision to live a 'greener' lifestyle. Therefore, in this their efforts appeared symbolically different to the other EE group, which desired energy efficiency for the sake of improving, comfort foremost rather than expressly as a lifestyle change:

Summary of Theme	Example Quote
Desire to eco-renovate	*Neil: "... I wanted to eco-renovate and cut the carbon emissions; this house was in poor condition and that's why we bought it apart from that the house did still have nice Edwardian features that could be retained ... so we did most of the works at the same time."*
Eco-friendly house	Pete: "*So that was our big push to be eco-friendly it cost us a lot of time and money and effort."*
Eco-refurbishment	*Steve: "I think the main driver for making the changes was that we felt cold in the house, and especially at that point we had refurbished house but not eco-refurbished it."*

10.2.6 Role of government or other local incentives

The availability of government incentives (e.g. the Feed-in Tariff (FIT) and Renewable Heat Incentive (RHI)) spurred nearly all participants purchasing solar panels and ASHP to investigate and then install renewable technologies in the home:

Summary of Theme	Example Quote

FiT and RHI payments incentive	*Lena: "I was very keen to have solar panels anyway and I was also very keen to make the most of the government scheme particularly the FiT and RHI payments and we got in just before the deadline. So we get £1,200 a year being paid to us..."*
FiT payments incentive	*Jenny: "Fitted solar panels in 2012 just before the FiT payment changes, and thermal insulation... There was a deadline because the FiT payments were going to change... and if we made a decision within a week, they could install before the FiT changed. We just got it..."*
Local insulation grant	*Interviewer: "What about whether you could get a grant or incentive?"* *Jim: "Well we've got our loft insulation for nothing which was a local grant that we went for."* *Interviewer: "So is payback an important factor for you?"* *Jim: "Yes it would be with the boiler; we couldn't afford to spend thousands of pounds but it was an option that you could pay back over time."*

Smarthomes scheme	*Amy: "... just the exterior walls through the Smarthomes, and the windows and lofts we are just doing separately."*

Three participants were not influenced by the incentives because they were not available at the time; their interests were stimulated by knowledge of an 'innovative' renewable energy technology and then finding out more about its benefits.

10.2.7 Motives for rejection or postponement

In addition to understanding decisions to adopt EET the research also considered decisions to not adopt – either outright rejection or postponement – which also helps contribute to a greater understanding of why some EET are chosen whilst others are not**.** The analysis identified the influence of two significant components in terms of the role of pre-formed meanings, and prior knowledge and experiences in the pre-purchase decision-making. These were likely to have a significant negative effect, even where it would appear to be an obvious or recommended solution, and occurred before purchasing decisions were made.

Three participants had not installed solar technology even though they had seriously considered it. They stated that they had rejected it based on what they had heard from others who had had negative experiences with the technology. Thus, exposure to others' bad experiences conflated with technology 'myths' or lack of awareness had led to the dismissal of the potentials of a relatively safe, viable and well-established technology:

Summary of Theme	Example Quote
Perception of poor payback in relation to solar panels	*Yanis: "I have heard about them* [solar panels] *... I had a colleague who said he did solar panel installation but it really isn't paying off; the idea is that if you do have solar panels you can sell back some of the energy and did it because he thought: a) it would save him on electrical costs; and b) he can sell some of the power back to the National Grid which is what is supposed to pay back the investment but it didn't..."*
Insurance/fire risk	*Yanis: "... there's also an insurance risk with them – the risk of catching fire and so apparently you have to notify your insurance company so you have to get their approval before you go ahead with it so you just cannot decide one day you want to have solar panels fitted in."*
Fire risk	*Lilly: "...well her whole house burnt down and she had to leave it three or four months while they rebuilt it ... hadn't put it on properly and one of the wires that comes into the loft wasn't screwed on properly and it caught fire..."*

A further example highlights how a misinformed perception of a relatively unfamiliar EET such as CHP was formed by one participant. He concluded that it was more disruptive than solar power and not so well developed, and therefore rejected it. Although, arguably it would be no more disruptive than if a householder had decided to renovate or extend their bathroom or kitchen:

Summary of Theme	Example Quote
Poor payback but also technology undeveloped	*Miles: "Well it requires an improvement in the technology; well when you're in an urban and residential situation... the payback for these things are very low... the CHP technology might work but there's so much disruption involved therefore solar PV or solar thermal is simple and it's proven and therefore that's where the market is."*

Another participant stated that solar energy was dismissed because of the poor orientation of the roof, which made it unfeasible for their house:

Summary of Theme	Example Quote
Orientation of roof acted as hindrance	*Rita: "No we don't have solar because our roofs did not face the right way; but we had considered them that's why we went and saw this neighbour who had solar... I think they confirmed that it is better done on roofs facing the right way... we are west–east and although there is a bit of flat roof at the back we didn't*

	think it was big enough to put solar panels up..."

Other more complex reasons forwarded for not adopting EET were:

Summary of Theme	Example Quote
Personal circumstances – thinking to move	*Miles: "We're still in limbo as to whether we are staying or leaving the property so not sure if we are ready to make that investment..."*
Solid walled house occupant that had installed solar energy but chose not to have any form of wall insulation	*James: "Not really, you accept the house as it is. Depends if single skin or nine-inch brick. You accept house with its liabilities. To do anything about it would be expensive. I would need convincing it would make a difference."* *Amanda: "We work on the principle it is a cool house in the summer and a warm house in the winter so it must have some insulation."*
Planning restrictions	*Dean: "Planning has put an article for direction which means we cannot make any changes without prior consent for any type of an external works."*
Weighing up of the pros and cons in wall	*Dean: "This wall would be a problem to do external because it's already rendered and this one that wall would definitely be external, and the problem is*

insulation	*dampness, therefore external would be better on this wall and then the front of the house would probably be neither actually because it's really awkward and because of the bays... I think with the internal we would have to think about the loss of space."*

10.2.8 Gathering information about EE solutions

A key aspect of appropriating a new technology into homes required participants to first find out about its potentials from somewhere before any purchase could occur. Most participants stated that the following were key sources of information: leaflets and newsletters through the door, radio, TV, talking to other people, local housing EE events, expert friends, builders and/or architects, magazines, membership of organisations and the Internet.

The following quotes exemplify the nature of how people first find out about either individual domestic EET or other solutions for their home:

Summary of Theme	Example Quote
Leaflet through the door for sash windows	*Patrick: "I normally put anything through the letter box into the recycling bin and I caught a glimpse of a leaflet about sash windows and these ones were very leaky... this sash window company I rang them*

	up and they came down; the first thing we wanted to do was get the windows replaced ... the guy who gave the quote gave us a quote for replacing.”
By accident on the Internet for solar PV	*Interviewer: “How did you first find out about the solar panels?* *Lilly: “Online.”* *Interviewer: “So it was your husband who found out about it?”* *Lilly: “Yeah he does all the browsing… he was browsing and he saw it and then he emailed them.”* *Interviewer: “Was there something specific he was looking for when he was browsing?”* *Lilly: “No not really; he was online and an advertisement popped up and then he clicked into it.”*
Radio station about loft insulation	*Jim: “Yes from my local radio station and local leaflet from the council...”*
Visiting other houses through	*Rita: “We did go to quite a few to those houses to see what they had*

'open home' event and finding out about a range of insulating solutions and solar energy	*done... in the early days I remember there was one in Camden that the council had been involved with I remember that quite well; so that had got me thinking so that's how one got to know about Kingspan... you could look and see what had been done in that house... look at different types of solar panels coming in then."*
Builders' recommendations and seeing the EET installed *in situ* in someone else's house	*Lena: "I think that was from talking to one of our builders or the plumber because I wanted more energy efficiency and he recommended this* [ASHP] *and we went out to see his house in north London* [put in 2011] *and we put another one of these in the outside shed to do the underfloor heating for the whole house."*
Local event about home energy efficiency	*Lena: "I went to a MHSG workshop when they had a day of all sorts of talks by energy specialists."*
Membership of a national environmental organisation and other ways home energy efficiency	*Lena: "Yes. I was also in Muswell Hill Friends of the Earth, as well as the national one. Anyway I went to one of their events and those kinds of events have helped me absolutely; I think all of these are Friends of the Earth magazines, the environment*

	page of the newspapers, I watch Grand Designs, and you pick up lots of bits from all these places..."
Magazine from CAT informed about **home energy efficiency issues**	*Anne: "We've been members of CAT – the Centre for Alternative Technology for many years... they do a journal every quarter and they are interested in sustainable living aspects... I think we visited them once and how we got to know about them I really can't remember ... I think it kept us informed right from the beginning and they're not just interested in sustainable buildings it's much more..."*
Expert friends and reliance on wider social network for a range of EE solutions	*Billy: "I had a friend who did building work and joinery; he did a little before going abroad and he connected me to people to carry on doing the work. Through my friend I managed to hook up with carpenters and electricians, the plumber was father of a colleague at work..."*

Notably, in this context participants displayed high levels of social capital that could be tapped into as and when needed for information, sharing knowledge and experiences, problem solving and other forms of communication. Closer examination suggested high levels of consumption of ‘green’ media: membership and magazine subscription for Friends of the Earth, the Centre for Alternative Technology (CAT); membership of local sustainability groups and attendance of their events and so forth.

One of the key benefits of having access to a broad range of information and a rich social network is that it seemed to provide a basis for people to make well-informed decisions about which EET products to buy and install, and for finding the right solutions for their property at the appropriation phase:

Summary of Theme	Example Quote
Affordable and appropriate product for the their household and property’s needs	*Interviewer: “How do you find a product and what are you looking for?”* *Pete: “Well cost and something that lasts. I understand stuff about buildings materials, I can work out the efficiency of certain types of glass... I went for a product called Velux, a glass fitted solar product; the advantage of glass over Tube is that it has a flat surface we have two panels and is calculated on the basis of the house size and the number of people on the roof.”*
Selection of effective insulation	*Billy: “Rockwool, two types, rafters were only 75mm and used 50 mm extruded*

	polystyrene for better insulation properties...”

10.2.9 The arrival of technologies in the home

The nature of EET means that they are not discrete or stand-alone (discrete technologies include TVs, washing machines, mobile phones, etc.); they are more system-like in their technological attributes so their point of entry into the HH was marked by their integration into the fabric of the house. Hence, EET were rarely bought off the shelf as stand-alone discrete technologies. In most cases the actual technology or product is brought into the home by the ‘installer’; prior selection is made from viewing *physical* brochures or online browsing of relevant websites, and electronic transactions are used to make payment directly to the installer. The action of installation allows the item to become integrated into the fabric or existing technological system of the house:

Summary of Theme	Example Quote
Telephone order for solar energy	*Patrick: “... we had to send them some photographs so they could see the roofs and we had to take lots of pictures ... so they just did it on the basis of photographs... but they had a standard price ... well I spoke to them on the phone, made the order (didn't shop around) did the paperwork for the order at*

	the time there were very few suppliers so no question of shopping around..."
Ordered online, home delivered and self-installed	*Interviewer: "So how does it arrive into your home?"* *Steve: "Well you measure your window you send the dimensions away; they cut it to size and then deliver it and then you put it up if you can use a tape measure you can do it yourself..."*

A few exceptions were found with loft and floor insulation where acquisition was made by going to the store and buying off the shelf (for DIY installation purposes), even though most were also available online and could be supplied by the installer.

Summary of Theme	Example Quote
Buying loft insulation from shop	*Patrick: "Yes I just got a friend with a van and we went off and picked it up from Homebase; it didn't cost a lot..."*

10.3 Objectification (Making Technology Fit)

Through objectification, the artefact is given a physical location and displayed in the home. Here analysis focuses on how EET were fitted materially into the home, but also symbolically in the minds of the owners/users. The diverse and complex nature of housing specific EET means that objectification could only be realistically reached once the 'process' of installation into the building has occurred. Only then could the physical position of the technology and/or its related parts or user interfaces be likely to influence and shape decisions about how it may or may not be used in everyday life.

10.3.1 Process of installation or integration into the building fabric

The systemic nature of housing EET means that they require someone to install before they can be of use. This suggests that the installation process overlaps between appropriation and objectification as EET often need to be physically integrated into the technological system of the existing house. Furthermore, the process of installation appears to be a task of variable complexity depending on the type of EET chosen, whether it is 'fabric', 'insulating' or 'renewable' system measures, which are to be integrated into the existing physical, space available. This is a process that needs to take account who installs, the time taken and other issues, discussed further below.

10.3.2 Who installs – lead appropriator

In the HH represented in this research, there was usually one individual that appeared to lead the appropriation of the technologies on behalf of the whole HH – described here as a ‘lead appropriator’. This person drove the decision-making (albeit usually consensually) for all the members in that HH in terms of what got purchased, what got installed and when; he or she also co-ordinated the necessary building works, and managed the delivery of the overall vision of the home improvements being undertaken.

In one case, whilst a couple (a husband/wife) agreed on the need to adopt EET, one partner was happy to take a backseat to allow the other partner to take the lead in decision-making (although no gender-specific dimension to this was observed). Additionally, in a few situations where couples made decisions together, one person would still lead the decision-making because they understood more and/or felt more comfortable about dealing with technology-related issues:

Summary of Theme	Example Quote
Lead appropriator	*Steve: “I'm lucky in that my wife isn't fussy about these things.”* *Interviewer: “How does she feel about this? Does she agree with these works?”* *Steve: “Yes she agrees with them and she recognised it was both warmer and quieter afterwards...”*
Feeling comfortable with technologies	*Molly: “Patrick did but I am still uncomfortable with new technologies so I switch off and rely on him... he's just cleverer than me when it comes to technology.”*

Reliance on one partner	*Interviewer: "When you're looking to get information about changes for your home where do you tend to look and which source do you trust?"* *Lilly: "My husband normally looks online."* *Interviewer: "Do you trust that source?"* *Lilly: "Well it depends; my husband would look at it in detail."*

However, what is also observable is that sometimes decisions required more effort and persuasion to bring everyone on board in the HH. For example, in one case where the lead appropriator had to pressurise family members to gain agreement over a period of time, the participant was someone who through her personal interests proactively kept informed about the latest green issues and technologies:

Summary of Theme	Example Quote
Persuading others in the family	*Lena: "... I knew it was technology that was on the rise... I had terrible rows about it as it was very expensive... so the deadline for the FiT was coming I had to bully everybody and our son was living with us at the time to get the solar panels so I kept saying we've got to get it and got to get it by December because it will save so much money; in the end and eventually I persuaded them because they never kept up with all the stuff – I always did."*

Thus, the evidence suggested that one person may a play a greater role in leading the adoption decision-making (whether that was the case in other aspects of their domestic life was not examined in this research). It is likely that this lead appropriator would be involved in the information gathering, which helps to build a picture of the kind of measures they would potentially need to adopt.

10.3.3 Who installs – self or others

In addition to the influential role of the lead user in most HH, people also consulted 'expert' installers for energy advice and support. In this process of information gathering the lead users often became the experts themselves – this was particularly the case for all those in the Eco group. A key consequence of this was that first, they could plan for the 'right' solutions to deliver their vision for their home; second, they could order, purchase the right materials and in the right quantities; and third, they could get the works executed by others by becoming the de facto project managers; in some cases they could self-install measures.

For example, one male participant was a retired architect, due to his previous experiences and high level of competence with building construction he was able to research and project manage the large-scale renovations and the implementation of a suite of EET, and therefore reduce his overall costs:

Summary of Theme	Example Quote
Self-project manage	*Billy: "Yes got builders in and project managed myself as there was no main overall contractor and hired heating contractor."*

Another female participant during the course of retrofitting her entire house to Passive House (ENERPHiT) standards had difficulties in finding the right practitioners for her highly specialised set of works, and so decided to project manage the implementation process. In her words, this required working alongside an expert and then 'becoming the expert' herself:

Summary of Theme	Example Quote
Working with the expert	*Dawn: "So normally you would get the architect, his drawings which I will show you, we have details showing how the roof edge should go, or whether skylight should be, so everything is design up front and then you implement and start talking to the builders and then you start building."*
Adapting to the role of project manager	*Dawn: "Well I had to adapt to it, I had to manage it because I didn't find the right people to do the things... I had to talk to all the builders and sort all their communication issues... Actually, it's a learning process for both sides. It also requires skilful builders and works well with a reasonably small team... you need to educate everyone on the site including the plumber, the electrician, the builders, etc. It needs good teamwork, it requires the builders to do something different from what they are used."*

However, in three cases participants undertook 'self or DIY' installation of loft and floor insulation. In two cases, male participants had bought and fitted loft insulation over a few days themselves:

Summary of Theme	Example Quote
DIY project	*Mick: "There was loft insulation but it was not adequate. I doubled the insulation; I installed Rockwool, between raised joists, insulated the rafters."*

In the third and more exceptional case, the male participant was an engineer who had become an energy expert himself over time through engaging with other energy experts and through the course of researching and implementing a whole-house eco strategy. He suggested that his professional background gave him confidence in researching and finding the right solutions for his home, and then feeling he had the ability to fit his chosen solutions by himself, thereby managing the execution of the whole project. This participant had built experience incrementally over time by learning, trialling and self-installing other measures such as secondary glazing, internal wall insulation, draught-proofing the doors and so on, to deliver his whole-house vision of an energy-efficient and eco house:

Summary of Theme	Example Quote
Self-installing underfloor insulation	*Steve: "I'm an engineer, a civil engineer... I did it myself because I can get in that space underneath... and then I pushed the wool up from underneath towards the floorboard and there's chicken wire*

	underneath the joist to hold things up... This is sheep's wool the whole of the ground floor has sheep's wool insulation, along the joist. Wool is the product to use because you can touch it ... put in five years ago ... done as a DIY job... it would have taken me a while as I am doing it by myself, but for example knowing what I know now it would take me two days probably but I did it over weeks... probably over two months... what I did was I bought all the materials upfront… I researched stuff online...”

10.3.4 Length of time taken to install

The ending of the process of installing is undoubtedly an important part of the domesticating process, and a key signifier of the technologies’ arrival and integration into the home. It could be fairly short or a long and protracted process depending on the type of EET being installed. For example, in the case of solar panels, they could take a day (for one or two panels) to a few days (for approx. 8–18 panels) with minimal disruption. Furthermore, one participant’s account suggested that the same type of works (external wall insulation) on a slightly different wall on a similar terraced house could take much longer for some builders:

Summary of Theme	Example Quote

Short installation period	*Neil: "... and they were very efficient they did 100 m² on its gable wall and this wall and did the whole thing in three days, and there is a house just down the road and it would have taken them a day although they did also have a trickier wall..."*

In cases where several EET were, being installed as a whole-house eco strategy combined with other general renovation works there was a longer period in the installation period. For example, one participant implemented his whole-house strategy in phases over a period of a year. This involved decamping into one part of the house whilst works were being carried out in another. In this case, the participant also admitted to '*putting the works off*' over many years due a desire to do it '*properly*' and being able to make the time to allow the lengthy disruption required for such works:

Summary of Theme	Example Quote
Phased process	*Billy: "We did not go away. The work was phased... The first thing we did were those sheds in the back could put a lot of junk in there we had to take out of the house while the work takes place. Then we did a lot of work on the front next door and put in temporary kitchen and we moved in there. So the builder could do the front part of this house and the back part of both houses, then we moved back in here."*

	Billy: "Yes just about for 25 years we had done nothing. The first year, 18 months it was a building site when we moved in, but we knew there was stuff we wanted to do but kept putting it off. Then we decided we want to do it all now with good materials so we don't have to do repairs..."

Another participant, employing a whole-house strategy but incrementally, did the work in two goes, almost a year apart from one another due to costs:

Summary of Theme	Example Quote
Incremental changes were affordable	*Miles: "Yes about five to six weeks and that was new windows new doors, insulate and then finish, at the back it took longer as we put in a new bathroom and kitchen suite... because we couldn't afford to do it all in one go so we just did the front part first and then during this summer we did the back we put in new windows and doors... they were all single glazed or secondary glazed..."*

10.3.5 Physical location: display

As part of understanding the objectification of EET, consideration was given to how technology was fitted materially into the geography of the home through the process of installation. Only once installation was completed and deemed to have occurred could the process of display (physical and symbolic) materialise. However, the evidence on this suggested that again there is an overlap between 'installation', 'location' and 'display' as these positions seem to materialise simultaneously (and not in isolated stages). The key findings for the location and display aspects of objectification were twofold:

(1) first, the physical location of housing EET obviously was pre-determined by the manufacturers designs; and

(2) secondly, once integrated into the building fabric their scope for display was then limited (almost invisible).

Whilst discrete technologies can have a number of locations in the geography of the house, non-discrete domestic EET are pre-defined. For example, solar panels are mostly designed to be located on a roof, while EWI or IWI, despite the availability of varying manufacturers' products, are designed for walls only. Thus, they have little scope for variability as their physical locations were built into their designs requiring very little user interactions (due to their fit-and-forget quality). Furthermore, once installed and integrated into the building fabric, they acquired invisibility – although peripheral components such as pipework, water tanks, monitoring boxes, panels, wiring and other controls acted as visual reminders of the presence of the systems installed. The systemic nature of EET means they required occasional user interactions, such as switching on or off, modifications, servicing or repairs.

Throughout, there was a narrative of how participants had to make the technology fit and adapt it materially and symbolically into their home. The examples below, illustrate the varying forms of post-installation ‘physicality’ embodied by the various EET:

Summary of Theme	Example Quote
A specific cupboard was built to house monitors relating to SPV and ASHP, gas and electricity meters which is easily accessible from the living room and deliberately not located peripherally elsewhere in house	*Interviewer: "With the solar panel presumably there is somewhere you can monitor your usage?"* *Lena: "**Yes in that cupboard. All the meters are in there**...* [Bespoke cupboard in living room]*."* *Lena: "More than anything else it makes you think about your energy use all the time... so I take the energy reading from **... this is the electricity meter, and that's the solar panel one...**"*
The prior space allocation of the boiler water tank provided adequate space for the location of the new STHW hot water tank	*Steve: "... you **get a big tank and that stored in the attic** a normal hot water tank is that height but a solar hot water is very big I thought it silly to replace our old tank ... they looked and measured the space that we had and said it will fit in here luckily where the old tank was **there was more room for the bigger tank...**"*

In this case the participant did not deliberate where it should go as the installer decided its location; solar energy use was monitored via Internet tools and therefore did not look at the physical box	*Steve: "There's a* ***box under the stairs*** *which tells you how many kilowatt you've generated, but I never look at the box because is also linked to the Internet this device comes within the price..."*
On the landing, between living room and bathroom/bedrooms	*Interviewer: "How do you interact with it, is there a monitor?"* [Shows the box in hallway on wall at eye level.] *Patrick: "Daily and it's in* ***a handy position*** *and look at it before I go to bed."*
Space allocated in outdoor shed	*Lena: "... and we put another* ***one of these in the outside shed*** *to do the underfloor heating for the whole house."*
Limited space on roof	*Steve: "... it gives us all our hot water for almost half a year and it's really hot and those two panels... and* ***there is only space for two on the roof*** *if*

	there was space for three I might have got three."

Whilst the location of the EET's peripheral components was physically fixed, the act of '*fitting in'* takes both a material and symbolic form. The peripheral components act as a physical and symbolic reminder of their existence in the home, but also that they now live in a changed home environment, which appeared to have implications for the way the house and specific EET were used. For example, the installation of underfloor heating and insulation resulted in the removal of radiators and allowed the resident to use the room layout and space more flexibly:

Summary of Theme	Example Quote
Radiator removal	*Lena: "Yes it* [underfloor insulation and heating] *is for the entire house, while because radiators are a pain, they get in the way when it comes to furniture and so on, and the floor heating seemed so much more sensible... there used to be radiators but we took them out..."*

The installation of a biomass stove resulted in the creation of a new physical and symbolic focal point to the house:

Summary of Theme	Example Quote

New focal point	*Steve: "... you know it's the best thing in the house... A wood burner is something like once you've got one why would you not to have one and if you've got a house that can accommodate it why would you not want one; the wood burner is the most important thing in the house..."*

One participant, having installed internal wall insulation in one room, was now able to place a sofa by the window and sit near the *insulated* wall – something she could not do before, as it was too cold. However, it had also reduced the room size:

Summary of Theme	Example Quote
Room could be used as needed	*Anne: "While before we wouldn't have this over here* [sofa is against the bay window] *because it was too cold."*
Reduction in the room size following wall insulation	*Anne: "It was 100 mm* [she shows where it is and the depth against the wall] *so the room has been reduced by about that much* [100mm]*."* *Interviewer: "Was that a concern for you?"* *Anne: "Well in this room it's all right it's a big size... we had to take the entire PowerPoint off and shelves taken off."*

The evidence suggests that with different EET there were varying levels of a physical presence for the occupiers, which may allow differing aspects of material and symbolical display and interactions – these are summarised in Table 18.

10.4 Incorporation (Use)

Following the *spatial location* of technology (objectification), the incorporation phase focuses attention upon the themes of post-installation user experience and technology utility. It specifically considers how technologies find a place in the HH 'routines' and 'rituals' of 'everyday life'. Hence, understanding the incorporation phase required consideration of whether new and/or modified domestic practices emerged; the ease of use and effectiveness of adopted measures; whether the intended functions or user expectations were satisfied; and how values, tastes and styles were expressed in the symbolic aspects through everyday use. It also required a specific focus on the 'temporality' of use in terms of when and how EET were used and for how long (or evidence of the release of time for other activities).

10.4.1 Serves intended purpose

The EET installed were selected with specific features in mind, and in most cases appear to have served their intended primary purposes for their adoptees. For example, for reducing coldness, improving the overall comfort and warmth as well making the house look 'nicer'. Hence, a participant's motivations for appropriating EET seem to align here with its incorporation into everyday life – which firstly needed to serve its intended use or purpose, and could only be conveyed and affirmed by user experiences and satisfaction:

Summary of Theme	Example Quote

Living in an energy-efficient home	*Interviewer: "Do energy-efficient houses feel any different to a house that's not efficient?"* *Miles: "Well it's more comfortable than anything else, the temperatures more even whereas now before it wasn't the way we were heating it* [electric heaters] *there wasn't an even temperature throughout the house ... the draughts have gone and everywhere we have the same temperature; before it wasn't; before we were having problems heating up the rooms."*
A more comfortable home	*Dave: "... you put it in because it makes it more comfortable as well as looking nice."*

One key point highlighted by many participants was that the apparent reliability and efficiency of their new or modified systems contributed to making their house a more comfortable home. For example, being able to obtain adequate heating and hot water whenever needed, not having to use the gas boiler for hot water or heating as much as before – all of which contributed to a reduction in overall HH fuel costs and a sense of being in control of energy consumption:

Summary of Theme	Example Quote

Comfort and pleasure of having water from renewable source	*Molly: "… huge benefits every time I have a solar shower it makes me happy; it's a very joyful experience and I've never really got used to that."*
Fuel cost savings, control, right temperature	*Pete: "Well I save my gas bills and I get hot water constantly and never ever not have hot water, also our hot water is not set for boiling it is bearable."*

10.4.2 Use of controls/settings/manuals

As part of fulfilling its intended purpose, the users of the EET acquired some degree of knowledge pre-appropriation or post-installation about how to best use their EET or their modified EE home environment. Very few participants stated that they used the user manuals that came with their devices/technologies, and regularly interacted with any settings.

