Retrofitting the domestic built environment: investigating household perspectives towards energy efficiency technologies and behaviour

Marcos Pelenur

Department of Engineering

University of Cambridge, Queens' College

This thesis submitted for the degree of

Doctor of Philosophy

2013

I would like to dedicate this thesis to my loving wife Kirsty, who left *Aotearoa* with me to to pursue a dream in Cambridge. This journey would not have been possible without your patience, encouragement, and support.

This thesis is also dedicated to my loving parents Lisette and Horacio, who always supported me selflessly. Thank you.

Declaration

I, Marcos Pelenur, hereby declare that this thesis is the result of my own work and includes nothing which is the outcome of work done in collaboration except where specifically indicated in the text. This thesis does not exceed the prescribed 65,000 word or 150 figure limit.

Signed:

Date: 14 October 2013

Acknowledgements

The research in this thesis would not have been possible without the support, patience and encouragement of many people. Foremost, I would like to thank my supervisor, Dr. Heather Cruickshank. Starting from the MPhil, and following through to the PhD, Heather graciously supported me with insightful advice, words of encouragement, and a sympathetic ear. I am proud to be one of her students.

I would also like to thank the capable staff at the Centre for Sustainable Development, Rosalie Orriss and Sian Owen, as well as the full-time faculty, Dr. Dick Fenner and Prof. Peter Guthrie. Together, they made the Centre for Sustainable Development a warm and welcoming environment in which to research. Similarly, I would like to acknowledge my fellow PhD students and friends at the Centre. We shared the victories and shouldered the frustrations together. For that comradery, I am forever grateful.

This research would not have been possible without the generous financial support of the Cambridge Commonwealth Trust, the Department of Engineering, Queens' College, and the Engineering and Physical Science Research Council. I am indebted and grateful to these institutions for their continual support.

I would also like to thank all of the friendly interviewees in Manchester and Cardiff, who opened their homes to me and provided many welcomed cups of tea. The shared conversations and stories made the hours of door-knocking worthwhile. I am also grateful to my advisor, Dr. Doug Crawford-Brown and the anonymous reviewers who commented on my papers and this thesis. This thesis is undoubtedly better as a result of their feedback.

Finally, I would like to acknowledge the two kings that solemnly sat on my desk as photos and watched over me during my years of research. Thank you HM King Siaosi Tupou V for reminding me that every man should be the king of their island, no matter the size, and thank you King Arthur Pendragon for being an inspiration of conviction and magic.

Summary

Retrofitting the UK domestic built environment presents an excellent opportunity to improve its energy performance. However, retrofitting homes is a complex challenge conflated by multiple factors. Due to this complexity, a shortfall exists between the full potential and realised adoption of energy efficiency measures in the UK, a phenomenon termed the 'Energy Efficiency Gap'. While a number of technical or economic factors may help explain this gap, difficult to quantify factors, such as social motivations, barriers, and viewpoints towards energy are also significant and often under-emphasised in public policy. As such, in order to improve the understanding of the Energy Efficiency Gap and the uptake of future retrofit initiatives, this research adopted a socio-technical approach that considered social and technical retrofit factors together.

Specifically, this research collected data from interviews, questionnaires, and a Q Study in the cities of Manchester and Cardiff, alongside a questionnaire that measured energy efficiency technology and behaviour preferences. An original contribution to knowledge was using the data to empirically identify motivations and barriers to adopting energy efficient technologies, as well as identifying household viewpoints towards energy use and linking them to retrofit technology and energy efficiency behaviour preferences. As a result of this research, specific policy recommendations are presented to help promote energy efficiency retrofits in the UK. This research was carried out as part of the Engineering & Physical Science Research Council and Sustainable Urban Environment research programme, *"Re-Engineering the City 2020-2050 Urban Foresight and Transition Management (RETROFIT 2050)"*.