In the case of renewable technologies, MVHR and new boiler systems where some interactions were feasible with setting/controls, participants again stated very little day-to-day level interactions with their EET systems. Nearly all participants claimed that they had a '*good working knowledge*' of their EET and how to use them. Most participants stated most of the instructions were those given to them at the time of installation by their builder or installer, and that oral instruction of how to use the technologies formed the basis of their everyday use:

Summary of Theme	Example Quote
Advice on how to use by installer	*Lena: "... so what they told us to do with the solar panels is use as much electricity as you can during the day so ... we would try and do more of that during the day ... they deemed the customer to be using half what they produce so if you use more than half then you're okay..."*

There was some evidence to suggest that the lead appropriator would be the one educating the family on appropriate use of EET once installed. It also seems that after the initial setting up by the installers, there is very little interaction with the technology, and many people do not change settings either:

Summary of Theme	Example Quote
New boiler and timer	*Interviewer: "So do you need to interact with it daily?"* *Yanis: "No we don't need to do anything with it now it is all set up so we've got four different timer set up... initially the engineer set it up and I was trained on how to use it by him and then I kind of trained my wife and the other two as well."*

10.4.3 Learning to live with an EE home: by trial and error

Many participants described how they had to learn how to use their newly fitted technology over time. This required a period of trial and error where initially participants did not quite know how to operate the system optimally or to their satisfaction. For example, one participant who had put in an ASHP and had a BB installed to supplement room heating, described how she learnt to overcome difficulties in using the various EET effectively and adapting her life around them:

Summary of Theme	Example Quote
Learning to live with EET through trial and error	*Lena: "... well we've had to experiment over the last three years since we've had this... I used to have it at a different temperature during the day on the thermostat; that didn't work at all because it takes much longer with underfloor heating to get up and down it can take over an hour to heat up so basically now we have it on the same heat the whole time; well at night it goes down a bit; most of the day we have it on, and of course we are around during the day so that's been the most difficult thing to learn to live with and learn to use efficiently and that's because we never had underfloor heating before and so we had to get used to the system and used to how it works ... the trick is not to fiddle around too much with it temperature. I turn it down in the night*

	because you don't want it on when sleeping..."
Understanding the systems of the home	*Steve: "Well you learn over time isn't it... the thing with the solar stuff is initially when we had it I wouldn't have known how much water we will use... so just by trial and error... I know it works because the boiler is switched off on a day like this I can sense how much sun there has been on a day like this were getting all our hot water; if at the end of the day if I found there wasn't any hot water then I would decide that something wasn't working but that hasn't happened."*

10.4.4 Complementarity between systems

In addition to learning through use and experience over time, there was evidence that specific EET began to serve a complementary role and purpose within the existing sociotechnical system of the house. Solar energy sources often complemented existing gas boiler systems and nearly always became the primary source for electricity use in the home; STHW often became the primary source for hot water, but was topped up by the gas boiler system when there was a shortfall; the BB could serve the role of both a secondary or even primary room heating source, resulting in less use of the existing gas central heating systems; ASHPs served to replace existing boiler systems where they supplied hot water only, and where they were used for underfloor heating – they could replace the existing gas central heating system too.

Table 16 Summary of the complementarity between energy systems

Adoption of new EET	Primary effects	Secondary effects
SPV	Main source of electricity supply	Less use of mains electricity; acts as back-up
STHW	Main source of hot water generation	Gas boiler acts as backup
ASHP – hot water	Main source of hot water generation	Replaces gas boiler
ASHP – underfloor heating	Main room heating source complemented by other source, e.g. BB or gas central heating	Gas central heating radiators removed
MHVR	Main ventilation system	No need for air extraction fans No need to open windows
BB	Both primary/secondary use	Gas central heating system used less

The evidence of complementarity of use between energy systems meant that for nearly all participant's daily and seasonal adjustments between newly adopted EETs and in conjunction with the existing energy system infrastructure in the home were required:

Summary of Theme	Example Quote
Switching to daytime use	*Patrick: "... which means on a day like this we can both go and have a shower and not have to put on the water heating ... during the winter we need the boiler."*
Adjusting use according to need	*Steve: "... in the evening time ... when the water is cold she will just put on the boiler or kids might say the water is not very hot so I'll switch the boiler on for half an hour..."*
Seasonal and daily variations	*Molly: "... not at this time of year, it is May. Sometimes I might decide to have a shower in the evening if it's been sunny all day and I know I have lots of hot water but once it gets to June, July, August it will be there all the time... we have a gas boiler and so we use the gas boiler very little between the end of April and the end of October..."*
Relying on	*Neil: "... we now have underfloor heating on the ground floor and upstairs and*

differing systems	*hallway we have central heating so it's a mixed system."*

One participant described developing an understanding of his hot water and heating system and recognising complementarity of their uses over time, and being able to respond to and adapt usage flexibly as and when required – cooking in the evenings and washing dishes by hand afterwards continued even though this could mean falling back on the boiler hot water source and not the solar hot water:

Summary of Theme	Example Quote
Complementarity of uses	*Steve: "Well you learn over time isn't it... the thing with the solar stuff is initially when we had it I wouldn't have known how much water we will use ... so just by trial and error ... I know it works because the boiler is switched off on a day like this; I can sense how much sun there has been on a day like this; we're getting all our hot water if at the end of the day if I found there wasn't any hot water then I would decide that something wasn't working but that hasn't happened."*
Adapting use of systems	*Steve: "We did adapt slightly ... we don't have a dishwasher ... I do all*

	the washing-up and my wife does the cooking so I can sense the water coming out of the tap I know I need to put the boiler on for 15 minutes by how hot the water is; I know now there is not enough hot water there for tomorrow morning when everybody wants the hot shower so if I wash up in the evening time say at nine o'clock... it's intuition..."

10.4.5 Everyday use

All those with solar energy technologies had adapted to using energy-consuming activities more during the daytime in order to maximise 'free' solar energy. For example, this was particularly applicable where one or more members of the HH were retired, worked from home, or worked as a 'homemaker' where dishwashing, clothes washing, cooking, ironing, showers and so on were deliberately undertaken during the day:

Summary of Theme	Example Quote
Switching to daytime use	*Jenny: "We would run dishwasher, washing machine during the day free of charge. If we have too much on at any one time we start using power."*
Switching to	*Steve: "Well they say try and use as much during the day so we started doing that. I would iron in the daytime; if we needed the*

daytime use	*washing machine I would run that during the daytime but there are certain things you can't do; my wife will bake but she won't do it in the middle of the day it's like with solar hot water theoretically you should be having a bath in the middle of the day but we don't do that we like to have our showers in the morning; the only thing with the hot water is if you know you're going to have a shower don't leave it until 10 o'clock at night have one at five o'clock because then the water had a chance to heat up again."*
Switching to daytime use	*Lena: "I wouldn't dream of putting on the dryer or the washing machine at night as we're retired we're here during the day and do it during the daytime."* *Interviewer: "Have you always done stuff during the day?"* *Lena: "Well no, before when we were working and we were out and about we tended to do these things in the evening."*

In all accounts, there appeared to be no reluctance in undertaking the more energy-consuming activities during the day; indeed, it was something that participants willingly embraced as part of living in a more energy-efficient way. However, there was not a rigid adherence but flexibility was often applied when adjustments to the everyday routines were required, e.g. when someone in the HH wanted to have a shower or cook in the evening.

In terms of showering and bathing practices, the increased daily availability of energy did not appear to result in excessive over-use for most participants. Moreover, the availability of 'free' hot water daily often resulted in maintaining the status quo – by being able to *indulge* in the need for daily showering which was facilitated by the solar energy system, even though this was now undertaken increasingly during the day:

Summary of Theme	Example Quote
Continuation of existing routines for showering	*Molly: "... I've never really got used to that there's loads of hot water all day while neither of us takes a shower every day were not in the modern way I was brought up with a bath once a week... Sometimes I might decide to have a shower in the evening if it's been sunny all day and I know I have lots of hot water..."*
Continuation of existing routines for showering	*Anne: "Well I continue to have a long shower with a lot of hot water every day and I can't live without that."*

10.4.6 Unintended use – new practices emerge

There is evidence that some EET exceed users' needs for warmth and expectations of specific technologies within their everyday lives. In one case, the participant highlighted that following underfloor insulation combined with underfloor heating, it had proved unnecessary to ever use the underfloor heating since the insulation was very effective at keeping the room to a comfortable temperature without the need for heating:

Summary of Theme	Example Quote
Underfloor heating underused	*Kate: "Yes we were quite warm in here, but I think the underfloor heating was a waste as we never use it – we never need to use it."*

This point is further reinforced by another case where underfloor insulation was fitted and the existing fireplaces became redundant:

Summary of Theme	Example Quote
Fireplace unused	*Rita: "... we haven't used the fireplaces in such a while in the last couple of years hardly because it is now more energy efficient..."*

Interestingly, a fundamental change can be observed here in the traditional room heating patterns. What is observable in most participants' accounts is that because of the overall improved thermal comfort achieved, the location and function of the radiators were changed, either by removal, relocation – away from out-facing walls – or complete disuse:

Summary of Theme	Example Quote
Little use of radiators	*Interviewer: "Don't you need radiators anymore?"* *Dave: "No we don't, although we do have two in the other room, we very rarely use it... the first winter I was here and how cold it was, I was virtually sitting next to the radiator, well that doesn't happen anymore... the house is warm and in the summer it is cool... don't need air conditioning, the insulation helps with that..."*
Radiators removed completely	*Lena: "Yes it* [underfloor heating through air source heat pump] *is for the entire house, while because radiators are a pain, they get in the way and when it comes to furniture and so on and so the floor heating seemed so much more sensible."*
Radiator position moved	*Steve: "... radiator used to be underneath the window, but there is no need for that as you lose the heat through the window; they used to put them there because they thought it would stop condensation* [now positioned on inside wall]*."*

10.4.7 Everyday practices and environmental concerns

The installation of EET improved the overall quality of life for most participants. In particular, the changes had heightened their appreciation of energy issues in other everyday routines. In many cases, participants had already embraced more energy-efficient practices prior to adopting EET:

Summary of Theme	Example Quote
Adjustment to routines	*Interviewer: "What was the impact of having these changes in your everyday life?"* *Neil: "Well we turn off the lights and we don't have the heating on to high on a cold day and we don't have the heating on at tropical temperatures... Charlotte puts on a sweater if it's too cold. I think I'm more energy conscious than my wife is. We have energy-saving kettle I will measure the cup of water and I will always switch off lights; we try not to leave windows and doors open."*
Seeking an energy-efficient appliance	*Patrick: "We did recently change the fridge and the old one was going and what I did was I went round the corner and I know the people in the shop and I just said I want the best*

	energy-rated fridge is just a fridge with a tiny little freeze blocks... as we eat most of our things fresh."
Water and energy-efficient use of appliances and in everyday practices	*Dave: "... I have dual flush and water-saving appliances, which also have energy-saving or eco-settings, and you can wash at lower temperatures, I'm quite sparing when I wash dishes or use water..."*

10.4.8 Reduced fuel bills and energy savings

As noted earlier, for nearly all participants increasing the EE of their home did not result in increased or unfettered energy consumption practices, even where it may have been feasible. For example, the STHW producing an abundant free hot water supply did not result in more or longer showers or hot water wastage, and so on. In this context, documentary evidence of fuel bills was not examined to see whether energy consumption had measurably been reduced in relation to their stated experiences.

However, two distinct observations could be made between the Eco group and the EE group. The Eco group stated they had actively decreased their energy use and had seen a "substantial" reduction in their energy bills. They were also able to state assertively the amount of energy and carbon savings that had been made in their home. In contrast, the EE group stated they continued their pre-existing levels of energy use yet stated that their bills had reduced to some degree but it was not clear how much to them - following EET adoption:

Summary of Theme	Example Quote
Stated energy consumption reduction	*Patrick: "... we generate at least three-quarters of our energy; I measured how much electricity we used the year before we put in the solar panels and ever since then we have generated three-quarters of the energy that we use and a quarter is what we have to pay for."*
	Steve: "I would say we actually use less... what would you say my gas bills are per month? It's £4 per month and electric is £8 a month... there are people around here who pay £200 to £250 per month... this is a big house and in terms of energy usage per square metre I've calculated this is 7% of the UK average..."
	Pete: "The gas is roughly about a quarter of what we were used to... the money thing is slightly difficult to judge because we do it by direct debit and they owe us about 400 quid on the gas bill which we don't seem to be getting back."

This observation aligns with existing research (set out in Chapter 4) that whilst most EE interventions alone in the home can deliver some notable EE savings, their potential cannot be fully maximised without addressing all aspects of EE that can be delivered as a whole house package and aided by HH occupants actively changing their energy consumption.

Furthermore, gaining a reduction in energy bills took time and required the ability to use the differing systems in the home effectively:

Summary of Theme	Example Quote
Slowly getting use right and reducing energy consumption	*Anne: "Although the first year was a bit of a disaster because we hadn't got the system working properly we hadn't cut down on our bills at all; we now have worked out how to do it."*

10.4.9 Increased monitoring activities

Notably, Eco group stated that they were increasingly vigilant about their energy consumption and reduction, and had been monitoring this prior to and post-EET adoption. This feature manifests itself in many ways. For example, in one case, energy use monitoring before and after implementing EET had allowed one participant to plan and deliver a whole-house strategy incrementally to his house. It allowed the participant to measure energy consumption following each EE intervention and calculate the energy reduction achieved:

Summary of Theme	Example Quote
Before EE interventions to the home	*Interviewer: "So you did all this before you got your solar energy?"* *Steve: "Yes... well I had data on how much energy I used particularly after I'd done all the insulation works but roughly; so I was monitoring, and I was also thinking and I'd read of little bit about that that 60% of energy use is heating 20% is your hot water and 20% is your electricity rough numbers; so once I tackled the heating I thought what about the hot water and I knew we had a south-facing roof..."*
After EE interventions to the home	*Steve: "One of the drivers... we put in the wood burning stove and then after that we insulated walls so after that we got the solar. I monitored the electrical use of all the electrical appliances... you see this gadget here I got it on the Internet; if you put that in a socket and then you plug your other thing in it will tell you how many watts you're using and then you can get an idea of how long you're using something for... your fridge is on all the time but how long is a laptop on for? I've assumed mine will probably be on for ten hours a day, or how long is a hairdryer on for - with a hairdryer you use 2000 watts or*

	something whereas a laptop is 30 watts so a hairdryer is very, very energy intensive or a toaster is very energy intensive for a very short period whereas the fridge is on all the time but it's lower [shows a graph table with appliance energy consumption showing in it] *I know what my total fixed energy use is and then I work out I used about 2000 kW a year and then I work out what all those things cost... and I work out the number of hours they are on."*

These participants monitored their use through a variety of tools: one participant used their own Excel spreadsheet to keep track of what they were using, whereas others used Internet-based ICT software that they paid a subscription into. In all these cases, the underlying benefit was that participants reported actively making adjustments, reducing how much energy they used in relation to particular technologies in their home:

Summary of Theme	Example Quote
Monitoring energy use on web-based software on laptop	*Steve: "There's a box under the stairs which tells you how many kilowatt you've generated but I never look at the box because it's also linked to the Internet; this device comes within the price... you know to the minute how much you are using, you also know how*

	many of the eight panels are working; the way it works is with the Feed-in Tariff. They assume that 50% of what you generate you're going to feed into the grid. They assume you don't actually measure that's the assumption; the whole thing doesn't actually work very well... I know on average we buy from the grid about three kW a day so I monitor how much I buy from the grid; I know how much I generate I assume we use half of what we generate."
Monitoring via web-based software	*Lena: "Yes I joined something called 'I measure'; it was free but now they charge a small fee about a pound a month you put in your meter readings gas and electricity meter readings once a week when you set it up you have to tell them where you live which weather station you're close to and then it monitors the weather and it tells you how efficient you are being in terms of your usage... so I watch it every week and see if it's gone up I'll show you."*
	Interviewer: "Is there somewhere you can monitor your energy use?" *Dawn: "Yes we have normal gas and electricity meters, and one for the solars... I put the numbers into an Excel*

	sheet so you can visualise what you use."
Daily monitoring of energy use	*Patrick: "Daily and it's in a handy position and look at it before I go to bed."* *Molly: "But you don't have to look at it but we are interested in knowing how doing and I never bother."*

In sum, these participants had become more energy conscious in their everyday life, making the invisibility of energy more visible:

Summary of Theme	Example Quote
Increased comfort, more energy conscious	*Rita: "... it's made a lot of difference upstairs mostly because of the double glazing makes them a lot more comfortable rooms to live in... When the bedrooms are not used we do we do turn off the heating and shut the doors so we do not lose heat. So we are more conscious about how we use energy."*

10.5 Conversion Phase

The process of domestication can only be considered as successful when a technology firstly reaches a 'taken-for-granted' status and becomes a part of the user's everyday life, and secondly carries symbolic values to the outside world. Thus, during this phase the user displays their ownership and competence both materially and symbolically in a public culture.

The concept of conversion, and whether it had occurred, was a very complex dimension to analyse. Hence, an understanding of the conversion phase required consideration of the taken-for-granted aspects and 'communication to the outside world'. The analysis breaks down these two sub-themes further, considering whether or not participants share their knowledge and experiences with others (within and outside their social networks), and if so, the mediums they use; how they express any future plans; whether participants were comfortable with the technologies installed; and how the visibility and/or 'invisibility' of the technologies adopted were articulated.

10.5.1 Taken-for-granted status – future plans

One strand of understanding taken-for-granted status was considered through examination of whether user satisfaction and expectations had been met – an aspect that was also explored in the incorporation phase. However, here taken-for-granted status required consideration of participants' future plans too by determining whether in the minds of the users there were aspects of their home improvements that were either complete or incomplete, and whether they felt any sense of discontent with the situation. To this question, there was a varied range of responses.

For most participants, the evidence suggested that a sense of an end point in general home renovation activities and EE retrofits had been reached, thus implying HH not wanting or needing to do a lot more to their homes:

Summary of Theme	Example Quote
Sense of nothing more to do to home	*Lena: "I think we've done virtually everything we can do because all our kitchen appliances are energy efficient; we had all new Miel products those are very low energy appliances ... we have LED lighting everywhere."*
	Jim: "Well I think we have done as much as we can, may be too save energy."

Although, as expected, there were some exceptions where the EE components had reached an end point but further general home improvements and refurbishing would continue as an ongoing process of the project of making the 'house a home':

Summary of Theme	Example Quote
More left to do in home	*Anne: "Well, there aren't that many houses that have done these works ... even now the works aren't finished."*
Further planned changes	*Molly: "I think perhaps have my kitchen done I do want a new one and new flooring in the kitchen this is so ancient."*

New curtains	*Lena: "... new curtains for our bedroom which will cost an arm and a leg they will have thermal lining."*
Unfinished business	*Rita: "... because it's been a gradual process it still feels unfinished."*

The discussions of future plans could therefore be grouped into three categories of people: those that felt they could not think of anything more to do; those considering making some small minor additions; and those thinking of some additional EET adoption, which required a large financial investment. For example, one participant was considering having further wall insulation, one participant without solar energy was now considering that and another participant with STHW was now considering solar PV:

Summary of Theme	Example Quote
Considering further EET adoption	*Rita: "Yes, insulation whether it's external or internal, particularly the internal walls at the front of the house; it is a question of time and energy and money and those things coming together..."*
	Anne: "Well, we are considering solar PV with its plan to originally have it on the dormer window."

Most of the Eco group stated they were always on the look-out for further changes and seeking further novel technologies that were just emerging on the market, or had installed such devices, such as a 'hot kettle water tap', 'thermal conductor' or 'energy storage' devices designed to retain and re-use unused energy within the house – all had the aim of reducing energy costs further:

Summary of Theme	Example Quote
Acquisition of new technologies	*Lena: "We went looking for it... the kettle tap which is a bit expensive but you don't have to waste any gas heating up anything you can just put your pasta underneath and get your boiling water... it works from electricity with a highly insulated tank so it brings up the water to 99° so when you turn it on it due to that last one degree."*
Further technologies to enhance home EE	*Pete: "We do have plans, it's a thermal conductor it's equipment that is connected to the consumer unit it captures any non-used energy in the house... the conductor is about 700 pounds now and someone would have to have fitted in the system for my home would cost about £1,500 and I'm probably may be going to get it this year it can control the boilers and the pumps etc. Those pumps have to be constantly on ... it cuts to zero... I worked out for the year I worked out I would pay off after three years and after that I would start saving money I have calculated roughly*

	from our use I am only paying £20–£30 a month right now...”
Further technologies to enhance home EE	*Steve: “... I don’t know if you heard of Tesla ... a company in America that makes electric cars but what they have recently come out with is using the same technology for energy storage they come up with batteries for houses they seen a gap in the market... so there's no way I'm going to be feeding into the grid for more than another year I'm going to buy my battery so everything I generate that I don't use I'm going to put on my battery so I would get paid the same amount of make money regardless of how I used it...”*

10.5.2 Taken-for-granted status – visibility and invisibility

For the purpose of this analysis, another key indicator of successful achievement of a taken-for-granted status was the degree of visibility/invisibility or presence an EET manifests symbolically once installed – this holds implications for energy use reduction. Firstly, the EET adopted physically helped prevent heat loss from the building itself, and then lessened the need for participants to use energy to heat rooms in the building as it was generally a more comfortable environment. The evidence suggested that some participants were able to better micro-manage their energy use and proactively sought to use less energy post-EET retrofits (e.g. by actively monitoring and adjusting energy use).

Secondly, symbolically the Eco group had purposefully and comprehensively constructed a home that was highly energy efficient, so in their minds there appeared to be a symbolic visibility or presence retained as a result in their everyday psyche and/or conceptualisation of their home. For example, they referred to their house changes as 'eco' or 'green' and were able to state accurately the amount of carbon savings that had been made. There was also a desire to do more to save energy in the home, manifested through greater monitoring/feedback actions undertaken to keep energy use down. Most of these participants claimed that they monitored and gained feedback on their energy use via ICT software:

Summary of Theme	Example Quote
Online energy monitoring service use	*Lena: "... I joined something it's called 'I measure'... you put in your meter readings gas and electricity meter readings once a week when you set it up... so I watch it every week and see if it's gone up... More than anything else it makes you think about your energy use all the time... so I take the energy reading from here the gas is at the back of the house, this is the electricity meter, and that's the solar panel one, the solar panel one I have to do every three months, so I give our energy company our reading and a couple of months later they send a cheque* [FiT payment]*!"*

Inadvertently**,** the use of such monitoring tools not only provides the basis for gaining feedback on energy use but also acts as a form of exit point for the communications to the world outside of the home – the company that owns the ICT tool. The company potentially is part of an external feedback loop within the EE retrofitting supply chain, and customer information could help them develop an evidence base/benchmarks from energy results by house type, number of bedrooms and/or number of people and so on, which could also feed into policy.

10.5.3 Communications to the outside world

The theme of monitoring/feedback communications is connected to how personal meanings are attached to the technology and then communicated or 'conversed' to the outside world. In most cases the conversion of the experience of 'appropriation of meanings' could be was observed. Most technologies appeared to materially and symbolically satisfy the expectations and desires of their users. The key features of conversion in this research was taken to be indicated by:

- a desire to tell others about their experiences
- a desire to share knowledge, learning and competence with others ('learnt' best practice)
- a wish to display the home intervention by opening one's home to others (linked to various local public events)
- participating and attending local community events

10.5.4 Desire to tell others

The desire to tell others was a key feature running across all the participants' accounts. In the cases of Eco group, they had prior energy-related experiences through their occupations and connections to other participants motivated to adopt EET, there was a positive sense of discernment and self-identity being constructed through their desire to make their home an exemplary energy efficient eco home. In this endeavour, these participants had bought their building with the express purpose of being able to eco renovate it:

Summary of Theme	Example Quote
Creating an exemplary eco-home	*Dave: "the environment was a big reason for me and that's important and lowering our carbon footprint...* ***I also wanted it to be an example to show people how easy it could be to.****"*
Desire to create an energy-efficient home	*Pete: "... about 10 to 12 years ago but for about nine years nothing had been done...this was the line of the existing property* [shows where that was] *this was a tiny kitchen at the time I was here by myself and then rented one room* ***we decided we wanted to have an efficient a house as possible*** *and I'm in the eco-business."*
Home bought specifically to eco-renovate	*Neil: "Well I'm just interested and* ***I wanted to eco-renovate and cut the carbon emissions.*** *This house was in poor condition and that's why we bought it apart from that the house did still have nice Edwardian features of those are very nice tile floor and stain-glass panels in the window..."*

There is evidently accompanying this aim the desire to 'share' the acquired knowledge and competence with others. This is demonstrated in the participants' accounts of their ability to use and understand how their EET work; their conversations with friends and family; in some cases helping others to implement EET; and in their fulfilling the role of quasi-expert or lay expert by making recommendations and opinions about the technologies to others. Typically, participants' narratives show how things should be used and convey an advisory tone arising from their experiences over time:

Summary of Theme	Example Quote
Sharing knowledge of how EE adoption should happen	*Steve: "**Yes and that would be wasting your money, so you make sure you switch your boiler off.** You have to do this yourself. In the winter time, the boiler would come on for 20 minutes in the morning and for 20 minutes in the afternoon, because we wouldn't get enough sunshine to heat the hot water, however, even if there was a sunny day in December I would switch the boiler off because I know I could generate hot water... so in our house we wouldn't have the heating on for at least half a year."*
Advice about which measures to adopt	*Dawn: "... **start by doing what you can afford little by little what your thermostat use turn it down** and you can and find the window that is the worst window in your house save up and put in good quality*

	double glazing make sure your loft is insulated and these are relatively inexpensive options...”
Sharing knowledge and experience about EE measures installation	*Steve: “What we have on the walls is something called Sempax... what they call the miracle wallpaper... on the internal face of all the external walls... basically you glue that to the wall with a paintbrush... it comes in a 12 1/2 m square roll...* ***well if you can put up wallpaper you can do this yourself.*** *It's actually easier than putting up wallpaper. Wallpaper you have to line it up. I know people who have done this; I've done it in my mum’s house. I have a full-time job otherwise I do it for other people.”*
A learning process	*Dawn: “Yes a little bit.* ***Actually it's a learning process for both sides****. It also requires skilful builders and works well with a reasonably small team. With bigger companies you will get someone and they will give you someone else on the side... whereas you need to educate everyone on the site including the plumber, the electrician, the builders, etc. It needs good teamwork, it requires the builders to do something different from what they are used.”*

Most participants discuss their EET with others, typically friends and neighbours; however, on occasions others may also show a lack of interest, demonstrating that not everyone is sold on the idea of EET adoption:

Summary of Theme	Example Quote
Lack of interest from others	*Steve: "... after we had our PV, I remember having a conversation with the lady next door and I was telling her how many kilowatt hours I was generating at which point she said I have something on in the kitchen meaning she went inside and never came out again* [laughs] *it's saying it's a conversation I don't want to hear..."*

Four participants of the Eco group were increasingly involved in opening their homes to the public to demonstrate what they had done and to tell others about their experiences (as noted by Berry et al, 2014). This was either as part of local 'Open Homes' or 'Superhomes' events, and/or some other local initiative to promote and emphasise specifically EE adoption for older heritage buildings. There was a mix of explanations for doing this; however, there was an overall sense of trying to persuade others and feelings of a sense of duty to do this:

Summary of Theme	Example Quote
Allows people to find	*Dawn: "... **pleasure in seeing that people can change things** some people are so stubborn not willing to change things but*

solutions and differing options	*then they see this and they can see the difference or that there are alternatives. I'm showing that I have a 1930s ex-council house and it is possible to do things without having to spend a fortune."*
Encourage change	*Pete: "... **to encourage people to change**..."*
A desire to highlight best practice	*Lena: "Fine, **it's nice trying to turn people on to this idea** if you were in a lucky position like we were to do it all in one go and I know most people are not in that position..."*
Felt duty to impart knowledge	*Anne: "Well, there aren't that many houses that have done these works and **we felt obliged**... even now the works aren't finished."* *Interviewer: "What do you get out of doing this?"* *Anne: "Well I'm rather amazed that people don't do more of this I mean they are saving money as well is helping the environment is a no-brainer."*

These participants had, prior to opening their home, visited others who had opened their home. This also connected with the wider social networks these individuals were already engaged with. These networks provided a source of information, allowed the sharing of knowledge and experiences, problem solving and other forms of communications. Closer examination of such practices suggested high levels of social capital and consumption of 'green' media.

10.5.5 Taking part in research

Observations of the entire group of HH participants suggested that they could not only be defined as adopters but also converters. For example, a desire to tell others is notably reflected in all the participants' willingness to voluntarily take part in the interviews for this research. Their lively engagement in the research process provides a basis for self-reflection by setting out a time to think and discuss their experiences with someone from outside their home. Part of this process involved showing the researcher what they had done around their home, further reinforcing components of 'display'. Symbolically, participation in the research connected quite well with their sense of duty to share their knowledge and experiences with others – and in the process help diffuse this knowledge into the wider public domain. This reinforced the sense that it was not enough that they alone had undertaken environmental action: their actions would be more meaningful and effective if others understood and did the same:

Summary of Theme	Example Quote
Awareness that others need to do the same	*Dave: "I think I'm an early adopter; I don't think we need any more lead adopters because there's enough of us; what you actually need is the mainstream to pick up."*
Knowledge sharing	*Dawn: "For me just satisfaction share the knowledge which I'm happy to do; I will try and make it top notch and attractive cause*

	people will only and want to do this if it looks nice and I want to use my home to do this."
Feeling obliged to share knowledge	*Anne: "Well, there aren't that many houses that have done these works and we felt obliged... I'm rather amazed that people don't do more of this; I mean they are saving money as well as helping the environment it's a no-brainer..."*
Educate school children	*Dawn: "I want to do a lot of work with kids at my child's school and I hope that somehow we can fit it into the curriculum... I am part of the parents group; I want to work with kids because they need to know about these things and not to waste a lot of water, collect litter off the street and so then they won't throw it themselves and just to get them aware."*

10.6 Chapter Summary – The 'Whole-House' Domestication Process

The domestication framework was applied in two different ways, and offers two different perspectives: this chapter applied the domestication lens through a whole-house HH level perspective, and in the next chapter analysis will be based on a perspective that focuses on individual technologies. Although the application of this framework broadly covers similar themes, there were some key differences in the findings that could be observed and which contributed to a broader and holistic understanding of the domestication process.

10.6.1 House level domestication process

Appropriation mostly begins with a pre-purchase desire or goal to make the fabric of the entire house warmer, more comfortable and as energy efficient as is structurally and financially feasible. There was recognition by participants that no one single intervention would provide EE at the whole-house level, and therefore a suite of measures were selected and adopted. This was almost always executed alongside planned major home renovation activities and seldom implemented in isolation (with the exception of solar energy adoption). Furthermore, the selection of the suite of interventions was often influenced by the existing physical legacy or conditions of the house, and a desire to both preserve its heritage and modernise it at the same time.

Objectification in terms of location and display could only be made manifest once the suite of measures were installed and integrated, in effect changing the technical system of the house (regardless of whether that occurred incrementally or in one go through a whole-house strategy). Furthermore, participants were willing to proactively accommodate EET despite their potential constraints, such as a loss of floor-space, visual intrusion, disruption, loss of amenity and certain repair and maintenance requirements.

The incorporation of EET into the everyday lives of HH appears easily achieved, e.g. overall they require very low levels of user hands-on interaction with the device on a daily basis. The users can often quickly ascribe meanings to the use of EET and most appear willing to make adjustments to their daily routines in order to utilise the benefits from their adopted technologies. There was evidence of some new, modified and continued practices in the temporal patterns of HH life.

Finally, conversion is only reached through a desire for HH to proactively share their experiential knowledge with others outside the home; and there was a sense that the adoption and use of multiple EET was increasingly taken for granted through the ease with which HH appeared to have incorporated them into their lives. In most cases, technologies appeared to materially and symbolically satisfy the expectations and desires of users.

The multidimensional perspective offered by examining the processes of change at the whole-house level suggests that domestication unfolds overtime (sometimes days, weeks or months); and is composed of a series of processes within a wider process. The evidence also seems to support the idea that domestication is an ongoing and cyclical process: reaching each phase is not stepped or staged; there are many overlaps. It is a process that unfolds overtime (sometimes days, weeks, months and years) but it is often difficult to pinpoint in time when each stage has occurred or not.

10.6.2 Comparative differences in HH experiences

In relation to the HH interactions with EET, some very distinct observations could be made about participants. Chapter 9 identified two distinct groups – an Eco group and EE group – yet both were considered to be adopters and converters in their own way. These two groups suggest some qualitative differences in the way they participated in the house level domestication process. These are summarised here.

Pre-adoption, there was a notable symbolic difference in the efforts and desired outcomes from the reconfiguration of the house. The Eco group conceptualised their aim for EET adoption and home changes as one that would lead to an eco-house and an extension of their pursuit of a greener lifestyle. There was a desire to make their homes exemplary eco-homes, and they had bought their building with the express purpose of being able to do this. For the EE group the motivation was much more about a desire for greater energy efficiency, money savings and improved comfort. The Eco group expressed higher levels of environmental concerns, which seemed to underpin their motivations to adopt EET, whilst this aspect was less explicit in the EE group's stated motivations. A further difference could be observed in terms of the confidence expressed in delivering change, which related to their socio-demographic and interpersonal networks. In terms of access to and information gathering, the Eco group seemed to engage more with energy experts draw on their own professional background and manage the execution of the whole-house project by themselves.

In post-adoption, the Eco group stated that they had actively decreased their energy use and had seen a 'substantial' and quantifiable reduction in their energy bills. In contrast, the EE group stated that they had certainly become more energy conscious, yet continued their pre-existing levels of energy use and stated that their bills had reduced to some degree, although they stated they were unsure by how much. Furthermore, notably the Eco group stated adoption had led to increased energy consumption monitoring activities in everyday life. They stated that they were increasingly vigilant about their energy consumption and reduction, and had been monitoring this prior to and post-EET adoption.

Whilst most of the HH participants seemed to have reached conversion in the process of domesticating technologies, and could all be described as converters judging by their desire to display and convert others, again some differences could be observed in this aspect. The Eco group seemed more pro-active and took a step further than the EE group. More of them were on the lookout for further novel technologies that were just emerging on the market, and all had the aim of reducing energy costs further. They were increasingly involved in opening their homes to the public to demonstrate their purposefully created eco-home and tell others about their experiences. There was an overall sense of trying to persuade others and feelings of a sense of duty to do this. These participants had, prior to opening their home, visited others who had opened their home. This also connected with the wider social networks that these individuals stated they had and were already engaged with. These networks provided a source of information, allowed the sharing of knowledge and experiences, problem solving and other forms of communications.

Finally, these are some of the qualitative differences observed in the symbolic meanings these two groups attached to the technology domestication process in their homes. The qualitative nature and small size of the sample meant that no clear measurable difference could be established, apart from those inferred from what participants expressed (these are set out in Chapter 9). This analysis nonetheless was able to identify some subtle differences in the domestication process between HH in what appeared on the surface to be a relatively homogenous group of adoptees. The next chapter will provide a technology-focused analysis using the domestication lens.

Chapter 11 Findings on the Domestication of Individual EET

11.1 Introduction

As part of providing a dual perspective, and following on from the whole house perspective in Chapter 10, this chapter presents empirical findings derived using the domestication concept as an analytical framework and solely focused upon the domestication process of specific individual EET. This chapter is divided into three key sections:

- Section A – will present detailed findings using the D lens to outline the domestication processes for specific individual EET;
- Section B - summarise the differing attributes of the technology specific domestication process; and
- Section C - present visual models of the varying domestication processes of each EET and their specific policy implications.

11.2 Section A - Domestication processes for specific individual EET

11.2.1 Introduction

In this section, specific individual EET were chosen for further in-depth analysis, either increasingly popular technologies – solar PV (SPV), solar thermal hot water systems (STHWs) – or less common yet emerging technologies, such as external wall insulation (EWI); internal wall insulation (IWI); biomass burners (BB); air source seat pumps (ASHPs); and mechanical heat recovery ventilation systems (MHRVs). Importantly, these technologies were selected for further analysis because they are the ones advocated by policymakers and deemed the most advanced in design and effective in delivering the desired policy goals of reducing carbon and energy consumption in homes. Moreover, policy advocated the adoption of a package of EE measures as no single measure alone could increase the EE of existing homes (discussed in Chapter 2, section 2.8).

The existing evidence also suggested that this policy advocating a package of EE measures appears too blunt and fails to take account of the fact that each EET is qualitatively different with differing characteristics (also discussed in Chapter 2, section 2.8) and with potentially differing HH user experiences. Therefore a technology focused analysis could hold implications for greater understanding of the complex problem of low technology adoption rates and why some technologies are more or less successful than others, and their potential environmental outcomes.

A further dimension to undertaking this technology focused analysis is to illustrate that technology adoption by the HH is a complex sociotechnical process and not a single event. This sits against a backdrop of rationalistic policy assumes that adoption alone (e.g. installation) is sufficient and does not take account of the fact that each technology has a unique characteristics; and need to be used appropriately before their intended environmental credentials can materialise. Use of the domestication lens enables specific analysis of the journey of differing technologies into the home and their sociotechnical relations – such as how people attach new meanings and function to technologies and how the technologies may gain new characteristics. This analysis places specific emphasis on examining how the arrival of specific new technologies were experienced in the context of the home. This connects to understanding the notion of the 'biography of things' in the domestication process of technologies.

Table 17 sets out which measures were examined and how many of each were adopted across the 23 HH. The domestication process of each technology type is examined separately in turn: ASHP; BB; solar technologies – SPV and STHW; MVHR; and wall insulation – EWI and IWI. As discussed in Chapter 9, the most popular EET were the solar technologies and the least common were ASHP. In analysing each technology, it draws on data from those HH that had implemented that specific EET. For example, 3 ASHP's were adopted by HH in the sample; therefore the domestication analysis of that technology will only draw on data from those HH. Therefore, the in-depth analysis of each of the listed technologies shown in Table 18 will selectively draw on data only from the number of HH that had adopted that measure. It does not draw on the whole data set as it did for the analysis in Chapter 10. Only in order to understand reasons behind technology rejection themes, does it on occasion draw on the wider sample to gather understandings how other HH may have discussed some aspects of a specific technology.

Table 17: EET Adopted by Participants.

Measures	Number of technologies adopted:
1. Air Source Heat Pump (ASHP)	3
2. Biomass Burner (BB)	13
Solar Technologies	
3. Solar PV (SPV)	12
4. Solar thermal hot water (STHW)	9
5. Mechanical Heat Recovery Ventilation (MHRV)	8
Wall Insulation	
6. External wall insulation (EWI)	10
7. Internal wall insulation (IWI)	8

Therefore, Section A presents findings from questions about how EET were introduced into homes; what the processes of technological domestication looks like; why certain technologies were chosen over others; and how technologies were used and incorporated into everyday routines (see Interview Topic Guide, Appendix 1). This part of the empirical analysis again uses the four phases of DT as an analytical framework to structure the data analysis. It examines each of the selected EET individually, drawing on data from those individuals who had adopted the EET in question. It uses illustrative quotes in tables to exemplify key points or issues raised, as well as a summary of the key themes raised. It particularly focuses on specific responses to questions, which help reinforce and illuminate each of the four phases of domestication.

11.3 Air Source Heat Pump Domestication Process

11.3.1 Background

An air source heat pump (ASHP) is a micro-generation technology that is increasingly heralded for its eco benefits (once installed the renewable electricity is considered to be carbon neutral) and widely promoted in government policy through the Green Deal, RHI and other measures. Thus, government incentives were often available to reduce the cost for air and ground source heat pump. In addition, unlike gas boilers, heat pumps do not require annual maintenance and servicing costs (Energy Saving Trust, 2008; Burton, 2012; Greener Times Guide, 2014).

Only two HH had installed a total of three ASHPs between them in this study. One participant had two pumps (one located indoors and one in an outside shed), with one being used for underfloor heating and the other for hot water generation; the second participant used it for underfloor heating only.

11.3.2 Appropriation

In the two cases where ASHPs were installed, the participants did so as part of a package of measures that were designed to complement each other and contribute to a whole-house EE strategy (described in Chapter 9). For one female participant with two pumps, the ASHPs were put in with a very specific function – to generate hot water only – something which her solar panels could not do, as they were only installed for electricity generation purposes. The second ASHP was specifically put in for underfloor heating only on the ground floor of her single-storey detached bungalow.

Both participants primarily found out about this technology by word of mouth recommendations from builders they had employed for other works. In both cases, the participants had visited someone else's house that had installed and was using ASHP – which proved to be a strong motivating force for adopting the technology:

Recommendation of builder	*Lena: "I think that was from talking to one of our builders or the plumber because I wanted more energy efficiency and he recommended this and we went out to see his house in north London* [put in 2011] *and we put another one of these in the outside shed to do the underfloor heating for the whole house."*
Installed for specific function	*Billy: "... we had 16 panels and purely for electricity generation and this is what we've put it in for hot water generation – an air source heat pump."*

Both participants demonstrated a good working knowledge of the technology. They had previously heard about it through the media and then researched what the technology was supposed to do on the Internet; they also took into account what their installer had told them:

Knowledge of the workings of EET adopted	*Billy: "It's like a fridge but backwards or like an air-conditioner backwards... the way they work is they have a liquid; if you ever look on the back of the fridge you can see these radiator-like things that's carrying liquid it's not a very nice liquid its chemicals... they absorb and release heat during those cycles when you pump it round... so for an air source heat pump it literally takes air and compresses it heats it up and compresses it and then you've got hot water that you can then pump around..."*

Both participants claimed that they had been persuaded by visiting another home and seeing the technology in situ, and were strongly mobilised by the government's FiT and RHI payments. In one case, the participant installed the ASHP alongside solar renewables, and then applied for both FiT and RHI in order to supplement a retirement income.

11.3.4 Objectification

The pumps required a significant amount of space allocation, whether in the home or outside – approximately one square metre of floor space. Thus, they had a notable presence when located in the home; in both cases, the participants had situated the appliance in an enclosed space - a utility room. One participant with two ASHPs located the second pump in a specially built outdoor shed space.

In one case, the adoption of ASHP resulted in the removal of all the radiators in the home – a direct consequence of the underfloor heating provided by the ASHP. This meant that the user could now reconfigure the internal ground floor open-plan space freely, where previously the room layout and where furniture could be placed had been restricted, limiting where the participant's family could sit or eat, etc. Hence, the ASHP (as a form of underfloor heating system) enhanced the living room and enabled it to be reconfigured flexibly in any way the user wanted:

Enhanced room configuration following EET adoption	*Lena: "Yes it is for the entire house, while because radiators are a pain... but we took them out ... they get in the way when it comes to furniture and so on, and the floor heating seemed so much more sensible and we can arrange the rooms how we want..."*

11.3.5 Incorporation

One participant had to address a minor error with the technology in the initial early days after its installation although the installer easily and immediately rectified this. In both cases, participants very rarely used the instruction manuals provided with the machine, but mostly referred to the verbal instructions and advice on how to use the product provided by their respective installers.

The participant with two pumps had installed each one to serve very specific functions: one to produce hot water and the second to provide room heating via the underfloor heating system in the living room areas. This had meant being aware of how the system worked and adapting daily activities and routines around it, which was similar to the way they were already using solar energy in their HH. The participant acknowledged that whilst the system was complex to use, she and her husband were still learning how to use and manage the ASHP system more effectively. The participant's response demonstrates that trial and error was to be expected of any new technologies:

Trial and error allowed learning of EET use	*Lena: "It's nice and warm on the floor ... yes; we still find it complicated to work out everything."* *Interviewer: "So what's involved in the use of it?"* *Lena: "Absolutely nothing if not at the time because it works automatically when you've used a lot of hot water it automatically kicks in..."* *Interviewer: "So, on a day-to-day basis you don't need to operate it?"* *Lena: "No it just gives you hot water all the time..."* *Interviewer: "So you have to manage it a little bit?"* *Lena: "Yes, as you do with any system, I mean unless you have one of those instants..."*

The everyday use of such technologies also required an understanding of their workings and how far they could be pushed: for example, to provide enough water for the daily routines of showering and any extra demands placed on the system due to additional pressures from visiting guests. An understanding the rhythms of the system itself and then adapting routines around that was also important:

Adapting routines	*Lena: "... once we had my cousin and her husband staying and the two of us and I think we all had showers one after another."* *Interviewer: "And how did that work out?"* *Lena: "Towards the end after four adults having a shower it was running out of hot water, yet easy to tell very quickly."* *Interviewer: "What happens when you run out?"* *Lena: "Well then you leave it for an hour and it heats up again."*

For both HH, a working knowledge and effective use of the system was acquired largely by trial and error, which involved varying use on demand regularly, seasonally, and bi-annually:

Trial and error and experimentation	*Interviewer: "So in the winter how long would you have your underfloor heating on?"*

	Lena: "Well we've had to experiment over the last three years that we've had this... and now we've got it. I used to have it at a different temperature during the day on the thermostat that didn't work at all because it takes much longer with underfloor heating to get up and down; it can take over an hour to heat up so basically now we have it on the same heat the whole time well at night it goes down a bit most of the day; we have it on and of course we are around during the day so that's been the most difficult thing to learn to live with and learn to use efficiently and that's because we never had underfloor heating before and so we had to get used to the system and used to how it works... the trick is not to fiddle around too much with its temperature. I turn it down in the night because you don't want it on when sleeping..."

One participant also ended up removing the more conventional room heating radiators as they were no longer required; at the same time she installed a biomass stove to complement the underfloor heating system:

Making way for a new system	*Lena: "Yes, it's nice having that warmth ... in the daytime when you're moving around you don't need it* [wood stove] *you just need that 18 to 19° and that's fine but then in the evening if you want*

and routines	*to watch TV or do ... and it's so quick that we just use that too..."*

11.3.7 Conversion

Both participants stated that they have told others about the virtues of installing ASHP:

Telling others of benefits	*Lena: "... we tell people about the air source heat pumps that you need thousands of pounds and to change other systems but we also tell people about the cheap things like the kettle tap which is a bit expensive but you don't have to waste any gas heating up anything you can just put your pasta underneath and get your boiling water..."*

In order to understand reasons behind technology rejection themes, here it draws on the wider sample for examples. For example, one participant explained that his decision to reject the adoption of ASHP's involved a weighing up of the costs and benefits of the differing heat pumps and heating options for his home. He rejected adopting ASHP's on the basis firstly, that it was a very expensive measure, with '*poor payback*', and which at the time had no government incentive to induce him either; and secondly, the pumps appeared to offer poor performance with very low levels of heat when compared with the existing conventional radiators already in place. E.g.:

Perceived poor performance informed decision to reject technology	*Dan: "... the underfloor heating system only gets to about 40 to 50°... if I was using a radiator it would get closer to 70°... you don't have much space so you need to have a lot of heat coming out... but air source heat pumps can only go to about 50° so you need much more space to transfer the heat you can have whole walls as big as that radiator and that would work to 50° and all of that emitting heat..."*

Comments made by another participant (from the wider sample) who had also seriously considered installing ASHP but in the end opted for solar panels comments seemed to summarise the problem. E.g.:

Public perceptions of technology	*Neil: "I think that's the one* [solar panels] *that caught people's imaginations working; the others need quite a lot of investment such as the heat pumps* [e.g. ASHP] *and you have to have do it absolutely right otherwise they don't work properly..."*

11.4 Biomass Burner Domestication Process

11.4.1 Background

BB (sometimes referred to as wood/organic material burning stoves) were increasingly perceived as a viable and sustainable energy option as they were regarded as being carbon neutral. BBs offered several options: they could be used as standalone stoves to heat a single room; they could be fitted with a back boiler to provide hot water, be used to fuel a main boiler connected to a property's central heating and/or hot water systems (Burton, 2012; Greener Times Guide, 2014).

Thirteen HH participants had installed a BB, and of those 12 had done so as part of a whole-house strategy. In all cases except one, participants lived in older pre-1900 houses, with solid walls, which had previously had open fireplaces and chimney breasts. These were now disused and/or being closed up and/or located in rooms without any sources of heating. Thus, BBs were seen as a replacement for an old fireplace, often to add heating to a new room and in all cases to provide a new focal point for the rooms in question. The BBs represented were of numerous types, including those that used wood logs, wood pellets and wood chips, and of varying manufacturing designs and models (the interview process did not specifically ask for the names nor interrogate and verify numbers in each model type). As a reflection of the various designs and forms BB's are available in, participants also used differing labels to refer to them, i.e. a '*wood burner*', '*wood burning stove*' or '*wood stove*'

11.4.2 Appropriation

Most participants stated that they had installed the BB primarily for entwined environmental and cultural reasons: it was seen to be a more 'environmentally sustainable' source of energy and an alternative to the more unsustainable gas and coal sources. One participant used salvaged wood off the street (which would '*otherwise end up in landfill*') and/or recycled from trees from his own or his friends' gardens as this was cheaper than buying the logs; he had bought machinery to help him cut the wood down to size before burning:

Recycling unwanted wood	*Dean: "It's anything, any wood we find we never bought any... as you can see over there those whole bits of wood in it...* [piles of pieces of wood of various shapes which have been salvaged]... *and those are my neighbour's old roof batons so there's my machine to cut it with and there's a wood shed behind you and that is full with old wood ..."*

The desired sustainable lifestyle is complemented by its ability to provide a sense of self-sufficiency and energy security for one participant:

Sustainability and self-sufficiency	*Steve: "... the wood burner heats up the house; it saves heating basically; it ... heats up the whole house ... and the wood burner is good for space heating and you're burning wood not gas; I like to be self-sufficient it is quite nice and to not be reliant on gas; I love there to be a power cut here today so I could be nice and warm..."*

In terms of its cultural resonance, a BB is also perceived as an expensive luxury and novelty object of consumption – one signifying a 'rustic' lifestyle quality:

As an object of desire and sustainability	*Dean: "Firstly, because it was something we really wanted... it's also quite environmentally sustainable ... and they're quite a novelty at the time. We liked the idea of having fires..."*
Part of lifestyle	*Interviewer: "Why did you have the wood stove?"* *Steve: "Why would you not want one... you know it's the best thing in the house and it's a whole lifestyle of getting your own wood and cutting it and making your own fire... I have my own axe – I'll show you those later ... this is all zero carbon wood recycled it's not coming from Brazil and you've got all the pleasure of lighting a fire..."*

In many cases, it was used as a secondary or supplementary heating source, which helped keep other fuel costs down and save money. For example, the use of the system required only heating one room rather than the entire house through central heating:

As an object of desire and	*Dean: "Firstly because it was something we really wanted... it's also quite environmentally sustainable ... and they're quite a novelty at the time. We liked the idea of having fires and it also meant when*

sustainability	*it was just us that was the only room we needed to heat."*

More explicitly, a specific masculine gender identity appeared to be expressed by two male participants through the pleasure they gained from cutting wood to size through using an axe or machinery:

Wood cutting as a lifestyle feature	*Steve: "... it's a whole lifestyle of getting your own wood and cutting it and making your own fire... I have my own axe – I'll show you those later ...the children will be interested in my axe collection... this is all the zero carbon wood recycled it's not coming from Brazil and you've got all the pleasure of lighting a fire..."*

For most participants, the benefits outweigh any negatives that could be associated with the BB, i.e. the 'messiness' of cleaning out the ashes. The main virtues were related to its perceived efficiency, greenness, ease and convenience of use and maintenance:

Ease of use	*Lena: "... this thing – the wood stove – is fantastic. You can forget about Boy Scouts and Girl Scouts lighting a campfire. This is so easy; it's a highly efficient wood burner – West Fire – not a Scandinavian name. It is incredibly*

	easy to light and incredibly easy to clean... we have some beeswax lighters not chemicals so they're clean green you light that and within five minutes it's transformed the place."
Ease of use and no mess	*Anne: "... everything is burnt so you hardly get any ash we would clean the ash pan every fortnight."*

11.4.3 Objectification

All of the BB appliances had come from many differing manufacturing companies with differing specs and differing costs. It was conveyed that this was an expensive item signifying luxury, and its presence displayed exclusivity in the participants' minds and their homes. This was an expense that they were nevertheless willing to pay as the benefits it offered significantly outweighed its high monetary costs, including the ongoing costs:

Expensive acquisition	*Anne: "... this is one of the smallest ones they do but one of the most expensive that is pretty hot ... it took about a day to install."*

The BB created a strong sense of identity, rituals surrounding their use and contributed to ideas of constructing a home and symbolic aspects of homeliness, epitomised in the following:

Symbolic aspects of the meaning of home	*Steve: "A wood burner is something like once you've got one why would you not have one, and if you've got a house that can accommodate it why would you not want one. The wood burner is the most important thing in the house – and that's after my wife!* [laughs] *the wood burner is even on the days when it's not that cold is very tempting just to light the wood burner a day late this in the evening time..."*

In nearly all cases, the BB was located in the main living space, although in two cases it was located in a kitchen/diner area and in one an attic/loft conversion room. It appeared to take centre stage and was perceived as a focal point in the given room.

In all cases, participants had either one or at the most two BBs in their house. In most cases, they were either using the BB to heat either single rooms or the whole house. Thus, the BB served as a stand-alone supplementary heating system to heat specific single rooms that were considered too cold, and/or where the existing heating system was either ineffective or unavailable:

To warm a small	*Micky: "... because we do not use that room enough, one reason is because it is a little bit cool...we put a small stove in*

less used room	*there so you can sit in that room and read."*

11.4.4 Incorporation

In many cases the BB was also inadvertently being used to heat the entire house despite being installed for one specific room, e.g. typically the ground floor living room. It also served as the first port of call for occupants when feeling chilly in a room and where additional layers of clothing could not eradicate their '*feeling cold*'. Moreover, it was particularly used outside of the winter months when it was considered too early to resort to using the central heating system – although in the winter both sources of heating would be sometimes used intermittently alongside each other. Thus, the BB appeared to play a complementary role to the existing heating system, increasingly acquiring the status of primary heating system for at least three of its users:

Increasingly used to heat whole house	*Steve: "... the wood burner heats up the house it saves heating; basically it ... heats up the whole house this well there's a fan on top of it which pushes the air and the air flows round the house we leave the doors open and some rooms are warmer than others and the wood burner is good for space heating and you're burning wood not gas..."*

Increasingly used to heat whole house	*Anne: "... and then we light this and open all the doors and it heats the whole house this house is good because it doesn't have a back extension; a lot of these Edwardian houses have a long back extension of this is more central so around the stairwells the heat goes straight up and heats up the whole house... we also have underfloor insulation."*

Participants were aware that in many instances it was cheaper for them to use the BB than their central heating system. In one account, a participant describes how the co-existence and co-use of two sources of heating can also create incompatibilities – of being too hot and wasting energy – leading to having to switch one of them off, and not using the conventional central heating as much:

Co-existence and co-use of systems	*Anne: "... we had the new boiler installed which is weather controlled... by itself it's not a problem. The problem is that it wasn't designed for as well insulated house nor stove, so when it's cold outside it heats the house too much and actually if it's getting warmer outside it cools the house too much; and with this stove on, it takes no notice of that so you could completely boil alive, so we have to turn the central heating off and then we light this and open all the doors and it heats the whole house..."*

In one case, the BB was ineffective in making the room warm enough; underfloor insulation was added in response, but only to that room:

Insulation added to make BB impact more effective	*Kate: "We put a wood burning stove in there but that didn't make any difference so on the advice of a neighbour I got a builder to go under the crawlspace under the rooms to put up insulation onto the floor boards* [ground floor]*."*

The participants demonstrated a good working knowledge of the technology and had over time learnt how to use the system through trial and error and from the basic verbal instructions, their installer had given them – although very few consulted the manufacturer's instruction manuals. People had learnt how to manage their use of the BB alongside the other systems in their home. In some cases, participants had developed innovative uses, for example adding new features or adapting the way they used the BB system and their homes.

One participant learnt how to burn the BB so efficiently that it had the unintended consequence of making the room too hot, therefore requiring all the room doors to be opened to enable the heat to redistribute throughout the rest of the house. Another participant later added a fan to improve the performance of the BB, and yet another learnt that a specific product could be used to make the heat last longer even when the BB was off at night:

Innovative use	*Anne: "... the people who manufactured it created this thing called a secondary burn so when you burn logs it gives off fumes and then those fumes are burnt is supposed to be much*

	more efficient... in the winter we burn it about teatime and the manufacturers say you should burn it quite hot in order to maximise your burning, but if you burn it will be too hot for a room that you in this room we will open all the doors and also the central heating doesn't do very well to having another heating source..."