Contents

List of Figures

List of Tables

Nomenclature

Mathematical symbols

Φ	Odds ratio
π	probability
c	Number of columns
df	Degrees of freedom
E	Expectation
H_1	Alternative hypothesis
H_o	Null hypothesis
m_{ij}	Number of participants who selected item i on the first variable and item j in the second
n	Number of participants
r	Number of rows
$X^2_{MM}(AL)$	First-order corrected Rao-Scott chi-square statistic for multiple by multiple response
$X^2_{SM}(AL)$	First-order corrected Rao-Scott chi-square statistic for single by multiple response

Equation subscripts

i	row subscript index

j	column subscript index

Acronyms

CO_2	Carbon dioxide
$MtCO_2e$	Million metric tonnes of carbon dioxide equivalent
Q	Q Methodology
ANOVA	Analysis of Variance
BH step-up	Benjamini-Hochberg procedure
BRE	Building Research Establishment
CBI	Confederation of British Industry
CERT	Carbon Emissions Reduction Target
CESP	Community Energy Saving Programme
CHP	Combined Heat and Power
DEC	Display Energy Certificates
DEFRA	Department of Food and Rural Affairs
ECO	Energy Company Obligation
EEPfH	Energy Efficiency Partnership for Homes
EPC	Energy Performance Certificate
EPSRC	Engineering & Physical Science Research Council
ERDF	European Regional Development Fund
FDR	False discovery rate
FIT	Feed-in Tariff
GHG	Greenhouse has

Nomenclature

HEED	Homes Energy Efficiency Database
IPCC	Intergovernmental Panel on Climate Change
MANOVA	Multivariate analysis of variance
PACE	Property Assessed Clean Energy
PBC	Perceived behaviour control
PV	Photovoltaic
RdSAP	Reduced Data Standard Assessment Procedure
RHI	Renewable Heat Incentive
RICS	Royal Institute of Chartered Surveyors
RtF	Retrofit for the Future
SAP	Standard Assessment Procedure
SM	Single-by-multiple
SUE	Sustainable Urban Environment
TPB	Theory of Planned Behaviour
TRA	Theory of reasoned action
TSB	Technology Strategy Board

1 | Introduction

This PhD was conducted as part of the Engineering & Physical Science Research Council (EPSRC) Towards a Sustainable Urban Environment (SUE) research programme, *"Re-Engineering the City 2020-2050 Urban Foresight and Transition Management (RETROFIT 2050)"*. The aim of the overarching research programme was to illuminate challenging but realistic social and technological options for systemic retrofitting of the United Kingdom's urban built environment, specifically using Greater Manchester and Cardiff/South East Wales as case studies. Manchester and Cardiff are both cities of interest for retrofitting because "both have long industrial histories, both have suffered decline in recent decades and both are seeking to overcome this decline, regenerating themselves into modern, vibrant cities" [RETROFIT 2050, 2012]. In support of this selection, the building stock in Manchester and Cardiff also stands to benefit by systematic retrofitting, since as of 2012 there are still approximately 500,000 untreated lofts and cavity walls in Manchester [Low Carbon Housing Retrofit, 2012], and only approximately 18% of homes in Wales have cavity wall and loft insulation fitted [National Refurbishment Centre, 2012].

While retrofitting the UK domestic built environment presents an excellent opportunity to improve its energy performance; the scale of the challenge should not be underestimated [Kelly, 2009, 2010]. Retrofitting homes is a complex task conflated by multiple factors, ranging from pure economics to subjective psychology [Dixon & Eames, 2013; Institution of Mechanical Engineers, 2009; Kelly, 2009; Lior, 2010; Stafford *et al.*, 2012]. Such complexity invites inter-disciplinary collaboration and research. As such, in order to better understand how systemic city-wide retrofitting can be promoted, this research adopted a socio-technical approach that considered social and technical retrofit factors together.

Specifically, the original contribution to knowledge is empirically identifying motivations and barriers to adopting energy efficient technologies in Manchester and Cardiff, and linking those motivations/barriers to demographics [Pelenur & Cruickshank, 2012a, 2013a]. A further contribution is identifying household viewpoints towards energy consumption and linking them to retrofit technology and energy efficiency behaviour preferences [Pelenur & Cruickshank, 2013c]. As a result of this research, specific policy recommendations are presented to help promote city-wide energy efficiency retrofits in the UK.

Before introducing this research further, it is worth defining two important terms used throughout the thesis: *retrofitting* and *the built environment*.

1.1 Definitions

The terms *retrofitting* and the *built environment* are both broad with multifaceted definitions based on context. For example, the National Refurbishment Centre, defines *retrofitting* as the installation of a specific energy efficiency measure; while *refurbishment* is defined as the installation of multiple measures applied to the home sequentially, or as part of a whole home solution [National Refurbishment Centre, 2012]. For the purposes of this research, the term *retrofitting* is simply defined as the installation of individual or multiple energy efficiency measures to an existing building. An energy efficiency measure is any technology that improves the energy performance of the home, such as loft insulation, advanced heating controls, and renewable energy generation technologies.