Participants over time and through regular use learn and adapt their skills around burning and lighting a fire in the BB, such as knowing that the '*wood must be dry*', '*getting it hot quickly*':

Learnt to use correctly over time	*Anne: "Well, we learnt that the wood needed to be dry. And you need to get it hot really quickly and then you can burn almost anything on it you just turn the control and the flames come up and down. The instructions say to burn it cleanly you must burn it pretty hot we leave the doors open and the heat goes up and heats the whole house..."*

One participant as a precautionary measure had innovatively designed a fireplace tile that disguised the presence of a ventilation hole in order to allow the free flow of oxygen throughout the house, which she perceived to be undermined by the highly insulated nature of her home:

Innovative adaptation	*Anne: "We also have underfloor insulation; one strange thing is when we installed this we were told that we might have a problem if you have a well-insulated house and the stove and you will be competing for oxygen so we had this elaborate scheme...* [picks up tile that had been inlaid near burner] *I made these tiles in an evening class there is a hole going down here under the insulation to the freezing cold draught underneath and into the air vent..."*

Many participants liked to use the BB instead of switching on their central heating thermostat as it was considered easier to use and the warmth could be delivered more directly to the person or room quickly:

Ease of use	*Lena: "... however, if you're sitting and watching TV it can feel not quite warm enough, and yes you can put on extra socks or a jumper or sweater but we've got this thing* [the wood burner] *and it's so quick that we just use that... and in the winter we use the wood stove more..."*

The key outcome has been being able to use rooms in the house that would otherwise not be used as much, or using central heating less to heat specific rooms:

11.4.6 Conversion

The evidence suggested that the technology served its intended purpose readily by providing an effective sustainable source of heating which could also signify a particular aesthetic and lifestyle feature for most participants. It also acquired a taken-for-granted status quickly, and therefore became a technology that could be easily conversed about with others. Nearly all participants were very keen to talk about this EET in expanded detail, and the sense of pleasure derived from its use was self-evident in their expressions. There was an overwhelming sense that the BB not only provided a physical focal and talking point in the house, but also symbolically took pride of place and contributed to a feeling of homeliness and pleasure which other forms of heating or EET could not provide.

11.5 Solar Energy – (SPV and STHW)

11.5.1 Introduction

The key distinction between SPV and STHW is that the former utilises the sun's energy for electricity only, whilst the latter generates it for heating hot water only. SPV generates energy from sunlight via photovoltaic cells, which then generate electricity (even on a cloudy day) that can be used to run HH appliances and lighting. STHW uses free heat from the sun to warm domestic hot water via collectors fitted to the roof; the water is stored in a hot water cylinder (Burton, 2012; Greener Times Guide, 2014).

These two products were the most popular renewable energy technologies adopted. They were installed after 2009 and coincided with the availability of government policy incentives (with one exception where STHW was installed in 2006). Twelve participants had installed SPV and nine had STHW, or solar thermal systems. Of the 12 participants that had installed SPV, nine had also adopted STHW and implemented a whole-house EE strategy for their home. Both types of solar technologies will be examined together in this analysis, as there were many overlapping issues and themes.

11.5.2 Appropriation

The first prompts for pursuing solar energy appeared to come from a variety of information sources: doorstep cold calling; publicity flyers; news broadcasts either on radio, TV or the Internet; prior employment experiences; whilst seeking ideas about renovating a kitchen and so forth:

Unplanned uptake	*Jenny: "I think we went to Grand Designs show at Excel and we actually were thinking about redesigning the kitchen. While we were there we walked around and found a couple of stands with solar panels ... we told him we were thinking about them and he kept in touch with us. I think he probably got money from anyone he recommended to the providers and he encouraged us."*

By the time, participants had bought and then installed solar energy they had further accumulated quite complex information about which solar products to purchase and their effectiveness, and how it would work for their HH:

Complex knowledge of the technology	*Pete: "Well, cost and something that lasts. I understand stuff about buildings materials I can work out the efficiency of certain types of glass... I went for a product called Velux is a glass fitted solar product the advantage of glass over Tube is that it has a flat surface we have two panels and is calculated on the basis of the house size and the number of people... Glass has a type of crystals that is used on top of it which is more rigid if somebody threw a brick then the tubes will crack but the glass won't break so I looked at how long this thing is going to last what is the warranty on the glass how much is going*

	to cost... compared prices with other products..."

In the case of three retired participants, they had acquired prior experience with solar panels as they had already installed them in a second home in the UK that they owned. For most participants the main reasons for installing solar energy had been triggered by the availability of government incentives such as the Feed-in-Tariff (FiT) and/or Renewable Heat Incentives (RHI), which had become available since 2009. Thus, a number of deadlines relating to the FiT/RHI payments had driven many to affirm their decision to install solar PV systems:

Policy incentivises uptake	*Dean: "I think about 2010. It's something that we'd already been aware of; there was also a very good solar panel incentive related to the Feed-in-Tariff I think it was set up in 2009 and the Conservatives put a very short deadline on it so are we actually rushed it forward... At that time purely because of the incentive and the payback on the units of electricity generated was so good."*

The initial government incentives deadline was supplemented by other interrelated reasons which were about minimising financial costs and reducing fuel bills, wanting a supplementary income, generating one's own electricity and being self-sufficient and reducing dependency on energy companies to supply energy.

However, the personal financial benefits were accompanied by a strong sense of wanting to help the wider environment and to cut carbon emissions:

Driven by environmental concerns	*Patrick: "Well, the reason why we did it was to cut our carbon emissions ... you'll be amazed how many people ask how much do you save in terms of money but our main reason was to reduce carbon emissions – that was the main reason; that was our primary reason."*

As a pre-requisite for gaining grants for installing solar energy, in all cases except one participants were required to undertake adequate building 'fabric first' insulating measures – an obligation that was executed for government through the various companies administering the grants and installing solar energy:

Mandatory to insulate home prior to renewable technology adoption	*Patrick: "Yes to get the grant for the solar panels you got to do energy-saving light bulbs which we already had, our radiators had to have an individual control which we had to put in; we were required to have a certain amount of insulation in the loft, I went up and measured it and realised we were a little bit short and I actually bought another layer down so way over the recommended..."*

11.5.5 Objectification

In nearly all cases, the solar panels were only physically seen on the day of the installation. A technology was bought via prior arrangement with an installer and not off the shelf. In all cases, a paid professional from the company providing the solar technology undertook the installation. The process of installing and bringing the technology into the home happened quite rapidly as it was often easily installed in a matter of a day or a few days, requiring very little disruption to the interior of the house:

Fitting in within a day with little disruption	*Sue: "It took them one whole day… they came about eight in the morning and finished about two in the afternoon ... they worked mainly in the roof and the loft… they put scaffolding up and that didn't really affect us..."*

In fact, it was one of the quickest EET to install despite its highly complex technical configuration, and '*the lengthy bureaucratic*' processes involved in doing the paperwork for obtaining the government grants.

The ability to install this technology appeared to be pre-determined by a number of existing characteristics of the house, something the HH themselves had little control over. For example, participants noted needing to have the right building orientations (optimally south-facing roofs, but also south-east- and south-west-facing were considered acceptable); the right amount of roof space for the required roof panels; and ideally a pitched roof (although flat roofs could increasingly be accommodated too). Such factors determined the types and numbers of panels that could then be installed. Most participants had installed anything from two panels up to 18 per house on their roofs. The nature of solar technology means that it sustains a physical and visible presence on the roof once integrated into the house. It is also only publicly visible when installed on street-facing roofs. Public visibility has implications for its conversion discussed later here:

Public visibility on roofs	*Billy: "You can see the photovoltaic panels, just above the roof is the hot water, tubes on two houses* [pointing to the rear pitched roof of the house from back garden]*."*

Furthermore, once installed the panels on the roof are fixed and almost never moved/touched, apart from on the rare occasions when they require repair or maintenance. The participants appeared positively willing to accommodate the whole system being integrated into the house without complaint over any loss of amenity or aesthetics. However, inadequate roof orientation could result in other HH with similar houses being unable to have solar energy, thereby forcing them to reject the technology:

Some households reject due not having the right roof orientations	Billy: "*People on the other side of the street can't have photovoltaic as the south-facing side is on street side is a conservation area ... and the roof on the back is not south-facing... if you have a north- or east-facing roof it doesn't work as well..."*

Many houses had an 'inverter system' box, which helped maximise electricity production; it often came in the shape of a wall-mounted box. Monitoring boxes related to solar energy were typically located either on a hallway wall, in the hallway but inside a closet under the stairs, or in a utility room not in the main habitable rooms.

These boxes were also potentially the only point of contact participants were likely to have with the solar technology. Thus, their physical location in the peripheral or in unobtrusive areas holds implications for their incorporation into everyday life:

Box very rarely used due to its inaccessible location	*Steve: "There's a box under the stairs which tells you how many kilowatt you've generated, but I never look at the box."*

11.5.7 Incorporation

The eager acceptance of this technology resulted in participants ascribing new meanings to it as they incorporated it into their everyday routines. The daily practices related to energy use between participants followed a similar pattern, and were based largely on how they had been instructed to use it by their installers. For most participants this meant using and undertaking the most energy-intensive activities (showering, using the washing machine or dishwasher, ironing, cooking, etc.) during the daytime as this was the most cost-effective and energy-efficient approach. This has meant shifting formerly morning or evening activities to the middle of the day:

Shifting use	*Amanda: "... if the sun shines I use the washing machine..."*
Shifting everyday activities and	*James: "... it makes you change your behaviour; it makes you use electricity differently, so you start using it when it's free when the sun is shining. I'll do my laundry or put my dishwasher under the sun is shining.*

managing use	*Or sometimes I will wait for it but I wouldn't use it at night... just in daylight. So would use a timer to allow things to come on during the day whilst at work..."*

Adaptations in everyday routines were accompanied by using them with other existing systems in the house, such as the gas-powered boiler and central heating systems. Many could rely on solar energy to provide most of their hot water needs for just over half the year (typically from April to October). Day-to-day variations or improvisations of use could be implemented when solar energy could not provide enough energy for electricity or for hot water; participants usually fell back on the boiler system to meet shortfalls:

Solar energy meeting everyday needs and reducing reliance on other sources of energy	*Anne: "We would normally have the boiler heating the water and solar panel and boiler can almost communicate to each other anything until late October that you rely on the solar panels ... our reduction gas use is by two-thirds and most of it is for cooking... with reduced our overall consumption by about three-quarters so we only use about a quarter of what we used to."*
Solar energy meeting everyday needs and reducing	*Steve: "Yes and that would be wasting your money, so you make sure you switch your boiler off. You have to know this yourself. In the winter time, the boiler would come*

reliance on other sources of energy	*on for 20 minutes in the morning and for 20 minutes in the afternoon, because we wouldn't get enough sunshine to heat the hot water however even if there was a sunny day in December I would switch the boiler off because I know I could generate hot water."*

An understanding of how to get the most out of the system was only possible through regular/daily monitoring of the system via the user display boxes installed inside the house. For example, in one house the box was located in the corridor on the ground floor, and therefore became a frequent point of observation and feedback on energy being used:

Accessible location; increased monitoring of energy use	*Patrick: "I check daily and it's in a handy position and I look at it before I go to bed... this actually shows us how much we've generated today is 1.62... so it's a good day we actually had that box changed and that's how much we have generated since we got the box changed and that is what is generated at the moment and that actually shows what happened during the day the peaks..."*

It is through this daily use over time, that HH had increased their understandings of the readings shown on their monitors, and were consequently able to adjust energy use according to fluctuations in peak and non-peak outputs. A few participants also had their solar devices linked to the Internet, where they were able to accurately monitor energy use on a daily basis if needed:

In-depth knowledge of energy use and generation	*Micky: "... but we discovered the peak output is in spring not summer when there is more heat. In summer there is more light. When the panels get to a certain temperature you get a maximum output."* *Interviewer: "How do you know this?"* *Jenny: "We can see from the readings. At peak power we should be able to generate 2.9. Actually we are closer to generating 2.1 on a warm day."*
In-depth knowledge of energy use and generation	*Steve: "There's a box under the stairs which tells you how many kilowatts you've generated but I never look at the box because is also linked to the Internet this device comes within the price... you know to the minute how much you are using, you also know how many of the eight panels are working; the way it works is with the Feed-in-Tariff they assume that 50% of what you generate you're going to feed into the grid – they assume that they don't actually measure – that's the assumption the whole thing doesn't actually work very well I don't think that I know on average we buy from the grid about three kW a day so I*

	monitor how much I buy from the grid; I know how much I generate we assume we use half of what we generate."

However, for most the level of interaction with the solar system is relatively nominal – apart from gaining a visual numeric feedback or a set of readings there were no buttons or controls that needed to be operated in order to use the system. As suggested already, solar systems mostly require human interaction when servicing annually or on rare occasions when an unexpected repair was required:

Annual servicing	*Interviewer: "With the solar panels, is there any way you need to interact with it on a daily level?"* *Anne: "No they said just service it every five years...* [solar engineer] *he was here for an hour ... It really doesn't need any attention to be making savings on our bills."*

11.5.8 Conversion

This technology was stated to be one of the costliest. However, the availability of the government grants was instrumental in incentivising uptake for most participants, thereby enabling them to avoid its key associated barrier – high upfront costs. The key motivation to adopt appeared entangled with financial, personal and environmental benefits, although it was difficult to ascertain if one was more salient than another was.

All the HH appeared to have reached a taken-for-granted status in their solar energy use, although some trial and error in the early use did occur. The process of learning to live with this technology seemed to raise awareness of energy consumption; this meant participants now regularly monitored and adjusted their energy use in order to reduce overall HH energy consumption. Importantly, they were all keen adopters, and therefore nearly all had engaged in communicating this to other people they knew.

11.6 MVHR

11.6.1 Background

MVHR systems are designed to help ventilate rather than heat homes, and by definition are less of an EE technology. They are typically found in newly built homes, but increasingly they are being retrofitted into existing homes too. Whilst there are many variations found in heat recovery systems, the two main types tend to be either whole house or single room. For the purpose of this research, MVHR is used to refer to both types of mechanical ventilation systems. They both work in similar ways by extracting warm moisture-laden air from rooms in order to expel it, at the same time interacting with incoming fresh air via a heat exchange cell within the unit, which then results in the pre-heated filtered fresh air being supplied into rooms in the house. The main benefits are: first, it improves indoor air quality; second, it helps eliminate condensation which causes mould and damp – particularly expedient in highly insulated older buildings; and third, it helps with reducing energy costs as the heat exchange cell is likely to be able to recover up to approximately 75% of the heat that would normally be extracted outside the house (Burton, 2012; Greener Times Guide, 2014).

Only eight participants stated that they had an MVHR system in their house: of those, seven HH had the single room heat recovery ventilation versions, mainly installed in bathrooms, kitchens or open-plan kitchen and living spaces; only in one case did the HH have a whole-house MVHR system which was specifically designed for a house that had been retrofitted to Passivhaus standards. The research did not ask in-depth questions relating to the model's name or manufacturer's details.

11.6.2 Appropriation

In most cases, participants had actively chosen to put this measure in for practical purposes, e.g. – in order to ventilate the bathroom adequately and or to prevent condensation, and to gain fresh air for the kitchen or living room space. One participant talked about building a wet room but needing to put the MVHR as the room did not have a window:

Ventilation without losing the heat	*Billy: "... extract fan with heat recovery ... you can have it for a whole house. We have it for this room and the room with the tub. Also room with boiler has it ... we needed mechanical ventilation as a way of getting ventilation without losing the heat. It is humidity activated."*

One participant occupying the retrofitted to passive house (ENERPHiT) standard had to have a whole house ventilation system, which is an integral part of the standard:

Whole-house ventilation to suit occupant and house size	*Dawn: "... so either you build it tight, but then you need to have some ventilation; this is a clever type of ventilation... it's in every room and it's a balanced system; it's called mechanical heat recovery ventilation is a centralised system you can just have one unit in your shower or something; the important thing about it is it offers reasonably high ventilation rate; it can exchange the entire amount of air in the house maybe 18 times a day which is also designed into the house based on*

	how many square metres you've got how many people you've got; normally there are rules of thumb for every room."

When asked if the system needed to be operated in any particular way, participants suggested that on a daily basis no interaction was required. However, seasonal variations or a shower boost button could be operated when required or even potentially switched off. Most participants stated that they never interacted with the system, only when it was annually serviced – even then, a systems engineer generally undertook this task. The system was left on throughout the year (even though it could be switched off in the summer if required), and this was justified on the basis that it used nominal amounts of energy:

Removes excess moisture and creates comfortable room	*Dawn: "... it is different in that your clothes will dry indoors; you don't have any problems even in the winter... you don't have cold corners, you don't have any funny mould in the bathroom or around the windows and... It's just a very comfortable environment..."*

The passive house retrofit occupant, more than the other participants, demonstrated a relatively high and almost expert level of functional understanding of how the mechanical ventilation system worked in her home. This knowledge demonstrated the essentials of what her system was supposed to do – to ventilate highly insulated buildings. Most participants found out about their MVHR by accident, from either talking to their builder or a friend and whilst discussing other issues or seeking other products for their home. For example, one participant, found out about MVHR whilst discussing various options that would improve the overall EE of their home, and through a deliberate desire '*to do as much as she could'* which resulted in her builder suggesting MVHR and a subsequent visit to his house to see '*how it worked'*:

Recommendation of builder	*Lena: "I think that was from talking to one of our builders or the plumber, because I wanted more energy efficiency and he recommended this and we went out to see his house in north London."*
Personal experiences and advice from friend	*Billy: "I knew about it from technical information as an architect... we had an adviser on solar, a former colleague of mine, heating engineer, he specified this, and he is a professional, more or less retired but does this stuff."*

11.6.4 Objectification

In nearly all cases, this technology is only physically seen once the builder has installed it, although the product image, specs and other details are discussed and seen in a print brochure beforehand. The nature of this product means there is virtually no interaction required once it is installed (except in the unlikely event of it breaking down or requiring a service). Although a small vent could be observed in the ceiling of the room in which it was installed, it acquired an almost invisible presence. Since this is a technology that is placed mostly in the bathroom/kitchen ceiling, it is almost out of sight, silent and with virtually no controls to adjust in most cases – it thus acquires a passive 'in the background' existence.

Passive presence in home	*Dawn: "... it's just there... you know it's working..."*

11.6.5 Incorporation

One participant described how it prevents the shower from steaming up, and that it works automatically without requiring any actions on their part:

Showers never steam room up	*Lena: "... it works automatically ... as having a shower it never gets steamed up in the bathroom because when you're having a shower it starts working, sucks the hot air in the shower area you never get these steamed up mirrors – it is wonderful."*

With the exception of the passive house resident, none of the participants had ever serviced their system or repaired it. Most participants also stated that they knew that any signs of condensation or mould growth would trigger them into investigating whether or not their system was working correctly; only then would they get a service engineer in to look at the system. The passive house resident stated that she only knew when her system was not working when it started becoming noisy and she could feel the airflow was restricted when standing below and placing her hand above the vent; she relied on just sensing her comfort levels in the house before servicing the product:

Developing knowledge of	*Dawn: "It filters air dust for the whole house; it's a large machine,*

when the device was not working correctly and needing servicing	*it starts to get noisier when it fills up, so it's extra energy for the machine to run... if you stand here you feel the air coming in and that's where it goes out and then it circulates around the whole house..."*

11.6.7 Conversion

When asked which EE measures were installed in their home, none of the participants specifically mentioned MHVR. The presence of the MHVR was only mentioned in passing whilst discussing other issues or during the tour of the houses in question. This oversight could be due to the nature of the product itself, as it is not immediately apparent where in the spectrum of potential EE measures it actually sits: it does not directly contribute to the fabric (insulation) EE measures, but rather functions as a supplementary system and appliance (which is regulated to be energy efficient in its design) that supports living in a highly insulated and EE home environment.

Because participants mentioned this device, only in passing it would also suggest that it is unlikely to be readily discussed with others outside the home in the way that perhaps people with solar panels would talk about them. This suggests that it has more limited communications across into wider society; this is connected to the fact that the taken-for-granted dimension may be immediate through technology installation, but the 'telling others' dimension may not so easily materialise.

11.7 Wall Insulation

11.7.1 Introduction

As discussed in earlier chapters, it is widely accepted that housing is one of the largest energy consuming sectors, and in uninsulated houses most heating energy is likely to be lost through the walls. Therefore, wall insulation is perceived as one of the most cost-effective technical solutions that could be made to any building. Broadly speaking, wall insulation consists of three forms: external, cavity, or internal, and there are numerous different variations of the products/technological solutions currently available or emerging into the market for domestic consumers. However, this analysis focuses only on EWI and IWI rather than cavity wall insulation, as these were the most predominant solutions for the solid-walled houses captured in this sample (Burton, 2012; Greener Times Guide, 2014).

A large proportion of participants (17) stated that they had some form of wall insulation in their houses. Of those who had insulated the walls using EWI or IWI (or both) measures, only eight participants had implemented it comprehensively throughout their entire house. There was also a small contingent of participants that implemented either EWI (three) or IWI (three), and only partially to either a single room or a single wall, e.g. following a single or two-storey extension where the new walls had to be insulated to meet building regulations.

11.7.2 Appropriation

In most cases, participants had actively chosen to introduce some form of wall insulation for practical or thermal comfort needs:

Addressing the poor original building construction	*Lilly: "... so it was a combination of feeling uncomfortable to live there... because it was either too hot or too cold... can you imagine charcoal plasterboard, a layer of felt and tiles there is no insulation in there at all so you might as well be sleeping under the stars so I knew something had to be done so I felt it was money that I could spend without adding value to the house specifically..."*

A number of participants had undertaken both EWI and IWI because one solution alone could not be fully applied to the whole house due to constraints created by the existing building legacy. In three cases, participants had installed wall insulation only in one room, which was considered to be particularly cold due its poor thermal condition:

Partial insulation of walls	*Dan: "... I had* [partial] *internal* [front elevation] *and external wall* [side wall of semi-detached house] *insulation here in this room..."*
Irregular walls means only partial solution feasible	*Pete: "... see how the house is protruding as a result of external insulation, approximately 60 cm, and this part couldn't be insulated ... so for this protrusion I had to use internal insulation..."*
Single room intervention	*Kelly: "... because it was freezing cold and in a room that is on the outlying part*

	of the house yet we also put in extra glazing in their double glazed and replaced those doors that lead into the garden so that does help.”

For most participants there was an overall sense that not wasting money on ineffective energy consumption was primarily a common sense thing to do:

Preventing heat loss and not wasting money	*Miles: “... for example where we had a bad winter a couple of years ago my roof had a lot of snow sitting on it and then somebody asked why does your house have lots of snow sitting on it whilst the house next door had none, and I said that's because all your heat is escaping your home; to me it's common sense: why would you pay to heat the outside of your home?”*

In many cases, participants had undertaken insulation as a pre-requisite to installing solar renewable energy; it was an obligation set by government policy on solar and/or renewable energy installers. Participants were quite willing to do this, as they appeared to understand the justification:

Insulation as a pre-requisite to installing solar	*Jill: “... before we did the solar panels we had someone come and assess. We realised we needed to do a lot more to the house to improve insulation... there was loft insulation but it was not adequate. We doubled the insulation... installed*

renewable energy	*Rockwool, between raised joists, insulated the rafters."*

In most cases, participants with wall insulation sought expert advice and specialist installers. However, nearly all participants had also carried out a great deal of research about the products, and verbalised detailed knowledge of the type of product they had had installed into their home. In most cases, the technology itself was only seen on the day of installation.

Nearly all participants had a basic level of knowledge about the type of insulation that they had had installed, the product's name and the quantity that had been installed:

Knowledge of insulation type	*Lilly: "...so in terms of the walls they have all the latest part L spec and a bit more and they've all got the Rockwool insulation... that was also what I want to do..."*
Knowledge of technology and self-installation issues	*Pete:* "[shows a sample] *these products have a 10-year guarantee, this is platinum polystyrene product, better fire resistance hundred mm, better u value; for internal insulation use of 'space foam' this is 100mm and has the same u value as the external, both have you value of approximately 2.4 when fitted."*

Participants demonstrated a great knowledge of what solution would work for them – how it would fit into their existing home and aspirations. What is observable is a weighing up of differing solutions as no one solution would fit. Thus, participants who had installed EWI had done so by first rejecting IWI due its perceived shortcomings; and vice versa for those adopting IWI and rejecting EWI. However, there were two participants that had installed both, recognising the positives/negatives in each solution.

In some cases, EWI was actively rejected and IWI was chosen because the former would cover the original brickwork of the older Victorian house and thus detract from its original features. Furthermore, the cost of EWI was a deterrent and hence it was substantially cheaper and quicker to install IWI:

Keep original brickwork and costs of EWI as deterrent	*Steve: "... no we wanted to keep the brick... with the external stuff it has to marry in with all your windows on your doors and then once you look at the cost of a house like this it will cost about £20,000... So I didn't even start to look at it... internal for this whole house will have cost me £2–£3,000."*

A number of participants had chosen IWI on the basis of preserving the external appearance of their home and in spite of knowledge of its key weaknesses – the loss of internal floor space, particularly in a relatively small room. Secondary to this was the perceived greater level of disruption and complexity in moving power sockets:

Room size reduction	*Anne: "... it was 100 mm* [she shows where it is and the depth against the wall] *so the*

and disruption	*room has been reduced by about that much (100mm).”* *Interviewer: “Was that a concern for you?”* *Anne: “Well in this room it's all right we had to take the entire power point off and shelves taken off.”*

Furthermore, in one case, the external cladding of the house was in poor condition and therefore EWI was chosen as a remedial and cosmetic measure – improving its overall appearance and bringing it back into repair:

EWI chosen as a remedial measure	*Miles: “... we had external walls done ... there was timber cladding and that was rotting and so we had to take that off anyway... so on the side it is brick walls but at the front it is rows of white wooden panels ... now it looks great...”*

Despite the suitability of having either option, another participant had rejected both measures due to their perceived shortcomings:

Perceived shortcomings led to rejecting adoption of measure	*Rita: “They recommended either external or internal insulation and it would be up to us... I'm afraid we've just given up on both... we decided we didn't want the external and disturb all the traditional brickwork and having seen various others done we realised it wasn't for us... with the*

	internal stuff too would be very expensive and everything has to be redone..."

11.7.3 Objectification

Once installed, wall insulation would not have an observable visual presence like solar panels. Wall insulation has often been described as a 'fit-and-forget' measure for this reason. However, four respondents used EWI as a deliberate strategy to improve the external appearance of their otherwise '*unattractive*' building exterior (with stucco or render); it was seen as something that would improve their property value, and in three cases apparently it was felt that it might remove the stigma attached to ex-council homes:

EWI undertaken for repair yet enhances external appearance	*Miles: "... we had external walls done ... now it looks great and has added value to an otherwise unattractive ex-council house ... probably increased its value..."*

Both forms of wall insulation have varying advantages, disadvantages and complexities that need to be addressed when being applied to various building legacies. In some cases, the process of installation appeared to be simple and straightforward, and could be carried out in a matter of a few days to a few weeks depending on the building context and who was doing the installing:

Whole-house EWI	*Pete: "... it took three weeks to put on the whole house."*

implemented by installers	
Both EWI and IWI implemented to whole-house by installers	*Dan: "Three floors, couple days, they come in standard blocks and they fix them to the wall, it's a building project that does generate a lot of dust you get that inside of house and the outside of house you don't get affected by all that ... there is an increased condensation with insulation ... there's moisture generated in the house...near the kitchen and bathroom ... those are at the back of the house ... I don't think there's a risk for me..."*

In one exceptional case, IWI was carried out confidently as a self-installation DIY project:

Whole-house IWI – DIY project	*Steve: "Well, if you can put up wallpaper you can do this yourself. It's actually easier than putting up wallpaper ... but I did it over weeks ... probably over two months..."*

11.7.4 Incorporation

The fit-and-forget nature of wall insulation meant that the participants required no further interaction with the technology in everyday life. However, its impact could be felt immediately and less tangibly via the way it improved the quality of life for the other users. The most important benefits stated by participants following wall insulation were increased thermal comfort and '*warmth throughout the house*'; being able to use rooms in the way participants wanted to and when they were needed were also welcomed. Thus, it also contributed to the wider project of making a 'house a home':

Improved comfort in previously underused space	*Anne: "... the attic it was already a room and had been converted in the 60s it looked awful the windows were UPVC so it was unliveable and he said he could help with the insulation... now it's a warm and liveable bedroom space."*

11.7.5 Conversion

It is notable that when asked which EE measures were installed in their home, all participants mentioned insulation and specifically wall insulation; MHVR was only mentioned in passing. Participants were confident in their understandings of how this measure directly contributed to their buildings' fabric EE and created a warmer and more comfortable home environment; they also demonstrated a keen awareness of its money-saving potentials. The impact of this measure is felt relatively instantaneously once installed. There appeared to be no indication that participants had changed their everyday life in anyway, apart from using more fully parts of their house they could not use previously (this could potentially result in increased energy consumption for some). In a few cases, the EWI was chosen for its dual benefits: not only insulating the interior of the house but also improving its external appearance and commercial viability. Collectively, this aspect contributes both towards the utility and symbolic components of constructing an energy-efficient home.