Similarly broad, the *built environment* is defined as all buildings, places, and settlements that are created or modified by people everywhere, for example: homes; shops; schools; workplaces; hospitals; parks and recreational areas; and green and blue spaces [The Government Office for Science, 2008].While physical characteristics partly define the built environment, it is also shaped by the way in which people use it, and both aspects evolve over time [The Government Office for Science, 2008; Tweed & Sutherland, 2007]. As such, this broad definition allows for a wide range of research topics on multiple built environment themes. For example, a bridalway may be the subject of both social cultural heritage research, and geo-technical soil surveying. Therefore, in order to delimit a more focused scope of research, this thesis specifically investigated improving the uptake of energy efficiency retrofits in the domestic built environment using Manchester and Cardiff as case studies, i.e., improving the energy performance of existing city homes.

1.2 Thesis structure

This introductory chapter defines the rationale for the research and sets out the thesis context, research questions, and problem definition.

Chapter 2 is the literature review that examines the extant scholarship relevant to energy efficiency retrofits in the domestic built environment. The literature review is multi-disciplinary and synthesises multiple strands of research relevant to home retrofitting, including: engineering; sociology; psychology; and economics.

Chapter 3 presents the research design in two parts, first by theoretically outlining the research philosophy and methods, and second by describing the practical implementation of the design.

Chapter 4 outlines the combined and individual results based on research method and location (Manchester and Cardiff).

Chapter 5 then discusses the implications and significance of the results, with respect to the wider UK as well as comparing and contrasting between Manchester and Cardiff.

Finally, Chapter 6 presents the conclusions and recommendations to the target audience. By better reflecting the relationship between households and energy use, the aim of the research is to recommend ways to improve the effectiveness of future retrofit programmes.

1.3 Problem overview

Retrofitting the UK domestic built environment presents an excellent opportunity to cut CO_2 emissions, reduce national energy demand, and improve building performance [Kelly, 2009; Stafford *et al.*, 2012]. Currently, the heating and moving of air and water, and the use of appliances in existing homes accounts for 27% of all the anthropogenic carbon emissions in the UK, and an estimated 72% of household energy is used for space and water heating [Defra, 2007; Department of Energy and Climate Change, 2012b; Kelly, 2009, 2010]. However, retrofitting the domestic built environment is a complex challenge, conflated by many factors including the diversity of the building stock, range of occupant behaviour, and low new-build rates [Dixon & Eames, 2013; Institution of Mechanical Engineers, 2009; Kelly, 2009; Lior, 2010; Stafford *et al.*, 2012]. The result is that there exists a shortfall between the full potential and realised adoption of energy efficiency measures in the UK, a phenomenon termed the 'Energy Efficiency Gap' [Jaffe & Stavins, 1994]. In OECD countries, the energy savings loss due to the Energy Efficiency Gap is estimated at 30% of the total potential energy savings of the measures [Weber, 1997].

While a number of technical or economic factors may help explain this gap, difficult to quantify factors, such as social motivations, barriers, and viewpoints towards energy are also significant and often under-emphasised in public policy [Allcott & Mullainathan, 2010; Defra, 2008; Karvonen, 2013; Wilson & Dowlatabadi, 2007]. Therefore, a balanced approach that considers multiple factors together may be an effective means to address the Energy Efficiency Gap [Lutzenhiser, 1992; Stephenson *et al.*, 2010] . With this objective, this research adopted a socio-technical approach that considered retrofit social and technical factors together; in order to improve the adoption of retrofit programmes and the energy performance of the domestic built environment.

1.4 Research aims

The primary aim of this thesis was to identify UK household perspectives towards energy efficient technologies and behaviour, in order to help reduce domestic energy demand in the context of large UK cities. This was achieved by investigating the motivations and barriers to adopting energy efficient technologies, as well as identifying household viewpoints towards energy use and linking them to retrofit technology and energy efficiency behaviour preferences. The overall significance was to demonstrate a socio-technical approach to improve the uptake of future retrofit programmes.

1.5 Research questions

The research design and implementation were carried out to answer the following questions in the context of large UK cities:

- What are the viewpoints that the general public have about energy use in their homes?
- What are the barriers preventing households from adopting retrofit technologies and energy efficiency behaviours?
- What are the motivations driving households to adopt retrofit technologies and energy efficiency behaviours?
- What associations exist between household viewpoints towards energy use and their preference for various retrofit technologies and energy efficiency behaviours?

By answering these questions and synthesising the results, recommendations are presented to help UK cities address the Energy Efficiency Gap.

1.6 Target audience

The results, conclusions, and discussion are relevant to UK city-scale stakeholders, specifically:

- **Academics and researchers**: this research is targeted at academics and researchers investigating domestic retrofits in the UK, as well as social scientists investigating attitudes towards energy use.
- **Local city and county councillors**: the results are relevant to local city scale policy makers who are implementing retrofit programmes and policy.
- **National government policy makers**: at the national level, this research is also relevant to policy makers who are coordinating retrofit policy and initiatives. The results allow them to compare between two large UK cities, and improve the implementation of national domestic retrofit policies.

- **Construction & built environment industry professionals**: city planners, engineers, architects, and urban designers who are all working to improve the energy efficiency of the domestic built environment may benefit from this research.

- **Non-government organisations**: domestic focused but non-industry and apolitical organisations, such as the Energy Saving Trust, may also gain from this research as it provides insights that can be used to improve retrofit and resident engagement programmes.

1.7 Personal motivation

As a Chartered Engineer, the personal motivation to carry out this PhD was based on two observations acquired from my MPhil research[1] [Pelenur, 2010; Pelenur & Cruickshank, 2013b], and from several years of working as a professional in the energy utility industry. First, a great number of households waste energy either through occupant carelessness or poorly performing building fabric. Second, proven energy efficiency retrofits that are both cost effective and easy to install are not widely adopted. As such, academic curiosity spurred the investigation into this apparent paradox, 'given that there is scope to improve household energy performance, why are retrofit measures and energy efficiency behaviours not more widely adopted?'

Methodologically, this research approached the problem with the underlying belief that buildings don't use energy; people do [Janda, 2011]. Hence, the research methods focused on understanding household retrofit motivations, barriers, and viewpoints towards energy use, as well as preferences towards energy efficiency technologies and behaviours. The aim was to answer the research questions, and produce a balanced set of social and technical recommendations to increase the uptake of retrofit measures, thereby improving the energy performance of UK homes.

[1] MPhil Dissertation title: A study of energy management and its effect on well-being: can we thrive by using less energy?

1.8 Summary

In summary, this research was motivated by identifying ways of overcoming the Energy Efficiency Gap in UK households. Practically, since the problem was conflated by multi-disciplinary issues, a socio-technical approach was adopted. Specifically, the research was conducted in Manchester and Cardiff, and investigated retrofit motivations, barriers, and associations between technology/energy efficiency behaviour preferences and household viewpoints towards energy use. The conclusions from this research may also be applicable to other large UK cities, and based on the synthesis of results, a set of balanced recommendations are presented to improve the effectiveness of future retrofit programmes.

2 | Background

This chapter presents the extant scholarship relating to energy efficiency retrofits in the UK domestic built environment. The purpose is to review the various academic perspectives applied to understanding home energy performance, and highlight the unique contribution this research makes within an identified knowledge gap.

First, the context is outlined with a discussion of the existing UK building stock retrofit challenges and opportunities, particularly in Cardiff and Manchester, including physical characteristics and building regulations. Following the context, technical retrofit solutions are explored in the form of energy efficiency technologies, including a review of government policies in place to support their adoption. The gap between the full potential and realised adoption of these technologies (i.e. the Energy Efficiency Gap) is then discussed from various academic perspectives. In order to address this phenomenon, a knowledge gap is identified for more inter-disciplinary research that empirically considers both social and cultural retrofit factors alongside traditional technical and econometric measures. Hence to address this gap, the literature review concludes by presenting a socio-technical Energy Culture model, specifically developed to link retrofit household barriers and motivations with retrofit technologies and social attitudes towards energy.

2.1 Retrofitting the UK domestic built environment

Among the many opportunities to study the built environment, this research specifically narrowed its focus to retrofitting existing UK dwellings to improve their energy performance. As part of the RETROFIT 2050 research programme, the scope of the study was further narrowed to dwellings in the Manchester Metropolitan

District and the Cardiff Unitary Authority. Manchester and Cardiff are both cities of interest for retrofitting because of their strong industrial histories and potential for regeneration [RETROFIT 2050, 2012]. The building stock characteristics and retrofit potential for the UK, Manchester, and Cardiff are described in the following sections.