11.7.6 Section A - Summary

This section provided a selective analysis of the domestication process of specific individual EET that were chosen because they were often the ones advocated as part of an effectives package of measures for adoption by policymakers. Consequently, it demonstrated how the domestication processes could vary for differing EET and across differing HH. It highlighted in detail various aspects of the symbolic and material facets of this process.

It found that for some specific technologies it was possible to trace their progress through the four phases of the domestication process with clearly defined boundaries between the phases. In other cases, various phases appear to have been skipped, or were at least less apparent. This dimension is further visually summarised in the next section. These findings hold implications here, beyond the immediate conclusion suggesting that phases could potentially be skipped if participants buy EET but then do not install them, or even stop using specific EET measures once installed**.**

11.8 Section B – Technology attributes

11.8.1 Introduction

Following on from the detailed analyses of the domestication pathways for individual technologies, this section will summarise further through visual models the varying domestication processes of each EET. It will highlights how alterations and modifications to the traditional DT concept arises as a result of the differing attributes of the technologies, the levels of the user interactions and the influence of time dimensions. Section C goes on to discuss how these domestication pathways hold specific policy implications; which are discussed briefly in that section and more generally later in Chapter 12.

Table 18 provides a summary of an evaluation of the key features of the domestication process for each technology discussed in Section A. It summarises the key features of each of the seven technologies examined using the 4 phase framework. It assigns a qualitative scale of ‘high’, ‘medium’ and ‘low’ to assess the strength and weaknesses of the attribute and simple qualitative descriptions to indicate the role and significance of each attribute for each technology. For example, the adoption of the BB required high levels of knowledge and spatial visibility and high levels of user interactions. The salience of these attributes for each technology within the DF offer an impressionistic evaluation due to qualitative nature of the research. These are discussed below.

Table 18 Summary of the key domestication features of the seven EET examined.

	EWI & IWI	**MHVR**	**ASHP**	**SPV**	**STHW**	**BB**
Appropriation						
Purpose/functions	insulate	ventilate	Heating (space and hot water)	Electricity	Heating (Hot water)	Heating (Room only)
Functions - Relationship to other systems	Compliments/Standalone	Compliments	Compliments	Compliments/replaces	Replaces/compliments	Standalone/ Compliments
Knowledge	High	High	High	High	High	High
Objectification						
Visibility	low	low	low	High	High	High
display	low	low	low	High	High	High
Incorporation						
User interaction	Low	medium	medium	medium	medium	High
Change in everyday practices	Low	Low	medium	High	High	medium
Monitoring/feedback	Low	Low	High	High	High	Low
Conversion						
Time taken to reach take for granted status	Immediate	Immediate	gradually	gradually	gradually	gradually

Telling others	Low	Low	medium	High	High	High
Speed of Domestication process	fast	fast	slow	slow	slow	slow

11.8.2 Overview of technology attributes using the domestication framework

First, at the appropriation phase (as shown in Table 18) all the technologies chosen and installed because they served a particular functional relationship with other existing systems or new ones. Thus they could function to i.e. insulate, ventilate, heat, generate (electricity) and so on. Additionally, post-adoption and within the reconfigured house, they began functioning as either a primary or supplementary and/or secondary system. Notably nearly all these EET required high levels of user and installer knowledge to appropriate and use, particularly in relation to the renewable technologies where there seemed to be high levels of awareness of energy use in the home and environmental potentials of these technologies themselves.

Second, in the Objectification phase, over half of the EET (e.g. EWI/IWI, MVHR and ASHP) embodied low levels of spatial or material visibility. In contrast, the other half, e.g. SPV, STHW, BB and to some extent ASHP technologies, display relatively high levels of visibility in the domestic sphere and high symbolic presence in the mind-set of the adopters. However, one exception emerges in relation to MVHR systems. In appearance, it seems more like wall insulation and for the most part displays a 'fit-n-forget' quality yet has some control device elements, which means it needs some levels of user interaction. Therefore, its visual model looks similar to EWI/IWI and yet it nevertheless retains ambiguity due to its user controls depending on the level of importance given to its attributes.

Third, in their use and incorporation into everyday HH life, most EET required high to moderate levels of user interaction with the exception of the EWI/IWI technologies, which required almost no user interaction. Again, post installation, in relation to the renewable technologies there seemed to be increased awareness of energy (symbolic visibility) through greater commitment to conserve energy accompanied by high levels of monitoring. Furthermore, the conversion of these technologies seemed much slower when compared to EWI/IWI. The fit and forget quality of EWI/IWI meant that although it did not require user interactions following installation, however it was not forgotten by its users, due to its complimentary relationship with other systems of the house.

In terms of final conversion, nearly all had a somewhat gradual yet slightly differing domestication pathway. This meant that getting used to the technologies was gradual and took varying levels of time to normalise and gain 'in the background existence' which they nevertheless did. Nearly all HH were very pro-active in telling others about their EET in relation to the reconfiguration of their home.

11.8.3 Section B Summary

Importantly, whilst all the HH were adopters and converters (recruited specifically for this status), the adoption of multiple EET were not homogenously absorbed by this HH sample. Therefore, the alterations and modifications to the traditional DT concept were largely as a result of the differing attributes of the technologies, their differing levels of the user interactions and the influence of spatial and temporal dimensions. This technology focused analysis highlighted how differing technologies have differing attributes, which determine the ease and speed at which they can be adopted and embedded into HH life. The domestication pathways for each technology is visualised in models in the next section together with their specific implications for policy interventions

11.9 Section C - Domestication models for each EET

11.9.1 Introduction

The analysis detailed in Section A and B set out how the domestication pathway for each type of technology developed. This section has visualised these pathways by adapting of the classic domestication model (outlined in Chapter 7, section 7.2.2) and developed specific technology specific domestication models for each technology. Furthermore, it has also provided consideration of how these models could also serve as policy heuristics with their specific implications for technology specific policy design. It should be noted that the models presented in this section for each technology are done so for illustrative purposes of the domestication process of that technology. Due to the qualitative nature of the data, it is intended to be impressionistic and only presents an ideal type. Ideal types by their very nature are not intended to be regarded as categories but their configuration represents a unique set of variables and dimensions, which may help to unpack and organise the complexity of the phenomenon, examined - technology domestication processes.

These models were formulated from the analysis of the empirical data and follows on from the work by other theorists (e.g. Aune, 2007; Jensen et al, 2009) who have formulated similar impressionistic categorisations to help in explaining the complexities and patterns associated with the domestication process. For example, Aune (2007) used three different categories of homes to illustrate the various ways of domesticating a house (see, Chapter 7, sectionv7.5.1). Aune justifies her 'simplistic categories' on the basis they represent 'analytical constructions and not the complete picture of variation' on the basis that they help: "convey an understanding of a complexity..." (5464). Moreover, she suggests these groupings hold implications for energy policy interventions -this is an aspect also taken forward in the section below.

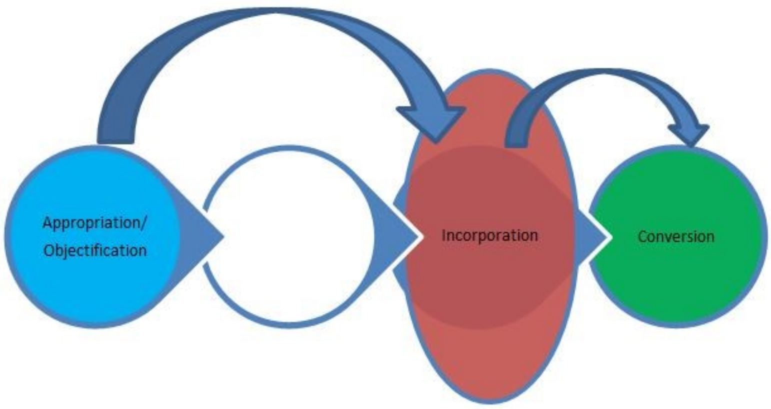
The domestication process of each technology is summarised, visualised and their specific policy implications is discussed separately in turn: ASHP; BB; solar technologies – SPV and STHW; MVHR; and wall insulation – EWI and IWI.

11.9.2 Summary of domestication process of ASHP

The experiences of the two 'adopter' participants suggest that the ASHP once installed does gain a particular spatial and symbolic presence either in the home or outside (the homeowner needs to find a suitable space for the technology). The technology post-installation acquires an almost 'invisible' status, as it does not require much daily interaction with controls, with only the noise of the compressor signalling its presence to the user. Both participants had installed this measure as a complementary measure contributing to a package of measures for a whole-house eco-strategy and not as a stand-alone measure. Thus, for both users despite its spatial invisibility ASHP retained a green symbolic presence in the mind of the users and their activities. They were positive about their experiences of ASHP, and pro-actively engaged in a period of learning how the technology worked and trying to fit it in and adapt HH routines around it. It nevertheless had to some extent acquired a taken-for-granted status in the users' lives. The adoption of the ASHP suggests the users' willingness to risk trialling quite novel, expensive and unconventional technologies for the sake of achieving a greener vision of their home and life.

Figure 11 illustrates through a 'model' what the domestication process of ASHP technology could look like. It suggests that the four phases do not occur concurrently. It suggests that appropriation and objectification may actually occur simultaneously with a relatively longer incorporation phase - indicated by a relatively larger size - of getting used to the technology and adapting some heating related energy practices. This is followed by a more muted conversion due to its invisibility under the floorboards or within an enclosed utility room. The systemic nature of the technology requires it to be integrated into the existing fabric of the building, while requiring very low levels of user interaction and monitoring. Therefore, the domestication of ASHP should be regarded as an ongoing process, which is open to change through its continual use (and even non-use in the event of breakdown and/or the user turning off its use.

Figure 11Visual Model of the Domestication process for ASHP



11.9.3 ASHP Policy implications

In relation to ASHP, the findings revealed that its high upfront costs, highly specialised knowledge requirement and installer skills results in its slower adoption and longer incorporation time. In addition, it is perceived poorer performance and added value when compared to other more familiar renewable EET are key considerations and of potential use for policymakers.

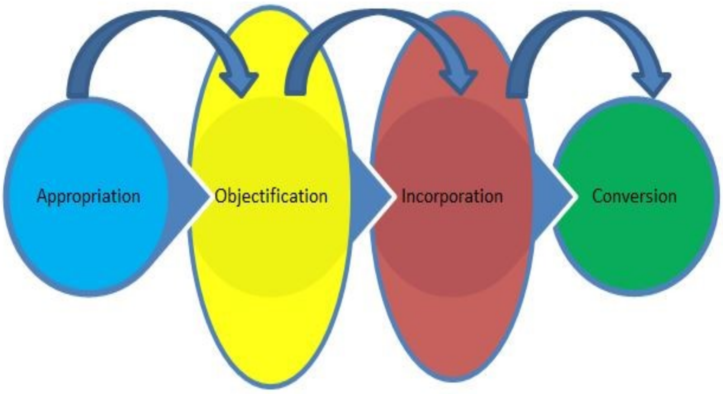
11.9.4 Summary of BB domestication process

The domestication process for the BB appears to follow a clearly defined process across the four phases of the domestication concept. The ease of its domestication is supported by the symbolic value it held for its adoptees. The symbolic and material appropriation of the BB technology registered easily with particular forms of consumption the participants desired, e.g. supporting a desire to obtain a greener lifestyle. Thus, the adoption and use of the BB supported these twin goals desired by participants. Its objectification through its prominent physical location in the home and incorporation via the engagement of a novel social practice of '*fire making*' and '*sitting by the fire*' were seen as part of an alternative yet '*nostalgic and rustic*' lifestyle. The BB held seasonal and climatic variations in its use, and complementarity with other existing domestic room heating systems and lead to various innovative adaptations. Its prominence within the domestic sphere and within the context of highly insulated homes with powerful boilers and central heating systems suggests that its presence, whilst almost surplus to requirements, is also an object of cultural consumption and less about EE.

Therefore, its contributions go beyond both the utility and symbolic components of constructing an energy-efficient home. The evidence suggests that the technology acquires a taken-for-granted status readily, and is an artefact that is also easily conversed about with others, implying the likelihood of more enthusiastic communications across the wider public sphere.

Figure 12 outlines a model of the domestication process for BB technology. It again suggests that in this process the phases occur in four distinct periods similar to the classic model apparently running sequentially from appropriation to conversion. However, the diagram denotes the objectification and incorporation phases as larger than the other two phases – with a middle heavy composition. This is to highlight the fact that these two phases appear most significant. Firstly, the BB by its very nature has greater potential for display through its central location and physical presence in the home; therefore, it is also likely to self-convert to visitors to the home. Second, its use is more enthusiastically incorporated materially and symbolically into everyday routines, often changing existing energy consumption practices (in terms of decreasing reliance on the conventional heating systems).

Figure 12 Visual model of the domestication process for biomass burners.



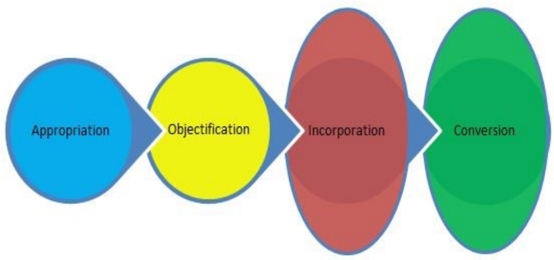
11.9.5 BB Policy Implications

In relation to BB, its attraction arises from its physical design and aesthetic quality – its high symbolic value - that make it an exclusive object of desire for the achievement of a particular lifestyle. The cost of this technology is high, including the messiness and complexity created by the differing biomass fuels available, so could be a deterrent to many. Its particular lifestyle and green symbolism could be greatly replicated to promote other EET.

11.9.6 Summary of the domestication process of solar energy

Figure 13 outlines a model of the domestication process for solar energy. It demonstrates a process occurring in four distinct phases, similar to the classic model, running sequentially from appropriation to conversion. However, the model depicts the incorporation and conversion phases larger than the other two phases – this is to highlight the fact that these two phases are most significant in relation to this technology. Firstly, through its greater visual display acquired through its physical location on the roof, the objectification of solar technologies was important for its conversion. This is attributed to the fact that the panels are likely to convey messages to neighbours and passers-by. For most HH, its incorporation is very important and required quite substantial reconfiguring of daily energy-related practices to daytime use. As demonstrated by the greater numbers adopting this measure, it is positive and speedy D can be attributed to its physicality, ease of installation and use and positive green symbolic associations. Therefore, it is likely to be more rapidly domesticated when compared to other EET.

Figure 13 Visual model of the domestication process for solar technologies.



11.9.7 SPV/STHW Policy Implications

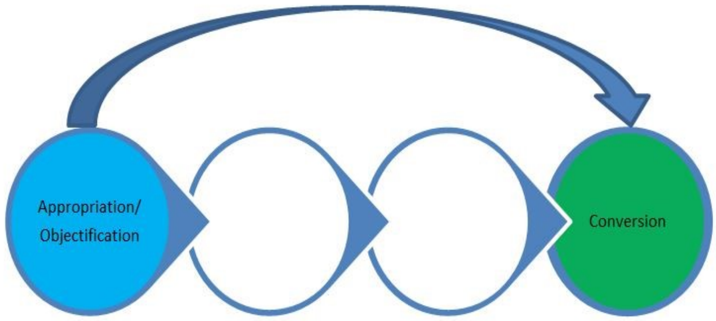
This EET is considered the most popularly adopted and easily domesticated due to its longer presence in the public domain. It is its ease of use and 'green' symbolism that makes it attractive to potential adoptees. However, the availability of financial incentive helped tackle high up-front costs. The reasons for its rejection relate to the way exiting roof space orientation could sometimes act as a deterrent to some HH. Thus, through innovative new design solutions this could be tackled. Its green symbolism could be further utilised to promote other EET and further attractive incentives to get more HH to adopt.

11.9.8 Summary of the domestication process of MVHR

What is evident in the wider context of the home is that nearly all of the participants who had installed the MVHR did so as part of a whole-house eco strategy (including the passive house). It appeared to play a significant complementary role, and contributed in preventing heat loss and ventilating a more airtight home environment. Therefore it contributes both towards the utility and symbolic components of constructing an energy-efficient or eco'-home. The nature of this particular EET means that despite initially being a relatively alien, invisible and benign device, it appears to be quite readily and quickly domesticated without too much of a lengthy acquisition decision-making process.

Figure 14 outlines a model of the domestication process for MVHR technology. It suggests that in this process the phases do not occur in four distinct phases running sequentially. In particular, it reflects a hollowed out process indicated by the missing colours in the middle phases. It suggests that the appropriation may lead straight into the conversion phase, whilst an explicit objectification and incorporation phase appears redundant. This is because this is a technology that appears to be appropriated and becomes 'functional to its users' quite quickly once installed and is relatively similar to the domestication process of EWI/IWW. This rapidly leads straight into conversion where it reaches a taken-for-granted status because residents can benefit as soon as the technology is installed and it does not require a great deal of learning or adaptation to everyday routines.

Figure 14 Visual model of the domestication process for MVHR.



11.9.9 MVHR Policy implications

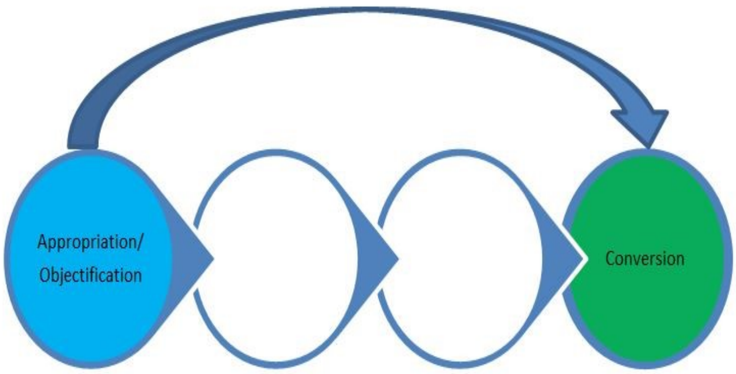
The findings revealed MVHR systems contain fit-and-forget qualities similar to EWI/IWI, requiring the least adjustments to everyday life. However, despite this they are not as commonly installed due to public unfamiliarity of its functions and its complimentary role in living in a highly insulated home. Thus raising awareness of this function in its specific marketing is of potential use to policymakers.

11.9.10 The domestication process of wall insulation

Figure 15 shows a visual model of the domestication process for this technology. It suggests that the four phases do not occur consecutively. The domestication process of this measure suggested that its appropriation might lead straight into its conversion, whilst an explicit objectification and incorporation phase appears redundant, similar to the case of MHVR. It suggests that once the need to insulate is identified it could quite quickly be appropriated and installed without a lengthy acquisition process. Again, once installed, this measure acquires an invisible quality, and does not seem to result in any significant changes in everyday routines. It domestication process suggests that appropriation and objectification may occur at the same time and lead straight into its conversion in terms of being easily taken for granted. However, it is not typically something that people highlight over enthusiastically compared to others such as SPV or BB.

However, conversion of this measure is complicated because on the one hand its invisibility once installed and lack of post-installation interaction requirements means that it may not be an obvious point of communications with others and wider society; yet by default becomes functional or beneficial to its users instantly (suggesting some level of incorporation), it could arguably reach a taken-for-granted status almost as soon as it is installed. The nature of this particular EET means that it was not regarded an *alien* technology, but was seen as socially acceptable due its longer presence in the public and policy domain.

Figure 15 Visual model of the domestication process for wall insulation.



11.9.11 EWI/IWI Policy Implications

The findings reveal that wall insulation contains fit and forget qualities and require the least adjustments to everyday life. However, despite this they were not as commonly installed. There is a distinction between the IWI and EWI and these need to be taken into consideration. For example, whilst IWI is cheaper than EWI, the fact that it reduces the overall room floor space can act as a deterrent. In contrast, EWI appears to be more desirable as it can act to increase the aesthetic quality and improve the value of a building. For both, the complexity of installing, the disruptive aspects to the existing infrastructures and time taken to install appears to delay adoption. Easier to install and cheaper products would be critical to new policy design.

11.9.12 Section C – Summary

The technology focused analysis highlighted how differing technologies have differing attributes, which determine the ease and speed at which they can be adopted and embedded into HH life. The individual technology domestication models presented above have suggested what domestication process would look like, that this is not a static process. In particular it shows critical points of interventions where a phase appears larger or skipped in the models. These findings hold particular implications for policy interventions for government and industry in relation to technology specific domestication processes. In sum, they suggest that policy needs to:

- be more targeted with tailored marketing for each type of EET;
- simply inform and raise awareness of the potentials of each EET;
- offer long term after sale support for each EET to retain its integrity throughout its life cycle; and
- offer bespoke innovative financial incentives for costlier EET.

Therefore, policy should be targeted at key points – in each phase of D – of decision and action. Thus, a mix of policy tools with careful tailor-made individualised targeting of EET could aid greater adoption and embedding. These are some suggestions that emerge as this by no means an exhaustive list of suggestions. A more detailed and generalised discussion of the policy implications for government and industry are discussed in Chapter 12, Section C.

11.10 Chapter Summary

The empirical findings illustrated in detail the reality of domesticating multiple EET through their entry into the domestic sphere. It highlighted that multiple technologies are not homogenously adopted due to their differ attributes resulting in their different uses and domestication outcomes. From this, it is possible to see that some are more easily or speedily domesticated whilst others are more slowly domesticated. The key implication of the results is that some technologies will better at contributing to environmental goals than others, and all of which are likely to result in differing HH energy consumption. Policy needs to pay particular attention to the differing attributes of technologies, their differing outcomes and certainly not forgotten once fitted.

Chapter 12: Discussion

12.1 Introduction

Section A of this chapter provides a discussion and synthesis of the findings of the empirical data set out in Chapters 9, 10 and 11. It does this through a thematic analysis of the empirical data using the D lens. Importantly, it highlights how understanding the domestication process at the HH level is complex and how the entry of multiple EET adds to its complexity. However, Section B reveals that analysis using the four-phase framework does not fully capture this set of complex issues and actors: the building, the people, their desires and intentions, their decisions and knowledge all feed into and shape what seems at first to be a linear process and provide a deeper understanding of it.

The findings highlight the multiple understandings of the domestication process, which could be unpacked, extended and/or modified in light of its unconventional application to housing and building-specific EET. The application of the D framework helped establish three distinct components relating to the domestication process at the 'whole' house HH level: first, a pre-existing sociotechnical context of the house and HH; two, the potential for multiple domestication pathways to be developed simultaneously; and three, a reconfigured sociotechnical system. These three dimensions help to unpack some of the complexities of the domestication process which suggests that it is more than a linear four-phase process.

Furthermore, the utilisation of the four-phase framework for data analysis at the HH level reveals particular policy implications for government and industry, which are discussed in Section C. In particular, it discusses how each phase (including what happens between phases) could serve as a more systematic heuristic tool for policy interventions. This chapter is divided as follows:

- **Section A – Discussion of the four-phase D framework**
- **Section B – Emergence of three distinct components within the process of D**
- **Section C – Policy implications for government and industry**

12.2 Section A – Discussion of the four-phases of domestication

12.2.1 Pre-adoption – Appropriation

The analysis of the whole house or HH level domestication suggests that it is a process that could be divided between a pre-adoption and post-adoption dimension, where appropriation is clearly positioned in the former. The analysis of the findings for the appropriation phase reveals, on the one hand, key aspects of the appropriation phase but also a pre-existing sociotechnical context that shapes this phase and goes on to shape the continuing process. This phase reveals itself as a key decision-making and acquisition process.

As the process unfolds it reveals aspects of its complexity which are related to issues such as the multiple motivations and reasons underpinning the desired changes, the influence of the existing sociotechnical legacy and a desire to preserve the existing heritage of the house; the search for, selection or rejection of specific EET solutions; accessing specialist information and knowledge for EE solutions; and the role of government incentives to support purchase. These are some of the issues that define appropriation and will be discussed further in this section. The findings suggested that appropriation is a process that could be divided into three further distinct time periods: pre-purchase; acquisition (purchase); and post-purchase.

12.2.2 Pre-purchase – Active engagement and multiple motivations for adoption

Most participants, regardless of whether the appropriation of a single or multiple technologies was involved, were actively engaged throughout the process of domestication, and were not passive adoptees or users once installed (e.g. as noted by Aune, 2002; Silverstone, Hirsch & Morley, 1992). The findings revealed multiple, interrelated yet practical and qualitative reasons for seeking EET, broadly falling between the social, personal, economic, environmental, technical and structural (including the physical legacy of the house) – e.g. similar to the motivations identified by Tengvard and Palm (2009) underpinning HH motives to adopt, reject or delay investment in relation to small-scale energy technologies.

Feeling cold and improving the thermal condition of the house was one of the most common reasons for pursuing change – this supports the findings of a number of researchers (e.g. Banfi et al. 2008; Cooper et al. 2012; Shove, 2003) who suggest that people often seek the benefits of increased thermal comfort over all other benefits. Thus, pre-purchase, the goal to make the fabric of the entire house energy efficient often resulted in the recognition that no single intervention would be sufficient and therefore multiple measures were selected. There were further contextual dimensions that shaped this selection of technologies: choice was often influenced by a desire to preserve the heritage of the house and almost always executed alongside other planned major home renovation activities and seldom implemented in isolation; it often coincided with various HH life cycle events (retirement, requiring more space for children, etc.). This reinforces some of the understandings already forwarded by a number of existing studies (e.g. Fawcett & Killip, 2014; Maller & Horne, 2011; Nair et al. 2010a, 2010b; Stiess & Dunkleberg, 2013).

Crosbie and Baker (2010) identified lifestyle as a key motivational 'pull' factor in HH technology adoption decisions; they suggest that HH were likely to overlook some well-established technologies for those that fit in with their lifestyle – for example, buying an EE fridge-freezer (a tangible technology with a 'positive lifestyle attribute') but not insulation (one with a negative attribute). This research found that many HH claimed that they lived a green lifestyle through their everyday consumption and purchasing activities (see Chapter 9, Section 9.7 for a full breakdown). They also claimed that the adoption of EET was an extension of that lifestyle. However, the findings here differed from Crosbie and Baker's, in so far as they indicated that HH had no problem in adopting innovative technologies as well as conventional measures such as insulation despite their purported 'negative lifestyle attributes'.

12.2.3 Pre-purchase – Information and knowledge gathering

There was evidence that HH accumulated a 'critical mass' of information and knowledge before purchase. For example, there was a long 'gestation' or selection period where participants 'searched, researched, imagined and conversed' about the possible solutions or outcomes, they sought. This seems to align with the idea of an 'Imagination' phase,[69] during which HH *imagine* the role and purpose of the technology before acquisition, their imaginings based on pre-formed meanings created by design, advertising and sales of the products being considered. It is at this point that a process of decision-making unfolds, where some EET are rejected whilst others are selected based on existing pre-formed meanings and experiences. These might include knowledge about what the technologies do; their symbolic value; how something would fit into the home; financial incentives, costs and the experiences of others with this technology.

Therefore, appropriation as a *mental* decision-making process appears similar to the five-stepped process set out in Rogers's Diffusion of Innovation Theory (Rogers, 1995).[70] Rogers contends that HH first hear about a technology and what it could offer; they then research more information about it; they often speak to others about it; they form opinions and attitudes; and then they then may decide to adopt or reject a measure. If adopting they may begin a process of selecting and identifying products, and plan the interventions before eventual purchase. However, whilst the findings of this study did echo many of the characteristics in decision-making identified by Rogers, they nevertheless highlighted a more untidy process where activities often occur simultaneously, following no particular order and often not step wise.

69 This later version (Silverstone, Hirsch & Morley, 1994) of Domestication Theory contained the original four phases, but preceded by the 'Commodification' and 'Imagination' phases.
70 Discussed in Chapter 5.

12.2.4 Purchase and post-purchase

Due to the building specific and systemic nature of the technologies examined, they were seldom seen up front at the point of purchase, seeing examples in someone else's house being the exception. In nearly all cases these EET were only seen either on the day of installation or following installation. The arrival and entry of the EET into the house is symbolically and materially marked by the actual installation of the disassembled parts. It is at this point that they are integrated into the existing fabric of the house.

These technologies also seem to fulfil a specific relationship to the existing structures of the sociotechnical system of the house. Broadly, these measures modify the existing *fabric* of the sociotechnical construction of the house, which means that the insulating and ventilating measures physically change its fabric (i.e. improving its thermal performance); ventilating activates the house to possess greater 'responsiveness' to its new environment and users (e.g. to prevent humidity, condensation, mould growth and so on). They can only be activated and of use once installed.

Therefore, what is observable is that appropriation is a complex phase, which can broadly be divided between pre-purchase, purchase and post-purchase periods; the decision-making around the selection of particular EET takes place over longer periods of time than the actual point of purchase, which can be identified to a specific point in time. Thus, appropriation marks the physical and symbolic entry of EET into the home, a complex process that is far more than just possession and ownership as the original DT suggested.

12.2.5 Appropriation of multiple technologies

An alternate perspective provided by the technology focused analysis (discussed in Chapter 11) of individual EET suggested a duality in the process: whilst things happen at the strategic whole-house level, they can simultaneously occur at the individual technology level. Therefore, an examination of individual EET reveals greater depth in the domestication of such technologies. Firstly, when appropriating each technology it is selected and bought to deliver very specific functional requirements. For example, wall insulation was often bought for its *insulating* functions through a HH desire to create a warm and comfortable home environment, prevent heat loss and leakage; MHRV is bought for *ventilating* and acquiring fresh air quality and reducing condensation in rooms; ASHP is acquired for *heating* floors and rooms and hot water needs; BB for room *heating*; and solar energy for both room *heating* and hot water and *electricity* supply for HH appliances. Thus, the rationale underpinning the appropriation for each specific EET was different yet would collectively contribute to the whole – making the house an energy-efficient home. Importantly, this level of analysis also highlights the mutual relationships or the synergies that are created as a result of the introduction of multiple yet diverse technologies into the home.

12.2.6 Post-adoption – Objectification

The post-technology adoption dimension is marked by the objectification phase. Objectification explores the way the users actively make technologies fit into the domestic environment, their integration into the building fabric, physical display and location in the geography of the home. The evidence suggests that the transition between appropriation and objectification is often blurred. This is because there is often a delay between the purchase, display and use of EET due to its nature – it can only be of use when installed or integrated into the building fabric. A number of factors could cause the delay: purchasing problems; the length of time taken to install can vary widely between housing types; who leads the changes and who installs, regardless of whether it is a single or a multiple technology, could cause delays. It is for this reason unclear in which phase the process of installation should sit, as it appears to straddle and overlap both phases.

12.2.7 Physical location of multiple technologies

Alternatively, from a technology-focused perspective, the physical location and display appear to be mutually dependent and occur in varying forms, materially and symbolically. The physicality of each EET was different. Generally, most technologies required some space allocation in the footprint of the house (or even outside it). However, unlike discrete stand-alone 'plug and play' technologies, their systemic design meant that they could only be operationalised once integrated into the existing fabric and system of the house. In this process of integration they mostly acquired a peripheral location (less frequented or used spaces in the house), with the exception of the BB which was often given a central position within the house such as in the living room. Thus, these EET demonstrated varying degrees of presence in terms of visibility and invisibility as a result of their design, construction, functions and installation. Silverstone, Hirsch and Morley (1992) raise the importance of 'visibility'.

Furthermore, the accessibility of the user interface device in turn was likely to shape how HH incorporated devices in their everyday routine practices (e.g. when they would shower). In most cases, such devices served as a physical reminder of the presence of EET, despite its deep integration, hidden away in the building fabric. The overall material invisibility or the inert 'fit-'n'-forget' quality of most housing EET, means that by default they encapsulate less *display* attributes when compared to other discrete domestic technologies that HH may domesticate. Finally, what this analysis demonstrates is that the degree of accessibility to the location and the degree of presence – visibility/invisibility and the level of legibility and/or readability – may have an effect on the degree of user interaction required for incorporation into everyday life.

12.2.8 Incorporation – Fit into everyday life

The incorporation phase – part of the post-adoption dimension – enabled an examination of the degree of agency technology exerts on the everyday lives of HH. The focus of analysis was on how technologies were used and incorporated into everyday routines and energy consumption practices. One key overall observation is that their incorporation into everyday life appears more easily achieved via this active engagement. This reflects the fact that EET were actively and voluntarily appropriated in the home, and thus nearly all users had positive associations with them. For most HH it appeared such adjustments were consistent with living in their self-constructed energy-efficient and/or eco-house.

12.2.9 Lead appropriator

Haddon (1992:128) highlighted the importance of paying attention to ‘who’ decides which EET is to be ‘appropriated’, and to considering the role of the family/household as a unit as well as the differing positions of various family members. The issue of gender adds a further aspect to user interactions. The findings did not indicate the presence of a gendered dimension, however: evidence rather pointed towards the existence of a *lead* appropriator in the HH who drove decision-making around adoption and engaged with feedback/monitoring activities post installation. This role was split equally between male and female participants.

This unexpected and tentative finding of a lead appropriator suggests that they serve as role models (and gatekeepers) to other members of their social interpersonal network and beyond. The socio-demographic background of these lead appropriators suggests that they are aided by having control over substantial financial and social resources, which can help them afford the more expensive technologies and absorb any losses they may incur. They also seemed to have the competence to understand and apply complex technical information, and to facilitate the circulation and feedback of new ideas. Indeed, in many cases they appear to have become ‘lay experts' in the process through their experiences of adoption. Hence, they could help build critical mass of successful adoptees (through conversion).

12.2.10 Learning to use – Trial and error

The evidence suggested that a period of learning and experimentation occurred largely through trial and error in how to use the technologies effectively. This corresponds with Lehtonen's (2003) conception of the domestication process as a set of trials where new knowledge interacts within the existing moral economy of the HH. For example, many had relied upon the verbal instructions of the installer and the advice given by servicing and repair engineers when appropriate. Through such interactions HH were able to informally learn more about how to use the technology satisfactorily.

12.2.11 Use of controls, settings and interfaces

Most of the EET adopted had a 'fit-'n'-forget' quality that required very moderate user interactions with interfaces such as controls or settings on a regular or daily basis, although some had controls to make seasonal variations to the settings or for its switching off of the device if required (summarised in Table 18). Exceptionally with MHVR and ASHP there were some minor settings that could be adjusted if required, but this was very rarely done by the HH. Of the small numbers that had serviced their devices annually, nearly all had used that as an opportunity to check the device was working effectively; to find out how use could be adjusted to meet changing HH needs; and/or to correct any issues or problems that had been previously undetected. This interaction helps reinforce the integrity of the system in the minds of the users and potentially delivers the intended performance. However, evidence of the failure to carry out servicing/maintenance by some also raised the risk of the technology not performing effectively or optimally over time, and could ultimately lead to rejection as people may stop using devices.

12.2.12 Ease of use facilitated by the design of technology

The ‘hands-off’ design and limited need for user interaction with the EET on a daily basis meant that users quickly ascribed new meanings to the EET adopted. Most participants appeared active and willing to make seemingly effortless adjustments to their daily routines in order to accommodate and utilise the benefits of the technologies. It was clear that the adoption and use of EET had begun to shape the temporal patterns of daily and periodic routines in very specific ways. This supports some of the findings by Keirstead (2012), Juntunen (2014), Maller and Horne (2011) and others. However, for many it also meant a continuation of existing routine practices and/or with some changes or no changes in their temporal dimension, and/or some new practices emerging from existing ones. Thus, this reinforces the ‘evolutionary not revolutionary’ nature of change that the domestication of technologies may embody (as highlighted by Aune, 2007).

This manifested itself in many different ways: there were changes in when certain daily activities occurred, such as showering at midday rather than first thing in the morning; switching between and combining use of the conventional heating system and the new system; periodically switching off devices if required, or servicing when required; lessening the use of existing systems; lessening conventional practices to gain comfort in the house, such as not needing to open windows for ventilation; and the emergence of heightened awareness and new routines of monitoring one’s energy use (via monitoring/feedback). In particular, where solar renewable technology was concerned a significant change in the temporal patterns of everyday routines resulted in many HH ‘loading-shifting’ daily activities to daytime midday use (washing dishes, laundering, cooking, showering, etc.). This supports findings by Keirstead (2012) which showed high levels of environmental concerns, energy monitoring and personal commitment to reducing energy consumption amongst HH that had adopted solar PVs.

12.2.13 New activities – Monitoring and feedback

There appeared to be a strong relationship between the presence of some form of user interface device and the level of feedback/monitoring activities undertaken – as noted by Keirstead (2012) in relation to solar PV technologies. In particular, the introduction of new technologies such as SPV, STHW, MHVR and ASHP seemed to encourage users to monitor how much energy they used or generated. Hence, a spillover effect on HH, regardless of the measures installed, was evidence of an increased awareness and 'visibility' of how energy was being used in the users' mind-sets. This appeared to lead efforts to better manage and/or reduce overall energy consumption in the HH (e.g. heating rooms less often or at lower temperature). This finding to some extent contradicts the dominant perspective in the literature (e.g. Pierce, Schiano & Paulos, 2010; Hargreaves, Nye & Burgess, 2010) which suggested that most of people's energy consumption is invisible, and it is this invisibility that can pose a barrier to energy consumption reduction.

12.2.14 Environmental lifestyle

Furthermore, there was evidence that many of the participants were engaged in what they saw as a more environmentally friendly lifestyle, which their adoption of EET would reinforce. However, this sample was too small and qualitative in nature to be able to generalise or infer any cause and effect in that relationship. That said, it is clear that the desire for an environmentally friendly lifestyle emerged over time and may have existed before adoption of EET, and remain following adoption. This is discussed in further detail in Section B below.

12.2.15 Differing roles of technologies

Through their use, EET typically came to play either a primary and/or a complementary role in relation to the existing energy systems in the house. For example, STHW systems started off as a complementary system to the existing gas boiler central heating system, but over time the former was used increasingly for hot water, whilst the latter was used for that less often and more for room heating only. Similarly, a BB, often introduced as a complementary element, often became in effect the primary room heating source. In both cases the new technology became the dominant system and led to reduced use of the existing one – the latter often relegated to filling a supplementary role.

12.2.16 Conversion

Conversion is concerned with the symbolic communication of technologies outside the home, and sits in contrast to appropriation, which focuses on the entry of technologies into the home. The focus of analysis here was on its twin dimensions: first, material display and symbolic meanings of artefacts and their communication to the outside world; and second, how 'taken-for-granted' status materialises. It is also concerned with how the conversion of experiences of the appropriation of meaning in relation to technology is conveyed.

12.2.17 Taken-for-granted status

Most participants suggested that they now took the adopted technology for granted. In practice, this meant that they had been able to successfully ascribe personal meanings, and successfully use and develop a sense of ease of use that fitted it into their everyday life. This was underlined in nearly all cases by an overall positive association and experience with the adopted technologies, which seemed to foster a 'desire to tell others'. For example, this was exemplified by the fact that most participants felt quite comfortable with using and living with the EET adapted, to the point where they could forget it was there. The fit-'n'-forget aspects of some technologies, which mean that once they are integrated into the building they acquire a relative material invisibility while retaining a symbolic presence for their users, arguably also, facilitate this.

12.2.18 Telling others

Telling others unfolded in many ways, such as conversing with neighbours, friends, family and sometimes repair/servicing people, as well as opening and exhibiting the home as an exemplar to share best practices. In particular, the public opening of the home for visitors served as a tool to educate other potential adoptees contemplating appropriation of EET, thereby diffusing 'experiential' knowledge across the wider public realm. For example, most participants had started recommending various technologies to others they knew, leading to them installing similar measures. This reinforces similar findings of adopter experiences outlined by Fawcett and Killip (2014).

The act of telling others – typically through conversations – seemed to fulfil specific functions. It was a way of reflecting on positive and/or negative experiences, sharing knowledge about use and whether systems were working correctly; it was also a way of offering each other support and problem solving opportunities. Over time, these feedback activities seemed to have the combined effect of aiding the user to optimise the benefits and performance of their adopted EET. These exchanges represent a form of communication outside the home and highlighted the fact that without this phase the outcomes of the other three phases would remain hidden inside the private sphere of the home, and – in the theoretical sense at least – incomplete.

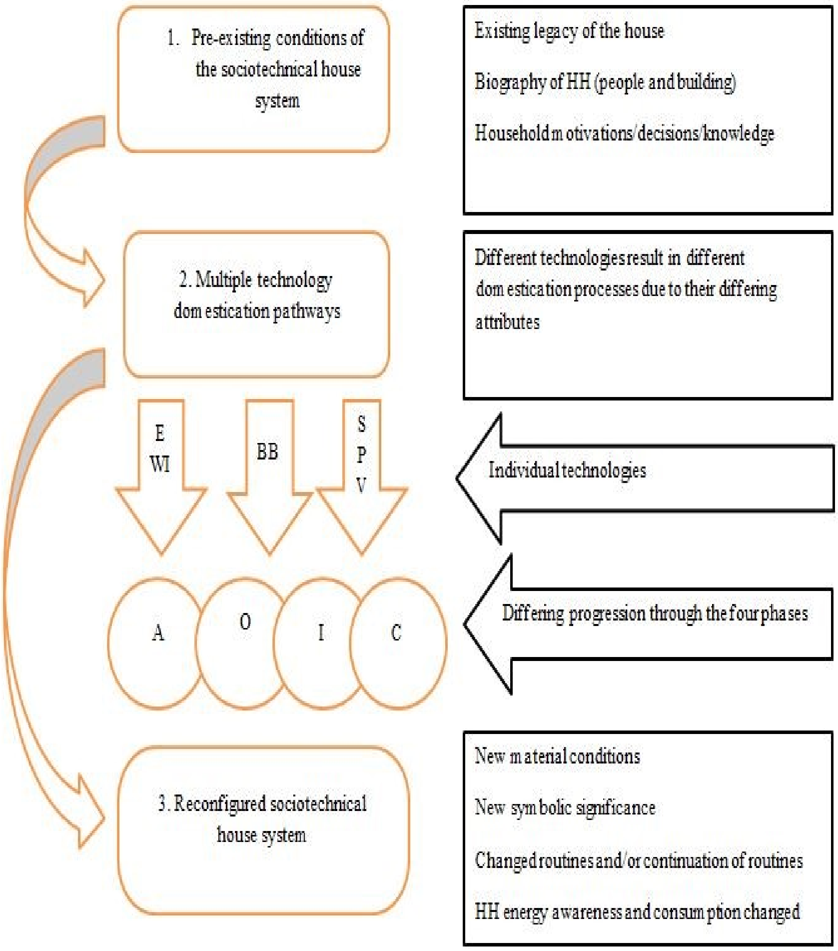
12.3 Section B – Emergence of three distinct components within the process of domestication

12.3.1 Introduction

The previous section discussed the empirical evidence using the four phases of domestication. It highlighted how the house is an already complex sociotechnical system and the entry of multiple EET adds to its complexity. The contention is that analysis using the four-phase framework does not fully capture this complexity. Furthermore, one of the pre-existing conditions of the domestication process is that it unfolds within the 'moral economy of the HH' (Silverstone, Hirsch & Morley, 1992). This research defined this to include consideration of the existing housing condition or building legacy and the biography of the HH occupants, which provide a contextual basis for the domestication process to emerge. In the domestication of multiple technologies, this research found that there are very specific crosscutting themes that are particularly salient throughout the four phases. The findings reveal three distinct contextual dimensions that are an important part of the complexity of the whole-house domestication process.

For example, first, there is a need to understand that the pre-existing sociotechnical context (including the moral economy of the HH) encompasses the building, the people and their desires pre-configure decisions for appropriation. Second, there is the presence of themes that emerge across the four phases within the multiple domestication pathways depending on the types of technologies adopted. The third dimension is linked to the former two components, which results in new conditions where things have changed within the HH and which give rise to a reconfigured sociotechnical house system. When these are taken into account, it requires modifications to the conceptualisation of domestication.

Figure 16 Overview of household level domestication process.



12.3.2 The pre-existing legacy of the sociotechnical system

The pre-existing sociotechnical context encompasses the building, the people and their desires, intentions and decisions. It provides the platform from which the domestication process can occur. More specifically, these existing contexts or conditions will preconfigure the technology adoption pathways taken. The most salient contexts relate to the existing biography of the HH (i.e. the social aspects of the people within the HH) and the existing physical legacy of the house. For example, the initial role of knowledge and learning for HH and understandings of what the technology can do may then preconfigure technology selection and adoption decisions.

Findings from the appropriation phase moved it from a reductive view – that it is simply about buying or the point of purchase – to a more complex process of decision-making and acquisition, one that the dominant behavioural psychological models/approaches do not embrace. It highlighted the contextual significance of the existing physical legacy or condition of the house in determining the nature and extent of future changes, i.e. those involving renovations and technology adoption decisions the HH may wish to undertake. In this research, the houses under analysis were older vernacular pre-war housing stock (their age breakdown is provided in Chapter 9, section 9.4). Influential spatial aspects of the existing legacy of the building included its location, its physical space and layout its aesthetic and heritage value. These acted as either constraints or opportunities in HH decisions.

HH living in pre-1900 housing often sought EET solutions that would preserve sympathetically existing historical features. However, the existing infrastructure and systems go to provide a template from which to 'add-on' other interventions. Therefore, the consideration of the existing building legacy is likely to feature right at the beginning of the appropriation decision-making phase, and is likely to have an effect on the available and potential technological solutions that are considered.

12.3.3 The existing household biography

In this analysis, aspects of the biography of things (as suggested by Kopytoff, 1986) become more apparent. This required an understanding of the interactions of the technological systems and artefacts of the house as well as the HH occupant's biography (e.g. their socio-demographic characteristics, their life events). . Thus, major changes within the HH over time could have positive or negative effects on how technological systems are used and perceived: people entering retirement, adult children moving out or moving back in, and new owners or renters moving into the house, might all have different perceptions on these systems. Moreover, the type of lifestyle aspirations and goals between HH and HH members seemed to shape the way technology was used and energy-consuming activities (see e.g. Juntunen, 2014; Stiess & Dunkleberg, 2013). The various HH members through their differing values, demands and use in the time and space of the house were likely to shape HH consumption processes (as suggested by Haddon, 2001, 2006). Thus, they influence the technology adoption decisions and the subsequent technology D pathways that unfold. The evidence in this research supports the view that no single motivational factor appeared influential in technology adoption decision-making; rather there was evidence of interplay in a combination of lifestyle, cultural, economic and environmental motivations that seemed to affect a homeowner's adoption decision-making.

The HH biography conception helps to place EET interventions within a wider context of HH renovation practices, and suggests how they were 'embedded within HH cultural practices and an integral part of homemaking' (as suggested by Maller & Horne, 2011:60). The existing research suggested that the differing components that may contribute collectively to the act of 'homemaking' can be characterised simply as HH goals, e.g. to improve comfort levels for its occupants, internal or external maintenance/repairs; to provide additional space; and to save energy. All were undertaken to suit homeowners' aspirations. This manifests over the length of the occupation (the temporal dimension) of the home in question, and can be undertaken as DIY or via a paid contractor. Hence, the adoption of EET was part of a series of EE investments in which achieving EE is but one of a number of HH goals (as suggested by Maller & Horne, 2011). These pre-existing contexts inevitably reconfigure qualitatively the sociotechnical system of the house symbolically and materially.

12.3.4 Development of multiple technology domestication pathways

The HH sample was selected because they were defined as adopters of multiple EET (detailed in Chapter 9, Section X). The adoption of multiple EET showed evidence of the development of multiple D pathways (detailed in Chapter 11). For example, HH efforts to create either an EE home or eco-home resulted in the recognition that only multiple measures would suffice in this endeavour; single measures were not enough. This corresponded with existing policy recommendations for the need to adopt a package of EET measures. However, whilst many EET were implemented at the same time, they nevertheless appeared to have differing domestication pathways over time. This reinforces Juntunen's findings of multiple technology domestication pathways from technology adoption. This research found that the varying technology D pathways could be linked to the nature of the technologies adopted, their functions and their material and symbolic attributes.

Additionally, DT suggests that the HH is multi-structured both spatially and temporally (Silverstone, Hirsch & Morley 1992). The salience of these two components has often been the focus of debate, which will doubtless continue: the research evidence here provides insight into how they may materialise and the extent of their agency in the context of the D of multiple building-specific EET.

12.3.5 The spatial dimension

The spatial (and material) dimension, whilst important for the entire domestication process, appears more central in the objectification phase. This encompassed the materiality of the existing physical space of the house and the physicality of the technologies themselves, their physical location once integrated into the house and how they then reconfigure the sociotechnical system of the house symbolically and materially.

The existing spatial dimension of the house and the physicality of the EET (e.g. the manufacturer's design and systemic nature of the technology), often determined its physical location, dictating where it could or could not be installed. Hence, the spatial location of a new boiler would take the space of the old one within the existing physical space (e.g. typically an airing cupboard) and use established connections to the existing infrastructures, i.e. the mains gas, electricity and water supply. This links back to the existing configuration of the house.

The spatial and physical location of multiple EET was different for each technology. This spatial dimension, however, did not necessarily lead to their symbolic marginalisation (or invisibility) in the HH users' minds – as will be discussed further below. Consequently, the physical integration of multiple EET materially and symbolically assisted in the reconfiguration of an existing energy inefficient house into an efficient one.

12.3.6 The temporal dimension

Linked to the spatial dimension, the evidence supports the view that the process of domesticating involves the location of technologies within a temporal dimension, a fact that is underlined by the presence of everyday consumption practices in the moral economy of the HH (Hynes & Richardson, 2009; Haddon, 2006). This could include how HH organise their time through their social commitments and the subjective way they may experience time (as suggested by Haddon, 2006). How the domestication process unfolds in time is a key component of the temporal dimension. This aspect is evident as a crosscutting theme across each of the four phases, but it also plays itself out differently in each phase and with each technology type.

Exploring the temporal dimension is an important part of fully understanding the domestication process itself. Consider, for example, how aspects of time unfold in the decision-making process for adoption; the length of time between selecting, deciding, purchasing and installing EET during the appropriation phase. The time taken for EET to be objectified and incorporated into the everyday life of HH, and how much time HH may have to dedicate to learn and use their technologies effectively (integral for the delivery of their environmental potentials) can vary; and, of course, use can quickly turn into non-use over time. Moreover, EET integrity needs to be maintained over time, and the time taken to communicate appropriation to the outside world merits consideration.

As already mentioned in Section A, whilst it was possible to determine a time frame at the appropriation phase (e.g. the point of purchase or a point at which installation was completed) and the transition into objectification, it was not possible to identify an exact time for when incorporation and conversion phases were likely to occur. Furthermore, nor was it feasible to articulate an end point where multiple technologies were domesticated into houses – even where they may all been installed at the same time. Hence, the evidence suggests that due to their different spatiality and temporality, together with their technical attributes and functionality, they all appeared to have differing D pathways.

From an HH perspective, it was difficult to generalise about the amount of time it took to utilise and symbolically fit the technology into everyday life and become comfortable with its presence in the home. The time taken varied: it could take one HH a matter of days and weeks to say that they finally felt comfortable with using the adopted technology in their everyday life, whilst for others it took several months or even years.

Moreover, telling others did not appear necessarily contingent upon ‘feeling comfortable’ as people could talk about their technology with others at any point (or in any phase). Exceptionally, where solar renewable technology was concerned a significant change in the temporal patterns of everyday routines resulted in many HH ‘loading-shifting’ daily activities to midday use. However, learning to use things correctly took time and was achieved through trial and error. Therefore, there was a suggestion here that variable levels of incorporation occurred depending on the type of technology installed and the functions delivered.

Therefore, it may be asserted that examination of the temporal dimension reveals how technologies will be used differently by differing HH and their members; and due to their technical attributes and their functions, they will be used differently at different times of day or year. Thus, the various HH members were very likely to shape HH consumption processes, supporting Haddon’s viewpoint (2001, 2006).

12.3.7 Knowledge, learning and competences

A consideration of the spatial and temporal dimensions also revealed how people learnt to adapt and live with new EET. The findings revealed the salience of knowledge, competences and learning that unfold in the process of domesticating multiple EET. It highlights the significance and interplay of different types of knowledge (formal and informal), learning and competences that differing HH develop and rely on at each phase and throughout the process. This reinforces Lehtonen's (2003) concept of D as a flexible set of 'learning' trials, which occur through people's interactions with technologies (discussed in Chapter 7, Section 7.5.4).

The knowledge acquisition component seemed to manifest in differing ways in each phase and for differing users. In the appropriation phase, knowledge seemed to play a significant role in supporting the adoption decision-making, which was more complex than just making an ordinary purchase decision. It involved a lengthy process of information gathering from multiple sources (e.g. the Internet and experts) from which people built up their knowledge, often drawing on their personal pre-existing experiences and know-how. The breadth of the knowledge that a person has acquired on the availability of the chosen technological solution is linked to the type of information they have access to, and is linked to their particular building's existing physical legacy shortcomings. This knowledge helps users 'imagine' what the technology can do for them in terms of solutions, e.g. envisioning of how to create an eco-home, or how it could be used in the home.

It was notable that in the incorporation phase, knowledge could be linked to *learning* which could be perceived as evolving into a form of tacit knowledge. This is a key 'learning by doing' phase, and includes learning through experimentation and trial and error, which was key to building tacit knowledge of how new, often alien systems work in relation to the existing sociotechnical system of the house (unlike a familiar technology such as a TV that is virtually ready to use). Hence, what they have to do is to tweak (adapt) it and understand how to bring it close to optimal levels (not maximising in most cases); the development of that knowledge then helps with the final phase. During this phase, HH seemed to rely quite heavily on specific forms of information, i.e. ‘verbal instructions’, and to a lesser extent on ‘written instructions’ of how to use.

In conversion, there is evidence of a form of experiential knowledge by many with ‘lay expertise’. This was gained from the interplay between informal learning, personal experiences and formal knowledge. This is where homeowners often sought to share their ‘practical and technical’ knowledge and experiences with others, particularly by aiding others within their interpersonal network to adopt EET and by opening their home for others to view what has worked for them in practice. This suggests a knowledge feedback loop between HH and wider society. Therefore what is evident is the mobilisation and interplay of different types of formal and informal knowledge in each phase, between ‘informative knowledge’, ‘expert knowledge’, ‘tacit knowledge’, ‘experiential knowledge’ and ‘textual’ knowledge (as theorised by Fleck, 1997).

In particular, the building up of ‘tacit knowledge’ (as suggested by Fleck, 1997) is likely to facilitate the final phase. This tacit knowledge is complemented by formal knowledge, which can be textual- or video-based. Thus, HH are in effect relying on their tacit knowledge for their available options rather than carrying out extensive research of the market and the solutions on offer. Therefore, what appears to be occurring particularly at the appropriation phase is a process of weighing up differing solutions and interventions. This appears to be constrained and modified by the fact that the decision-maker could be making a selection from a sub-set of technologies and from which he or she is prepared to consider one option. This holds synergies with economic viewpoints, which suggest that people in the real world often make transaction decisions based on *imperfect* or incomplete information (e.g. bounded rationality discussed in Chapter 6).

The evidence suggested that most HH were very well informed users and had acquired competences – skills and technical know-how – to make minor innovative adaptations to their devices and even install some measures as DIY. This means that they were likely to have greater control over the installation process and thus greater awareness of their incorporation and in the way, they wanted to use technology. Therefore, the evidence suggested homeowners make extensive use of formal knowledge (along with expert knowledge from practitioners) as well as relying on their own informally gained experiential knowledge and know-how. In effect, what must form before the desired outcome of technology adoption and implementation can be achieved and conversed is an intersection between the differing forms of knowledge, skills and capability, spread across a number of stakeholders.