2.1.1 Building stock

With millennia of history, the UK's domestic built environment now reflects a rich range of diverse housing types, sizes and age. As of 2010, there were 26.59 million households in the UK, with 22.19 million in England and 1.32 million in Wales [Department of Energy and Climate Change, 2012b]. Figures 2.1, 2.2 and 2.3 present the segmentation of UK homes according to dwelling type and age over time.

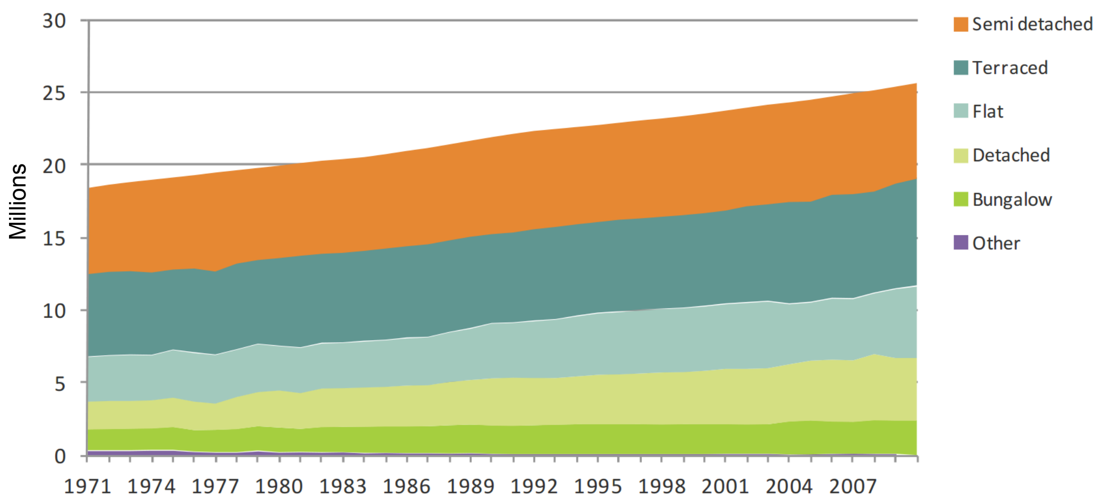

Figure 2.1: Housing stock distribution by type (millions)
Figure from: [Department of Energy and Climate Change, 2012b]

The building stock is also affected by a low demolition rate [Boardman *et al.*, 2005]. As a result, the UK domestic built environment is composed of a mix of historical homes. Figures 2.1, 2.2 and 2.3 highlight how the proportion of existing homes for all periods have stayed roughly the same, resulting in a varied housing

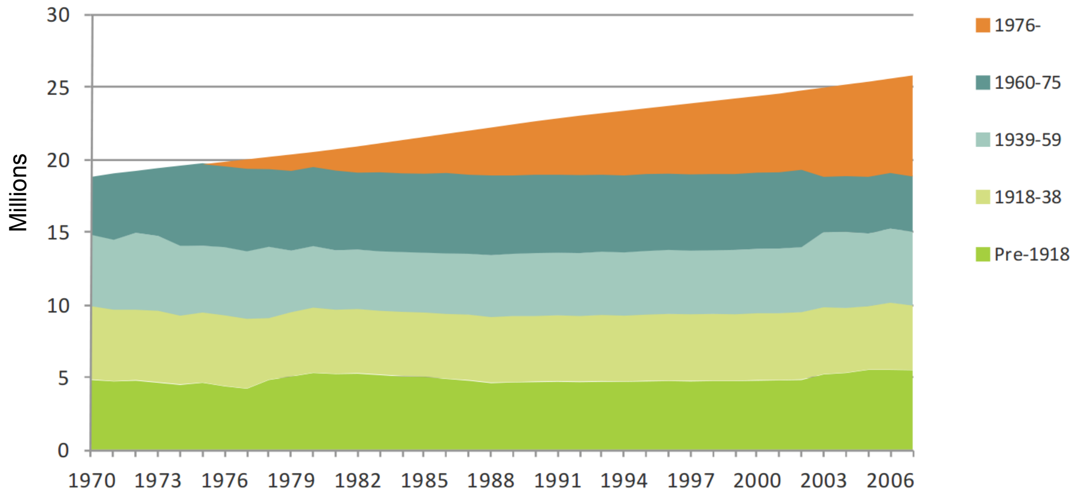

Figure 2.2: Housing stock distribution by age to 2007 (millions)
Figure from: [Department of Energy and Climate Change, 2012b]