12.3.8 A reconfigured sociotechnical house system

The adoption of multiple EET results in multiple D pathways, and leads into new conditions that significantly reconfigure the sociotechnical system of the house. In which the change signified a reconfigured social, material and symbolic aspects within the sociotechnical system. In particular, within this context the theme of visibility and/or invisibility of the adopted multiple technologies became more explicit.

The existing research has already raised the importance of this ‘visibility’ (Silverstone, Hirsch & Morley, 1992), and the possible consequences of the ‘physical disappearance’ of technologies in relation to ICTs. This points to the unconventional application of DT to building-based EET of this research as it is relatively inert and becomes invisible via integration into the building fabric. Thus, the EET examined demonstrated varying degrees of presence in terms of visibility and/or invisibility (materially and symbolically) as a result of design, construction, function and installation. Moreover, the relatively inert fit-'n'-forget and systemic nature of most housing EET means that by default they encapsulate less display – visibility – attributes when compared to other discrete domestic technologies. Although technologies such as SPV and STHW are manufactured with their own fittings and a 'hands-off' design, their rooftop positions nevertheless serve as visual reminders for their conversion.

Despite the relative invisibility of EET features, they seemed to retain a degree of prominence, a symbolic and material presence in the everyday lives and routines of their users. In particular, this becomes most apparent in the reconfigured house. The visibility/invisibility of EET interacts with how HH perceive and use the newly installed technologies, helping to create a more EE home and shaping everyday energy consumption practices.

These findings sit against a policy backdrop, which advocated a package of EE measures, which need to be combined with consumer lifestyle changes and correct usage to unlock full environmental potentials. In this research, the visibility and invisibility aspects of multiple technology adoption lead to the view that despite their seemingly fit-'n'-forget qualities, they were not forgotten by HH. The evidence suggested that the presence of the EET foregrounded in the users' minds awareness of how energy was being used and in some cases generated. This resulted in efforts to better manage and/or reduce overall energy consumption in the HH (e.g. supporting Keirstead's 2012 study).

12.3.9 New HH consumption practices

Importantly, the reconfiguration of the existing sociotechnical system resulted in not only observable structural changes to the house (i.e. new functions and uses) but also some changes in HH consumption practices. In relation to HH adopters, policy often misconstrues them as passive, rational consumers who will homogenously adopt multiple technologies in their home (as set out in Chapters 2 and 3). The findings here assert that whilst these HH were defined as adopters, they are by their very nature heterogeneous, and although they may adopt similar technologies, they were not passive consumers, and certainly did not use technologies in the same way as each other. This finding supports, e.g. Lees and Sexton's study (2012 discussed in Chapter 7).

As detailed in Chapter 10, section 10.6.2, notable qualitative differences were observed in the symbolic meanings between the two HH groups identified in relation to the technology domestication process. In this context, chapter 9 provided a full breakdown of the socio-demographic composition of the HH sample, although no socio-demographic correlation with their rationale for EET adoption could be drawn. The qualitative nature of the sample and its small size meant that a correlation of such difference could not be inferred fully.

Nonetheless, a more general difference could be observed in the mind-sets of the HH that fell into the Eco group when compared to the EE group. In particular, this HH group seemed to be the most pro-actively engaged in a set of actions, which suggested that they were willing to moderate their energy use in order to conserve it over time. This particular group expressed a desire to manage energy-consuming routines more efficiently, something that was accompanied by other perceived environmentally friendly activities and purchases in their everyday life (e.g. recycling, not leaving things on standby and buying energy-efficient appliances). This HH held slightly higher levels of knowledge about the technologies, possessed stronger environmental values or worldviews and self-identities, which were expressly about leading a green lifestyle; they were highly pro-active in managing and conserving their energy consumption through the monitoring devices and the collection of feedback.

The results suggested that the adoption of EET might represent a symbolic reinforcement of a personal dedication to responsible energy use and environmental values. These findings support the tentative observations of the double dividend effect in relation to HH SPV adoption made by Keirstead (2012).

Within the realms of a reconfigured sociotechnical system, two important elements emerge: on the one hand, a house that is subjectively better for the HH, and on the other a house that could be tangibly more EE. Thus, qualitatively better in an environmental sense and holding the potential to contribute towards carbon emission reduction goals. A heightened symbolic visibility of energy in everyday life becomes more explicit at the end of the technology domestication process within the reconfigured house.

12.3.10 Summary of Section B

The research findings highlighted the multiple ways understandings of the domestication process could be unpacked, extended and/or modified in light of its unconventional application to housing and building-specific EET. Following on from Section A, the application of the D framework helped establish three distinct components relating to the domestication process at the whole house level. These were, first, a pre-existing sociotechnical context of the house and HH – this refers to the physical legacy of the house and the HH biography that define adoption decision-making. Second, the salience of the potential for multiple domestication pathways to be developed simultaneously – this refers to the cross-cutting themes that influence all those pathways, e.g. the role of space, time, knowledge learning and skills, which change over time and which help in reconfiguring the sociotechnical. Third, the end result of the domestication process leads to a reconfigured sociotechnical system in which the house appears subjectively better for the HH, where HH consumption practices have changed, and one that is likely to be measurably more EE.

In the process of domesticating EET, the HH has to consider the underlying contextual basis of their house, which then determines their choice in technology adoption and the subsequent D pathways taken; progression through the multiple pathways occurs over time and is shaped by the differing characteristics of the technologies chosen. The end of the process is signified by evidence that there is a changed HH situation. These three dimensions help to unpack some of the complexities of the four phases of the domestication process, and suggest that it is far from being a straightforward, linear four-phase process. It shows that adoption is not a homogenous experience and it alone is not enough; it is not a meaningless consumer-based activity, but is an activity that needs to mutually interact with the social and technical dimensions to materialise.

12.4 Section C - Summary Policy Implications

12.4.1 Introduction

One of the key objectives for this study was to consider the policy implications of the empirical findings of the research. In particular, the aim was to establish the relevance of the domestication approach and qualitative data findings for key stakeholders, and to consider whether it could aid the formulation of more effective solutions. The ultimate aim was for EET to be more widely adopted so that the final domestication – conversion – phase could potentially be everyone's phase.

The empirical findings illustrate in detail the reality of domesticating multiple EET. This sits against a policy backdrop that supports the adoption of multiple measures where carbon reduction credentials are black-boxed into the technologies. However, this research showed that multiple technologies are not homogenously adopted, and due to their differing attributes, adoption often results in their different uses. Each EET is domesticated differently, and it is possible to see that some are speedily domesticated whilst others are domesticated much more slowly. As a result, some will be better at contributing to environmental goals than others, a fact which is likely to result in differing environmental policy outcomes. Policy needs to pay particular attention to the differing attributes of technologies, their differing user interaction levels and the subsequent outcomes.

The application of the four-phase framework for data analysis at the HH level reveals particular implications. What happens within and between different phases can provide important cues for effective policy interventions. Each phase could serve as a heuristic tool and distinct points for policy interventions. The examples discussed are summarised in Table 19 and include some of the more obvious and practical policy implications from the findings; however, this is not intended to be exhaustive list and other policy interpretations may be derived for each phase.

Policy needs to develop an appropriate mix of interventions that can target the sociotechnical complexity of the HH. The domestication lens suggests it also needs a set of interventions that are sensitive to the pre-adoption and post-adoption dimensions of the process, recognising that polices need to go beyond the short-term goal of just trying to encourage adoption and address the long-term biography and life cycle of the technologies once adopted.

12.4.2 Financial incentives for specific technologies

The availability of financial incentives can accelerate adoption and help reduce the high upfront costs that can be a deterrent to some. This research found that many of the solar renewable technologies adopted by HH had nearly always been stimulated by the availability of government financial subsidy via the FiT and to a limited extent the RHI. It also suggested that other, less familiar, renewable technologies may benefit from further directed subsidy and marketing (examples would be air source heat pumps, ground source heat pumps, biomass boilers, micro-chip, micro-wind, etc.); this may help develop the market beyond solar energy. Thus, targeted government support through subsidy and favourable FiT tariffs could aid later adopters – especially where economic motivations may be more important than environmental values. This assistance could be given until such renewable technologies become more established and affordable, and might help diffusion across different HH socio-demographic groups with a less green lifestyle outlook.

12.4.3 Access to the 'right' expert advice/information

From the outset during the appropriation phase having access to the right information is crucial. The research found that pre-adoption, the HH is actively engaged in a process of information gathering and building up a critical data mass, weighing up the pros and cons of differing interventions for their homes. Further policy recognition of the important role of having the 'right' information from the start, e.g. through the energy assessment from skilled advisors that could offer bespoke solutions to the idiosyncrasies of older existing housing, could help more people overcome the practical challenges they may encounter. Thus, in the short-term greater support through energy saving advice on use and maintenance behaviours is essential.

12.4.4 Support for EET adopter champions

The research specifically focused on adopter experiences, so by their very nature nearly all could be said to be converters. They hold the potential to serve a specific policy function of diffusing their knowledge to others, which could help them to adopt. The findings revealed that most of the participants seemed confident and knowledgeable about the process of adopting EET. Most described this as a gradual process of knowledge acquisition and learning. Many were able to project manage (designing and planning) and negotiate with paid contractors about how and what measures they wanted implemented. Through this acquired expertise and confidence, some were able to offer support and advice to others (as noted in the conversion phases). Aiding conversion, these people often became unofficial champions and their homes exemplars in many cases: this is something policy could capitalise upon and offer support for. In this context, understanding how adopter HH learn to use and interact with technologies could feed back into policymaking/design, e.g. to help adoption, correct use and maintenance over time and to convert others.

12.4.5 Support for user-friendly product designs

Most of the EET in this research were technologies that have been designed to fit into a pre-existing sociotechnical configuration of the house. Thus, the existing infrastructure and systemic design provided the template for the add-on of EET. There is a need for the market to make such add-on components more flexible, adaptable, multifunctional and easier to install in order to make them more mainstream so that more people can easily domesticate them (e.g. by buying off the shelf in high-street retail outlets). For example, there are moves in the industry to make easily applicable internal wall insulation available as a DIY project, where previously the product design would have been complicated and required implementation by trained specialists. This should increase accessibility to innovative and specialised materials that at the moment seem closed off to those unable to navigate the Internet (and other sources) to access the most relevant and innovative products and deals. Thus, another facet to this is the need to change these technologies from being highly specialised in design and installation to making them more familiar so that traditional builders could acquire the skills to avoid poor installation.

Thus, considerations of the effective lifetime of some of the EET systems will need to be easily adapted, upgraded, and reprogrammable with user-friendly interfaces that should ideally enable the mixing of differing technologies with differing energy sources. It should also take account of changing occupant lifestyle practices, which will have an effect on the overall HH energy savings.

12.4.6 Recognition of the complexity of motivations and everyday consumption practices

Once technologies are adopted, HH will attach their own meanings and may not adopt prescribed use as intended by their designers or policymakers. The symbolic meaning attached to technologies will not be uniform between HH; this variance of meanings may also mean not using technologies optimally for maximum financial and environmental gains but more sub-optimally over time. These user variations can have significant implications for technology use and its intended environmental performance.

Therefore, policy needs to understand the complex dimensions of everyday consumption practices and the reasons underpinning adoptions. This complexity has resulted in variations in the differing ways HH domesticate EET and many contradictions in everyday practices. The symbolic communication of EET in government campaigns may need to go beyond the 'saving money' message. It may need to promote a wider range of the benefits that EE adoption can contribute to, e.g. health, aesthetic, environmental and lifestyle benefits. For example, educational campaigns could highlight investment in and encourage greater savings from behaviour change in response to EET adoption, favourable FiT and environmental benefits.

The following are some examples of interventions suitable for the post-adoption phases:

12.4.7 Greater installer expertise and after-sale care

Key stakeholders such as energy advisors and technical sales people often play a key role in the acquisition of information about solutions and/or the supply and installation of products. They play an influential role in supporting householder decisions to adopt and incorporate EET into their everyday life; this can often determine what use a technology will have once installed. It suggests policy needs to further support this industry in making sure that workers have the right skills and competences and can offer adequate professional after-sales care following installation to their clients; this will increase the viability and integrity of technologies and aid speedier conversion.

12.4.8 Good housekeeping of technologies

High-quality installation and the continued integrity of the technologies are important to ensure that positive conversion – telling others – occurs. This is likely to affect the wider uptake of such technologies. Over half of the participants in this research reported that they only serviced their appliances when they became defective, rather than annually as recommended. In this sense, HH competence to carry our basic maintenance is important but many people cannot do this. This approach could hold obvious negative implications for the long-term effectiveness of such technologies. Furthermore, over time the physical integrity of adopted technologies is likely to decay, especially if there was never any process in place to check if systems were faulty or correctly integrated at the point of installation and immediately thereafter. Therefore, it is important for policy interventions to support long-term maintenance and repair, thereby protecting the integrity of the technology.

From the provider and installer end there seemed to be a 'hands-off' attitude towards after-sales customer care in ensuring that appliances had been fitted correctly, and then with supporting annual repairs/maintenance services to help maintain optimal performance of 'advanced' technologies such as solar technology, ASHP, MHVR, condensing boilers, etc. There is a suggestion that the existing institutional framework supporting good housekeeping of the technologies installed is inadequate in its current form. Providing more pro-active post-installation after-care would ensure the long-term integrity of the EET and the industry by avoiding negative public discourse, something that this research has shown could lead to rejection of some technologies even before the appropriation phase.

12.4.9 Tools for long-term energy management

The incorporation phase revealed how people need to fit and adapt their everyday life around new EET. The presence of EET seemed to increase awareness of energy consumption and increased monitoring and energy-conserving actions. In particular, technologies such as renewable micro-generation technology with some form of user interface device and the visibility of infrastructure can act as physical reminders to assist this process. In recognising the benefit of monitoring energy use in the home, the government has developed the smart meters initiative but this faces slow uptake. There are other equivalent technologies available to HH in their early days of use. Industry could play a greater role in the design and installation of monitors and user interfaces, which allow more real-time comparison of generation and overall energy consumption. This type of information will enable HH to more effectively manage their energy use.

12.4.10 Support for technology specific policies

The detailed examination of the domestication of each technology in Chapter 11 revealed unique attributes that contribute to the differing D pathways for each. The key policy lessons for each technology are summarised in Chapter 11. In sum, policy interventions will require more targeted and tailored marketing of each EET, campaigns to inform and raise awareness of the potentials of EET as well as after-sale support; overall, policy aimed at incentivising take-up would be desirable and could aid greater adoption.

Some of the issues with the design of differing technologies suggested that policies need to be more engaged in the design and development of technologies; these crucial stages should not be left to the industry. It needs to ensure that improved design of EET make the products more desirable aesthetically, especially where control devices need to be more user friendly, portable and/or located more centrally in the home. Policy also needs to be responsive to the biography of the HH so that adjustments to the systems can be made according to how many people live in the house and their lifestyle needs. Understanding how HH learn to use and interact with technologies feeds back into the work of policymakers/designers and improves what they do.

Table 19 Using the domestication framework as points for policy intervention

	Intervene at key points of Domestication	Key intervention description
Pre-adoption	**Appropriation**	policies that encourage the adoption of multiple measures
		more effective, targeted, technology-specific marketing
		support access to the right type of information, support access to expert opinions and knowledge
		provide attractive financial incentives
		select appropriate and most effective interventions for the existing house
Post-adoption	**Objectification**	support for user-friendly and well-designed technologies
		quality installation by qualified and skilled installers – creates quality assurances greater after-care support throughout the technologies' life cycle support regular repair and maintenance
	Incorporation	assisting learning for users to avoid performance gaps advice and support for living in an EE home important importance of feedback and monitoring for HH
		Greater installer and after-sale expertise available
		Good housekeeping of technologies by HH
	Conversion	better energy management good design and installation important for conversion visual reminders essential regular servicing is essential to the integrity and conversion telling others may help diffusion across other HH 'as lived experiences' feedback from early converters useful mechanism for policymakers

12.5 Section C Summary

Current policies are preoccupied with getting people to the point of adoption and the numbers that have adopted as success indicators; however, using the domestication lens suggests that policies need to go beyond the adoption phase by recognising the life cycle of technologies once adopted into the home. In the same way as there are no single solutions to tackling the energy inefficiency of existing homes, policy needs to develop an appropriate mix of interventions that can target the sociotechnical complexity of the house and HH. Furthermore, recognition that policies like EET will take time to embed and deliver their 'black boxed' goals.

The domestication lens suggested that the four phases, although non-linear, could serve as a heuristic policy device. What this means is that the four phases could be used as a rough guide for points for policy interventions, e.g. providing information tools when HH are making choices or decisions, such as in the appropriation phase (see Table 21). Furthermore, it must be recognised that people do not use technologies in a stable and coherent way once they arrive in the home, and certainly not always in the way designers/policymakers intend. Importantly, a policy mix should support how people live with technologies, and ultimately support the longevity and integrity of technologies in order to aid conversion, which is an ongoing process and does not end with adoption.

12.6 Chapter Summary

Section A of this chapter provided a discussion and synthesis of the findings of the domestication process set out in Chapters, 9, 10 and 11. It did this through a thematic analysis of the empirical data using the four phases of the domestication framework Section B revealed that analysis using the framework does not fully capture the complexity of this process, which is influenced by various issues and actors: the building, the people, their desires and intentions, their decisions and knowledge all feed into and shape a seemingly linear process and provide a deeper understanding of it. The findings highlighted three dimensions that help to unpack some of the complexities of the domestication process and which suggest that it is far more than a linear, four-phase process. Furthermore, the utilisation of the four-phase framework for data analysis at the HH level revealed particular policy implications for government and industry, which are discussed in Section C. In particular, it discussed how each phase could serve as a more systematic heuristic tool for policy interventions.

Chapter 13 Conclusion

13.1 Introduction

This study focused on understanding the developing relationships between HH, energy consumption, everyday life and technology adoption and use in efforts to meet carbon reduction and sustainability goals. The research was undertaken with the primary aim of understanding the problem of low adoption of housing EET through an alternative framing – that is, through the adopters' experiences and by using DT as a theoretical and analytical tool. It examined through a sociotechnical perspective, the issue of why some HH were successful in adopting and embedding EET into their everyday life. The discussion in Chapter 12 concluded that DT provided a more nuanced understanding of what happens to technology when it enters homes, together with its policy implications.

This chapter concludes by discussing the implications of the findings of the research aims and objectives; presents a summary evaluation of the empirical and theoretical contributions of the study; its policy implications, as well as the limitations of the study; and recommendations for future study. This chapter has been organised in the following key areas:

- research question, aim and objectives;
- context of study/problem;
- implications of the empirical findings;
- theoretical implications;
- policy implications; and
- recommendations and limitations of study.

13.2 Summary of Research Contributions

The key original contributions of this research are multidimensional: firstly, it has developed an alternative and unique framing of the adoption of housing EET through the domestication concept; secondly, by using the domestication lens it is able to offer a more holistic and systemic perspective of a complex sociotechnical problem, placing technology consumption and HH users' experiences of it as the foci of analysis; and finally, through DT's application in this way, it has expanded the traditional scope of DT into analysis of new technologies which are non-discrete and building based, something that had previously been overlooked within research field on housing EE.

13.3 Research Question, Aim and Objectives

This research began with the key aim of responding to the following research question: 'To what extent can the application of DT advance our current understandings of the processes of adoption and embedding EET into the everyday life of homeowners.' Through an examination of the experiences of HH 'adopters' the key objectives sought to:

1. outline through user experiences the processes of adoption and embedding EET into their homes and everyday lives;

2. determine whether DT offered an effective explanatory tool for the analysis of how homeowners adopt and embed EET into their homes and everyday lives; and

3. consider the policy implications for government and industry in relation to goals of increasing HH EET adoption and reducing HH energy consumption.

13.4 Key Aim Fulfilment

The empirical data analysis has shown that the application of DT can help advance current understandings of the processes of adoption and EET into the everyday life of homeowners. Through this, the study developed a holistic, alternative and in-depth perspective on the complexities of adoption and use, in contrast to the normative academic and policy discourses of the low adoption problem. In particular, Domestication's four-phase framework has proven to be useful as a conceptual and analytical tool, holding three distinct purposes aligned with its three objectives. First, at a practical level it helped synthesise and unpack a large and complex qualitative interview data set on adopter HH experiences. Second, it provided an almost tailor-made conceptual and theoretical framework, which is inherently designed to analyse the sociotechnical complexity of processes that unfold within the HH context (something that no other single theoretical model could offer). Third, the use of the D framework also indicated how it could serve as a heuristic tool for policy interventions (e.g. at key points or places in HH decision-making).

13.5 Context and Research Problem

This research sits against a policy backdrop in which policies and legislation highlight the important role of EET in tackling climate change; which supports the adoption of multiple EET adoption for the creation of low carbon buildings; and where CO_2 reduction is black-boxed into such technologies. In this context, and despite a range of policy interventions and the availability of a range of EET use and government-driven product innovations, there has been growing concern that government targets are unlikely to be met specifically within the existing housing sector due to low levels of adoption of EET. Additionally, policy success has often been equated with numbers installed or performance-based environmental outcomes rather user outcomes (Crosbie & Baker, 2010; Guy & Shove, 2000; Janda, 2011; DECC, 2011). The rate of adoption is perceived to be particularly low amongst private homeowners occupying existing dwellings. This meant that only a small minority of homeowners have been willing to adopt domestic EET; many have not (set out in Chapter 2 and 3).

Alongside this, existing research highlighted how the low carbon building problem is not simply about the building or the appliances: it is also about human behaviour. Thus, reducing energy demand effectively via housing is not simply about rationally adopting EET; it is also about changing everyday HECB (Janda, 2011; Guy & Shove, 2000) (detailed in Chapter 3). Yet policy has often sought technical and legislative solutions rather than tackling fundamental questions of how we live within social dimensions. These issues highlighted how this is a complex sociotechnical and interdisciplinary problem.

What appeared to be lacking is a greater in-depth understanding of who this small group of homeowner adoptees were, and why they had voluntarily adopted EET despite the perceived constraints. Furthermore, the dominant theoretical approaches had tended to focus on why individuals had not adopted EET through a tendency towards a ‘barriers drivers’ or ‘techno-rational’ framing of the problem. Furthermore, understanding how people live with technologies once they are adopted and brought into the home appeared underdeveloped in the dominant policy and research discourses. Through a focus on adopters this research took the sociotechnical position that understanding the social and technical – including the material dimensions of technology adoption – is important. This alternative framing could aid a better understanding of the challenges faced by policy makers in their strategies to increase EET adoption and managing HECB.

The sociotechnical position was also considered appropriate due to the limitations of the dominant academic and conceptual perspectives that often originate from rational economic, psychological, technical and sociological perspectives. These seemed to provide an inadequate understanding of the complexity of the problem – in particular they fail to understand both technology adoption and post-adoption lived experiences collectively (i.e. interactions with technologies once in the home), and this inadequacy is reflected in the inability of a single model from the dominant theories to tackle both the human (the socio) and non-human (the technical) dimensions: a sociotechnical approach such as DT can address this. These aspects provided the rationale for adopting DT as a research framework, as this appeared to offer the full potential and scope to fill this conceptual gap.

Using the domestication lens as a sociotechnical perspective did not seek causality, in contrast to the normative behavioural models, which are often decontextualised in the search for generalities. Importantly, whilst DT takes account of behavioural and individual decision-making dimensions, it does so in relation to human involvement with technologies, and foregrounds the complexity involved in technology-mediated change and consumption within their social contexts.

Hence, this research approach complements existing frames of knowledge about technology and consumption behaviours. It occupies a middle ground between behavioural and individualistic studies' notions of how people make decisions about purchase, and technical approaches that focus on building interventions and performance outcomes (as outlined in Table 1.1). Thus, using the D lens allowed an opportunity to take a more joined-up perspective by taking the social and material dimensions collectively and not as single isolated events; the issue was reframed by looking through the adopter experience at what happens after people have bought technologies and how they live with such technologies in an ongoing process. Thus DT is developed here as a specific critique of the presumptions of rationality in adoptions and use of technology that are evident in the dominant research and policy discourses and their over-emphasis on a blanket adoption of technological solutions over sustainable behaviour changes in HECB. In sum, the alternative framing used here sought to examine and trace technology's journey into the home, its life cycle and its user interactions in the HH.

13.6 Empirical Implications

The central aim of the empirical research was to explore to what extent Silverstone et al.'s (1992) DT and their four-phase framework of appropriation, objectification, incorporation and conversion could offer an effective explanatory tool for analysis of how homeowner HH adopt and embed EET into their everyday lives. The use of DT enabled the capture of a sociotechnical perspective by putting the social and technological relations at the centre of analysis. As the sociotechnical perspective does not specifically set out to find cause–effect relationships, the adoption of a qualitative approach was justified.

13.6.1 Research data analytical strategy

Semi-structured interviews were conducted in order to determine how well the DT framework could explain the process of adoption and embedding of EET. HH were asked questions on various themes organised across the four phases of the model. In particular, the four-phase framework of DT was used not only as a conceptual tool but also as an analytical and practical heuristic device for the analysis of the qualitative interview data gathered. Primary data was gathered from semi-structured interviews with 23 homeowner HH (26 participants in total) across England (and supported by some secondary data sources) who were defined as adopters The findings, firstly, draw on their expert knowledge as users; secondly, they draw on their memories, reflections, observations and meanings to build a multidimensional, in-depth picture of their lived experiences and interactions with technologies.

13.6.2 Two-tier analysis

A two-tiered analysis was undertaken because it would enable a more in-depth unpacking of the social and technical dimensions – although DT itself does not prescribe, how analysis of the interactions between these dimensions should be undertaken. The justification for a two-tiered analysis lies in the fact that this research problem takes a holistic and social shaping perspective on how users engage with technologies and how they can then shape their everyday practices. The study was interested in what was happening both at the HH and micro levels. This approach was supported by the existing research studies, which had applied DT in many different ways; and of course, DT itself can be conceptually regarded as a process operating at different levels. This enabled a deconstruction of the complexity of the sociotechnical relations in the HH domestication process in a less reductive way.

The application of the four-phase framework for analysis allowed examination of the complexity of the themes encompassing the domestication process in a more concrete and structured way as follows:

- Firstly, using a broader 'whole-house' or HH level of analysis. Here, multiple EET were integrated into the house contributing to its energy efficient sociotechnical reconfiguration (findings in Chapter 10).
- Secondly, using individual 'technology' as a unit of analysis. This examined the domestication of individual EET (findings in Chapter 11).

13.6.3 Household Sample

This research specifically sought to capture adopter HH experiences. HH were selected on the basis that they met the criteria that defined them as 'homeowner occupiers' of an existing single dwelling house (not new build) who had implemented building-specific technological change for improving the energy efficiency of their house. More specifically, they were selected on the basis that they had implemented conventional and basic level measures (e.g. loft insulation) in their homes, and also some of the higher impact intermediate or advanced measures which are more costly, novel and involve non-conventional technologies (set out in Chapter 9, Table 12 and Table 16).

Deeper analysis of the characteristics of what seemed on the surface to be a pre-selected homogenous adopter group (set out in Chapter 9) highlighted a clear distinction within it. This was reflected in the symbolic dimensions of the changes they had chosen. This distinction suggested that these adopters and their home changes could be further subdivided into two groups: between those seeking merely a more energy-efficient house, and those seeking an energy-efficient home but also a greener and 'eco' one. For example, for the 'eco' house group, adopting EET was an extension of their commitment to a greener lifestyle; this was also reflected in other purchase-related and environmentally friendly activities. In contrast, these characteristics seemed less significant in the experiences of the group seeing their home changes being more about achieving EE and less about a distinctive lifestyle. The sample size and qualitative nature of this research meant that it was difficult to compare and contrast these differences more definitely, and therefore it is noted here more as an emergent theme – one possibly worthy of further research.

Nevertheless, despite these subtle differences within the sample they were all still perceived to be early adopters and converters of technology. They all have domesticated multiple technologies in their homes and have actively engaged in conversing with others about their home changes and experiences of the technologies adopted; none have so far rejected the technologies they have adopted; their participation in this research project arguably also marks them out as early adopters and converters.

This sample of early adopters and converters could serve as a test group for learning and feedback for policymakers. For example, Chapter 4 suggested that there was a performance gap in houses and technologies once adopted (between the as-designed and as-lived components), and therefore there is a continued need to learn from the users of technology. How people (adopters) use technologies and then how the building performs as a result of that use have particular implications for policymakers wishing to capitalise on the environmental benefits of EET.

13.7 Theoretical Implications - Response to Objective 1

In responding to the first objective, the research was predominantly concerned with what happens before and post technology adoption in terms of how HH adopt and embed them into their everyday lives. Through this, it was able to visualise and unpack the complexity of what the process of D would look like at the HH level.

13.7.1 Summary of HH level analysis

The HH level analysis highlighted three distinct components relating to the domestication process of EET. First, the pre-existing sociotechnical context of the house and HH – this stressed the role of the pre-existing conditions or the physical legacy of the house and the HH biography in defining HH adoption decision-making. Second, the analysis demonstrated the potential for multiple technology D pathways to be developed simultaneously, e.g. the role of space, time, knowledge learning and skills which change over time and which help in reconfiguring the sociotechnical. Third, the end result of the domestication process leads to a reconfigured sociotechnical system in which the house appears subjectively better for the HH, one that is likely to be measurably more EE, and where HH consumption practices may have changed to some extent. These three dimensions make it clear that the domestication process is far from a being a simple linear four-phase process. Adoption is not a static or singular event or a homogenous experience, and it alone is not enough to understand the lived experience. Contrary to the dominant discourses, adoption is not a meaningless, rationalistic consumer-based activity, but is an activity that mutually interacts with the social and technical dimensions.

13.7.2 Summary of technology-specific analysis

Technology-specific analysis was undertaken of seven distinct EET. They were chosen because they were the types increasingly advocated by policymakers and deemed the most impactful in terms of delivering the desired policy goals. Alongside this, policy often advocated the adoption of multiple measures as no single measure could increase the EE of existing homes and turn them into low carbon ones (discussed in Chapter 2, Section 2.8).

The findings set out in Chapter 11 highlighted detailed aspects of the symbolic and material features of the way the four phases manifested for each technology in terms of why and how HH implement such measures into their homes and how they are then incorporated into their everyday lives. It found that for some specific technologies (e.g. solar technologies), it was possible to trace their progress through the four phases of the domestication process, but this was less apparent with others (e.g. MHVR). In such cases, various phases could arguably be regarded as holding more or less equal significance in the domestication process. This suggests that it is not a static process but one where differing technology attributes determine the ease and speed at which they can be domesticated into HH life.

These findings hold particular implications for current policy design. It has been suggested that the blanket policy approach advocating the adoption of multiple EET is too blunt and fails to take account of the fact that each EET is qualitatively different (discussed in Chapter 10 and 11); it follows from this that HH user experiences are potentially different. This also challenges the rationalistic policy assumptions that adoption alone is sufficient, which is clearly not the case as it does not take account of the fact that each technology has unique characteristics that need to be used appropriately before their intended environmental credentials can materialise. Therefore the technology-focused analysis allows for greater understanding of the complex problem of low technology adoption rates and the issue of why some technologies are more or less successful than others.

13.8 Response to Objective 2

In relation to the second objective, efforts were made to 'determine whether DT offered an effective explanatory tool for the analysis of how homeowners adopt and embed EET into their homes and everyday lives'. This objective required a response to the first objective and then permitted consideration of the theoretical implications of the application of the domestication framework as a conceptual basis and analytical framework in empirical data analysis.

As a theoretical framework and position, DT improved the limitations of the dominant theoretical approaches and models (highlighted in Chapter 6, Section A) by moving analysis of technology adoption as a singular individual behavioural event to perceiving it as a more complex ongoing process which takes account of the social and technical dimensions. Thus, DT can be taken as a critique of the dominant approaches in the literature. This moved the theoretical position into D territory, which required further consideration of how other D studies perceive adoption and embedding (discussed in Chapter 7, Section C). In relation to these studies, the empirical findings in part supported and reinforced many aspects of existing understandings of energy-related technology adoption (summarised in Section 7.5.8). However, it was able to expand this understanding further, in particular by unpacking the complexity of the domestication of building-specific and multiple technology domestications at the HH level through the two-tiered approach adopted – an approach that no other research had undertaken.

13.8.1 A unique dual perspective

Importantly, the two-tiered analysis of empirical data was undertaken not just for contrast purposes, but also for the complementary, yet differing perspectives it could offer on the sociotechnical dimensions. The application of the framework in this way served to demonstrate its flexibility and elasticity as an analytical and conceptual tool. The application of DT in the context of EET reveals its processes in two significant ways. Firstly, its symbolic significance is highlighted as a series of processes within the larger process of 'domesticating EET' by HH; and secondly, materially and physically as technological systems integrating into the pre-existing sociotechnological configuration of the house. These two components manifest simultaneously over time and represent an ongoing and continuous process in constructing and re-constructing the 'biography' of the house.

Through the dual perspective provided by the two-tier analysis, technology is examined in a concrete and multidimensional way; from individual technologies to technologies as systems within the sociotechnical system of the house. The dual perspective also allowed an understanding of its double articulation. For example, SPV is a technology that is not simply consumed; it is also a medium that provides a service to its adoptee once adopted – i.e. as a source of energy or heating – and it is also a source of energy use information which could in turn be used to control and manage it and enhance the technological and environmental performance of the building. DT was previously predominantly concerned with discrete technologies related to media and computing; this research broadens its continuum by applying it to technologies that are building and performance based. It is no longer concerned with a single technology but a whole suite or ensemble of products that come together with accompanying practices and uses; their integration changes what the technology is and alters the domestic sphere that it enters.

13.8.2 The process and the model

The research findings supported claims by previous studies (including those of the originating theorists) that the domestication process should be broadly viewed as *evolutionary* not *revolutionary*, and seen as an ongoing process of change rather than a one-off event. It has also reinforced the view that it is an *untidy* process, seldom stable, often incomplete and continually changing (e.g. Jenson et al. 2009; Aune, 2007; Juntunen, 2014). Through this research, it has been possible to contest and illuminate the seemingly linear appearance of the process by demonstrating its dynamic *non-linearity*. Importantly, it shows that domestication is a complex, cyclical process unfolding over time, in which there are a series of overlapping processes, which do not always occur synchronistically or chronologically. The temporal dimension between phases sometimes appears to be cyclical, sometimes abbreviated, sometimes syncretic or non-syncretic, and sometimes consecutive. Hence, the final observation of the domestication process suggests complexity in each stage and important overlapping linkages between each phase. However, it is important to note that the examined domestication processes only represented a snapshot of the process in time (i.e. at the time of the empirical study data collection).

Considering domestication at the whole-house or HH level (Chapter 10) was necessary to understanding the process more fully (as opposed to considering each phase in isolation). Through the empirical analysis, it has been possible to propose ways of updating a seemingly static model by revealing its complexity, variability and propensity to produce a greater variety of outcomes. However, what happens within and between the different phases can provide important cues for policy intervention. Furthermore, a key finding is that each individual technology suggested a differing domestication process that was determined by its attributes, how easy or how much effort was required to adopt and embed them into HH life. This helps explain why some technologies are commonly adopted whilst others – equally as viable – are not, and has particular implications for policy and the design of technology.

13.8.3 New understandings of the Domestication process to building-specific technologies

As already discussed, DT by its nature seeks to challenge the status quo. From the use of the four-phase framework, it is evident that the appropriation of EET is an active process: where HH are not passive recipients of EETs and technologies are not homogenously used. It is possible to understand why some technologies were selected over others, and see how HH had to actively engage in a process of re-inventing the technological products (materially and symbolically). The way HH then use their home following its reconfiguration embodies a critique in itself. The process of objectification and incorporation highlights a process of resistance and reconfiguration. However, before reconfiguration, a process of re-interpretation and possession must occur, and change in use and in the structure of the house must happen.

The reconfiguration of the existing sociotechnical system of the house results in observable structural changes to the house, and new functions and uses. It is also not a single event where adoption and use materialise into effective use; it is a more complex ongoing process of change that does not end with adoption. In this process, analysis using the domestication lens cannot be removed from the historically specific relations of the HH, the social and cultural relations and the interactions between people, artefacts and technologies. This is an important part of STS thinking.

13.8.4 The social shaping of technology (STS)

The use of DT has begun to throw light on the wider debate about the 'social shaping of technology' concept. Silverstone et al. (1992:27) suggest that 'within this model, technologies are both shaped and shaping and that the balance between the two is both a matter for further theoretical empirical enquiry'. Thus, in the context of this empirical enquiry, the use of the domestication lens helped trace the entry and introduction of technologies in the HH context, and highlighted the need to review both everyday life (the social) and technology (the material). It suggested that neither is everyday life stable nor technology revolutionary, and resulted in both changes and reinforced existing routines in HH. Therefore, technology consumers play an active role in its outcome and purpose in everyday life.

13.9 Response to Objective 3 - Policy implications

The third objective of the research was to consider the policy implications for government and industry in relation to goals to increase EET adoption and reduce HH energy consumption. In particular, it considered the usefulness of the D framework to serve as a heuristic tool for policy interventions for key stakeholders, and explored whether it could aid the formulation of more effective solutions, thus enabling EET to be more widely adopted. The ultimate goal is for the final domestication phase to potentially be open to everyone.

The empirical findings showed that multiple technologies are not homogenously adopted; indeed, due to their differing attributes their usage varies widely. Each EET is domesticated differently: where some are easily domesticated, others are more slowly domesticated. Thus, we may confidently suggest that some EET may be better at contributing to environmental goals than others, and all are likely to result in differing policy outcomes

The HH level analysis showed how HH learn to use and interact with technologies, something that could provide important feedback to policymakers and designers to improve what they do. The information gathered for this study suggests where HH must actively interact with technologies to get the most out of them, and confirms how HH interact and attach meaning to technologies is not uniform. Recognising that people will deviate in their use from what designers and policymakers may have intended is crucial if usage is ever to be more closely directed.

What happens within and between different phases can provide important cues for effective policy interventions. The application of the D lens suggested how policies could be targeted and tailor-made for the differing phases within the process of D, and also designed to take account of the differing characteristics of differing technologies. What this means is that the four phases could be used as a rough guide for policy interventions, e.g. providing information tools at the right time and place when HH are making choices or decisions, such as in the appropriation phase. DF could therefore provide a useful heuristic tool for a range of policy interventions detailed in Chapter 12, Section C.

It needs to be recognised that polices need to go beyond the short-term aim of just trying to encourage adoption and address the long-term biography and life cycle of the technologies once adopted. A policy mix should support how people live with technologies, and ultimately support the longevity and integrity of technologies to aid conversion.

13.10 Recommendations for Future Research

While addressing a gap in the existing research literature, this study has presented findings from 23 HH to highlight the processes of how they domesticate EET. It has been possible to identify some of the limitations of the study and suggest areas for future research. The suggestions for further work are:

13.10.1 Greater geographical spread

This research sought a UK perspective, but due to constraints of time and resources, it only managed to capture respondents from England, mostly in London with smaller sub-groups from Kent, Wiltshire and Birmingham. Therefore, one of the key limitations of this study is that it has not been able to capture a more diverse geographical spread of participants. Future research could seek to capture a greater geographical spread of data from across the whole of the UK, and from urban, suburban and rural locations. This would yield a more comprehensive picture of the dynamics of domestication, and help determine whether there are geographical variations – something that has not been considered in this research.

13.10.2 A cross-cultural comparison

Linked to the limited geographical spread of data are concerns that much of the existing research on EE and DT appears to be biased towards overseas case studies (e.g. Juntunen, 2014; Aune, 2000 and 2007 are based on case studies in Finland). Thus, a cross-cultural comparison between the UK and other countries across Europe could further validate the domestication approach in understanding EE issues and technology adoption.

13.10.3 Diversity in a socio-demographic dimension

Another key limitation of the study is that it has relied upon self-selection for participation and selected adoptees, excluding 'non-adopters' of EET. Together, this created scope for producing a biased sample even though the people coming forward may be to some extent typical of the people adopting EET (mostly white, middle class, older homeowners). Using the purposive sampling approach, the study sought to ameliorate this bias as much as was feasible, although it could not be completely avoided and the extent of the bias cannot be fully determined. Any further research, through a more effective sampling methodology, could seek to alleviate this bias.

Bias could be at least partially dealt with by using a form of representative sampling (e.g. a targeted quota sample selection), and/or through the mixed use of a quantitative survey method with qualitative methods; these should ensure the capture of data from a greater cross section of socio-demographic groups. What is currently missing in this research is an examination of whether there are ethnic differences, in addition to age and gender variations. Indeed, differences across ethnic groups are yet to be considered in existing domestication research and are under-represented in wider energy-related studies. Linked to this is the question of whether or not there are differences between affluent and poorer HH, and those in social housing compared to those in private housing. In particular, it would be beneficial to examine the effect of EET adoption on HH that did not specifically purchase the technology (especially those in social housing). The focus on adopters in this research sample means it does not examine why some HH could reject technologies once they are adopted – an area that could further develop and test the usefulness of the D lens.

13.10.4 Longitudinal research

The research suggested that domestication is an ongoing evolutionary process of change, which means that the full effects of domestication are yet to materialise. The very nature of this investigation captures a snapshot of a very specific period in time in the domestication process. Therefore, it cannot assume use, acceptance, and other adaptations will remain the same over future periods of time within the biography of the house and HH. In order to capture greater depth of the domestication processes of multiple EET, a more longitudinal research perspective would be desirable.

13.10.5 Knowledge and learning

The research began highlighting the different types of knowledge, know-how and learning homeowners utilised in aspects of the domestication process. In particular, 'learning by doing' and 'trial and error' played a key role in how people integrated different technologies in their everyday life. Existing research suggests that the cognitive process of learning continues throughout the life of the technology, hence further research on this learning process through a longitudinal strategy could examine whether the learning changes to a more stable situation over time where perhaps it acquires a more 'automatic' and/or 'habitual' cognitive status. It would tackle questions of whether this relatively newly adopted ensemble of technologies and their domestication configurations would be different in a few years' time.

13.11 Chapter Conclusion

This research makes a unique contribution to academic understandings of DT and offers scope for its theoretical modification and development. In particular, it concludes that the domestication of technologies occurs simultaneously alongside a broader continuous process of HH change that contributes to energy efficient sociotechnical reconfiguration. The specific nature of sociotechnical interactions can support, speed up or slow down successful domestication of EET. This research reinforced the view that improving housing EE at the same time as tackling HH energy consumption requires both technical and behavioural interventions. In addition, it contributes to debates on the interaction between sustainability policy, energy efficiency technologies, homeowners' everyday experiences and domestic practices. Finally, more detailed elucidation of the dynamic four-phase domestication model could contribute to achieving wider diffusion of HH energy-efficient technologies.

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APPENDICES

Appendix 1 - Interview Topic Guide

Organisation of Questions according to Domestication four-phase framework

1. Appropriation: purchase/installation

- What were your motivations and reasons associated with acquiring EET?
- When did you move to the house?
- What changes have been made since moving into the house?
- How were EET introduced into homes?
- How did you make decisions regarding EET purchases?
- What are the processes involved in finding the EET?
- How did you decide on which products to go with?
- How did you choose one product over another?
- What kind of information did you rely on?
- How did you purchase? E.g., did you physically go in shop or buy online or bought by others?
- When purchased?
- How much did it all cost? E.g. What were the cost of EET and the installation cost?
- Who in the household makes the decision to have the technology installed?
- What significance or status do EET acquire once installed;
- What benefits are sought and experienced?
- Why did you go for certain EET? E.g., what values or needs would they meet?

2. Objectification: location/display

- How did the installation take place?
- Who installed?
- Were there any constraints in installation along the way?
- How did you problem solve/ how did you innovate?
- When did things happen?
- How long did it take to install?
- How long did it take to complete the project: was it all in one go or in phases?
- Did changes coincide with other home improvements?
- Where are these technologies located physically in the home?
- What controls need to be operated?
- Is it is easily accessible?
- What values (e.g. aesthetic) does this technology add to everyday life?

3. Incorporation - use in everyday life

- Is there a particular lifestyle the householders seeks? (examine the way they talk about things)
- Do established practices emerge?
- How do EET become embedded into everyday-life routines?
- How are products used in everyday life?
- Are some products used differently from their intended purposes?
- Are some products used in more than way?
- What role does visibility/invisibility play in its use (increase/decrease in use)
- Early use: how did it feel afterwards? Is there any maintenance/repairs that needed to be carried out?
- Prior and post retrofit EPC rating if known/ gas/electricity bills (ask for figures or whether or not consumption changed/increased/decreased?
- Early use: how did it feel afterwards? Is there any maintenance that needed to be carried out?

- Routinized use – How is it now? Have they forgotten the presence of EET adoption?
- Does the technology interact with other household activities (e.g. showering, cooking)?
- Has HH behaviour changed since adoption?
- How are values, tastes, styles expressed in the symbolic aspects through everyday use?

4. Conversion - 'taken-for-granted' status

- How is the EET's meaning shared with others?
- Has it reached a taken-for-granted' status in everyday life?
- What has been the effect of these products on quality of life? (Have some been more effective than others? How has it affected family members?)
- Has EET been the object of conversations? (e.g. Do they talk to family, friends and interested parties about EET adopted and home changes)
- Do their attitudes something about their membership of a specific peer group or culture? Do they have friends with similar interests?
- Who in the family interacts with the EET most? Monitors it? Is it gendered?
- Routinized use – is the presence of the product forgotten?
- How did you find the usability of these products?
- Has the way you use the product changed overtime?
- Are you using any products differently from its intended purposes? (if so in what way)
- What meanings do people seek from energy efficiency technologies or from a more energy efficient home?
- What would you differently now from experiences?
- What have you learnt about this process of home change?
- Any planned future changes to the home?

Appendix 2 Household Background Information

<u>**Please use an X or specify details to answer the questions**</u>

1. Building Age	Estimate date property built:			
2. No of Bedrooms	--			
3. Gender:	Female		Male	
4. No of People in your home	No of Adults (over 18)		No of Children (under 18)	
5. Your Age:	Under 20	20-24	25-29	30-34
	35-39	40-44	45-49	50-54
	55-59	60-64	65-69	70 or over
6. Employment:	Employed full time	Employed part-time	Self Employed	Homemaker
	Volunteer	Retired	Studying	Unemployed
	Long-term sick	Other please specify:		
7. Field of work (if applicable):	Accountancy	Architecture/Construction	Charities/ Not for profit	Consultancy
	Economics	Education	Energy/Utilities	Environmental services
	Energy advice/consultancy	Financial services	Health	IT

	Law/legal services	Government/civil service	Manufacturing/engineering	Media/Arts
	Other please specify:			
8. Qualifications	No Qualifications	GCSE/O-Level/CSE/ NVQ1-2 equivalent	A level/NVQ3 or equivalent	Degree/HNC/ or equivalent
	PHD/DPhil or equivalent	Other		
9. Income (optional)	Under £14,999	£15,000-£29,999	£30,000-£49,999	£50,000-£99,000
	£100,000+			
10. Ethnicity	Please describe your ethnic background (e.g. White British, British Asian, etc.):			

NB: Please note all data is held securely and treated confidentially and is only used by the researcher and is not disclosed or shared with anyone else under any circumstances. For further clarification please contact the researcher: Rosita Aiesha: ar58@gre.ac.uk

Appendix 3 Environmental Actions – you already undertake

Please delete to put either Yes or No against all the things you do or do not do:

Purchase decisions

- buy home insulation **Yes/No**
- buy renewables (e.g. Solar PV) **Yes/No**
- buy energy efficiency bulbs/LED **Yes/No**
- energy efficient appliances **Yes/No**
- buy organic **Yes/No**
- fair trade **Yes/No**
- avoid aerosols **Yes/No**
- compost Garden waste **Yes/No**
- compost kitchen waste **Yes/No**
- avoid toxic detergents **Yes/No**
- reuse paper **Yes/No**
- reuse glass **Yes/No**
- buy recycled writing paper **Yes/No**
- buy recycled toilet roll **Yes/No**
- shop local stores **Yes/No**
- use own bag for shopping **Yes/No**
- less packaged items **Yes/No**

Habits

- turn off water when soaping in shower **Yes/No**
- reduced number of showers **Yes/No**
- reduced toilet flushes **Yes/No**
- turn Off tap when cleaning teeth **Yes/No**
- turn Off tap when washing dishes/ wash in bowl **Yes/No**
- reduce heat in used room **Yes/No**
- reduced hot water temperature **Yes/No**
- keep heating low to save energy **Yes/No**
- shower rather than Bath **Yes/No**
- wait till for full load for washing machine **Yes/No**
- wait till for full load for dishwasher **Yes/No**
- put on more clothes rather than heating up **Yes/No**
- lights off when not in room **Yes/No**
- set the thermostat to 18° maximally **Yes/No**
- avoid eating meat **Yes/No**
- do not leave appliances on standby **Yes/No**

Recycling

- Glass **Yes/No**
- Newspaper **Yes/No**
- Cans **Yes/No**
- plastic bottles **Yes/No**
- furniture to charity **Yes/No**
- clothes/household goods to charity **Yes/No**

Transport

- Drive energy efficient car **Yes/No**
- Do not own a car **Yes/No**
- walking short distances **Yes/No**
- cycling short distances **Yes/No**
- cycling to work **Yes/No**
- use public transport most often to get about **Yes/No**

PhD Energy Research Study (2015)

PARTICIPANT CONSENT FORM

To be completed by participants over 18 only.

- I have read the information sheet about this study
- I have had an opportunity to ask questions and discuss this study
- I have received satisfactory answers to all my questions
- I have received enough information about this study
- I understand that I am / the participant is free to withdraw from this study:
  - At any time (until such date as this will no longer be possible, which I have been told)
  - Without giving a reason for withdrawing
  - (If I am / the participant is, or intends to become, a student at the University of Greenwich) without affecting my / the participant's future with the University
- I agree to take part in this study ☐

Signed (participant)	Date
Name in block letters	
~~Signed (parent / guardian / other) (if under 18)~~	~~Date~~
Name in block letters	
Signature of researcher	Date
This project is supervised by: DR Anne-Marie Coles University of Greenwich; E-mail: A.Coles@greenwich.ac.uk	
Researcher's contact details (including telephone number and e-mail address):Rosita Aiesha: ar58@gre.ac.uk	

Appendix 6 Housing and Socio-demographic Profiles

Respondent Profile (26 people)

No	Code Name	Gender	Age Group	Ethnicity	Qualifications	Income	Employment	Total in HH	No of children (under 18)
1	Dawn	Female	35-39	White British/Hungarian	Degree	50-59k	Homemaker	2	2
2	Yanis	Male	45-49	British Asian	MBA	40-49k	F/T	4	2
3	Pete	Male	40-44	White British /Polish	Degree	40-49k	F/T	3	0
4	Dan	Male	45-49	White British /Asian	Degree	40-49k	F/T	2	0
5	Lena	Female	65-69	white British	A-Level/NVQ 3	30-39K	Retired	2	0
6	Neil	Male	65-69	white British	PhD/Equivalent	30-39K	Retired	3	0
7	Steve	Male	55-59	white British	Degree	70K	F/T	3	1
8	Anne	Female	65-69	white British	Degree	20-29K	P/T	2	1
9	Rita	Female	70+	white British	Degree	20-29K	Retired	2	0
10	Molly	Female	60-64	white/Irish	NVQ4/5	20-29K	P/T	2	0
11	Amy	Female	40-44	white/Asian	Degree	40-49k	F/T	5	3
12	Miles	Male	35-39	white British Irish	Degree	30-39K	F/T	2	0
13	Dean	Male	50-54	White British	Degree	30-39K	Homemaker	5	3
14	Kelly	Female	40-44	White British	Degree	70K	Homemaker	3	1

15	Nina	Female	40-44	Asian/British	Degree	60-69k	F/T	1	0
16	Lilly	Female	50-54	White British	Degree	40-49k	F/T	2	1
17	Billy	Male	70+	White British	PhD/Equivalent	50-59K	Retired	2	0
18	Jenny	Female	55-59	White British	Degree	70K	Retired	3	0
19	Kate	Female	50-54	White British	Degree	70K	P/T	2	2
20	Amanda	Female	65-69	White British	Degree	20-29K	Retired	2	0
21	Jim	Male	55-59	White British /Irish	A-Level/NVQ 3	40-49k	F/T	2	0
22	Keira	Female	40-44	Asian/British	Degree	50-59K	Homemaker	6	3
23	Jill	Female	40-44	White British	A-Level/NVQ 3	50-59K	P/T	5	3
24	Patrick	Male	70+	White British	Degree	20-29K	Retired	2	0
25	Micky	Male	55-59	White British	Degree	70K	Retired	3	0
26	Jack	Male	70+	White British	Degree	20-29K	Retired	2	0

Housing Profile (23 houses)

	Code Name	Location	Years	No of Beds	Age of House	type house	Changes	Insulation	Renewable	Other
1	Dawn	London	5	3	1919 - 1944	End-Terrace	Whole House	1	1	1
2	Yanis	SE	11	3	1919 - 1944	Semi	Basic	1	0	0
3	Pete	London	12	4	1919 - 1944	End-Terrace	Whole House	1	1	1
4	Dan	London	5	4	Before 1919	Semi	Whole House	1	1	1
5	Lena	London	4	2	1981 - 1990	Detached	Whole House	1	1	1
6	Neil	London	6	3	Before 1919	End-Terrace	Whole House	1	1	1
7	Steve	London	17	5	Before 1919	End-Terrace	Whole House	1	1	1
8	Anne	London	18	4	1919 - 1944	Mid-Terrace	Whole House	1	1	1
9	Rita	London	18	5	Before 1919	End-Terrace	Intermediate	1	0	0
10	Molly	London	23	2	Before 1919	End-Terrace	Intermediate	1	1	0
11	Amy	London	1	?	Before 1919	Mid-Terrace	Basic	1	0	0
12	Miles	London	3	3	1945 - 1964	Mid-Terrace	Intermediate	1	1	0
13	Dean	London	18	4	Before 1919	End-Terrace	Intermediate	1	1	0
14	Kelly	SE	6	?	Before 1919	Semi-Detached	Basic	1	0	0

15	Nina	London	7	2	1919 - 1944	Mid-Terrace	Basic	1	0	0
16	Lilly	SE	17	4	1945 - 1964	Detached	Intermediate	1	0	0
17	Billy	London	33	3	Before 1919	Mid-Terrace	Whole House	1	1	1
18	Jenny	London	15	5	Before 1919	End-Terrace	Whole House	1	1	1
19	Kate	London	17	6	Before 1919	Semi-Detached	Whole House	1	0	1
20	Amanda	SW	7	3	Before 1919	Semi-Detached	Intermediate	1	1	0
21	Jim	SE	13	3	1919 - 1944	detached	Basic	1	0	0
23	Keira	SW	10	4	1945 - 1964	Semi-Detached	Basic	1	0	0
24	Jill	London	12	4	Before 1919	Mid-Terrace	Basic	1	0	0

Appendix 7 Ethics Protocol

Importantly, as this research is qualitative social research, focusing on 'people, and their relationships to each other and to the world' it needed to be more mindful of situations that raise ethical issues (in terms of respecting the rights of others, avoiding harm and dealing with unexpected issues) (Walliman, 2005:340). Therefore, ethical issues in research could arise from any number of these two broad areas. Within the present research (from the best intents and purposes), these issues are considered, addressed and avoided through the following approach:

1. Clear research plan, aims/objectives - which are specified clearly to the participants of research;

2. Participant selection – gaining prior informed consent from all participants;

3. Offering complete anonymity and confidentiality for all participants and in some cases the sources of strategic documents or data sets;

4. Protecting participants from harm – participants were given a clear understanding of the issues to be covered and highlighting that no 'sensitive' topics will be discussed (or needed to be discussed and which was not required in this research topic);

5. Protecting researchers from harm – although most householder interviews were undertaken in people's homes adhering to prior protocols to protect from any potential risks to researcher (Ritchie & Lewis, 66-71)'; and

6. No findings have been made public without prior permission from participants.

Furthermore, in line with good practice, all these factors have been systematically addressed via the researcher's 'ethics' application form validated and approved by the University Ethics committee in order to proceed with research activities.