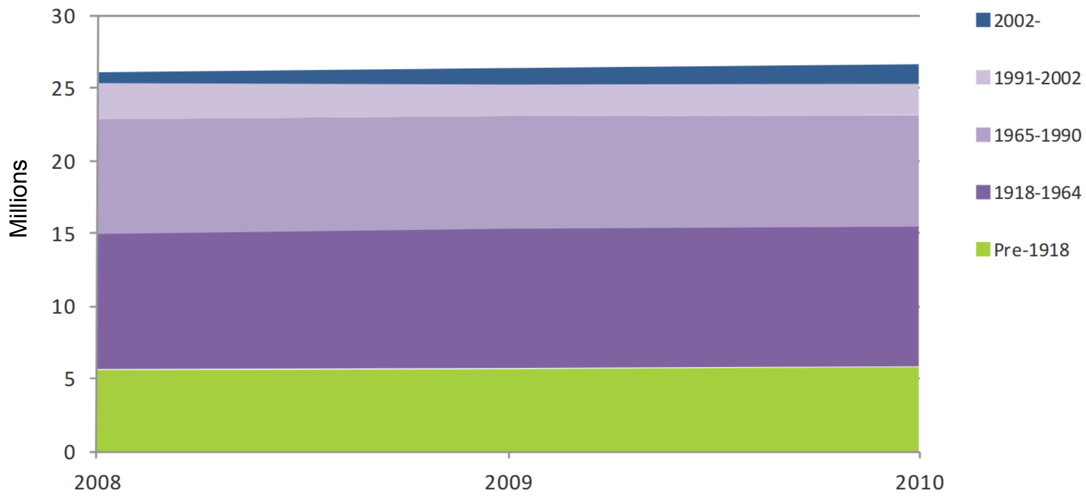

Figure 2.3: Housing stock distribution by age 2008-2010 (millions)
Figure from: [Department of Energy and Climate Change, 2012b]

stock [Department of Energy and Climate Change, 2012b]. The spike in the number of 1940s - 50s homes shown in Figure 2.2 and the dip in the 1960 - 70 homes is due to the change in the housing survey that took place that year [Department of Energy and Climate Change, 2012b]. While such a diverse building stock may be culturally rich, this heterogeneity between housing type, size, and age contributes to the complexity of the retrofit challenge [Stafford *et al.*, 2012]. The result is that UK homes are some of the oldest and most energy inefficient stock in Europe [Energy Saving Trust, 2009; Meijer *et al.*, 2009; Ward, 2008]. This heterogeneity also conflates the application of technical retrofit solutions, since 'one size fits all' designs may not be appropriate, nor are they likely to meet the requirements of all the occupants [Kelly, 2009; Tweed, 2013]. Examples of particularly difficult challenges are homes with solid walls, no loft space, or no ability to connect to a low cost fuel [Pelenur & Cruickshank, 2011b]. Since these homes cannot accommodate 'standard' energy efficiency measures, they are defined as 'hard to treat' properties by the Energy Efficiency Partnership for Homes (EEPfH) Fuel Poverty working group [Energy Saving Trust, 2009]. While the Office of National Statistics has no validated figures for hard to treat properties, an estimated 7m homes in the UK are of non-cavity wall construction [Energy Saving Trust, 2009].

From an energy and emissions perspective, the existing UK built environment accounts for approximately 50% of total UK energy demand [Lior, 2010], and 45% of its anthropogenic CO_2 emissions [Kelly, 2009; Lior, 2010]. Specifically for homes, the heating and moving of air and water, and the use of appliances in existing homes account for approximately 27% of all the anthropogenic carbon emissions in the UK, and an estimated 72% of household energy is used for space and water heating [Defra, 2007; Department of Energy and Climate Change, 2012b; Kelly, 2009]. As such, retrofitting the domestic built environment presents an excellent opportunity to help the UK government improve the energy performance of homes, meet its long-term emissions goals, and improve national energy security [Dixon & Eames, 2013; Karvonen, 2013; Kelly, 2010; Zero Carbon Hub, 2013]. Looking at the energy demand trend over time, Figure 2.4 compares the UK household energy consumption by end use from 1970 to 2012.

This Figure highlights the variability in space heating energy use, but overall the slow rate of change within the building stock as the profile within homes

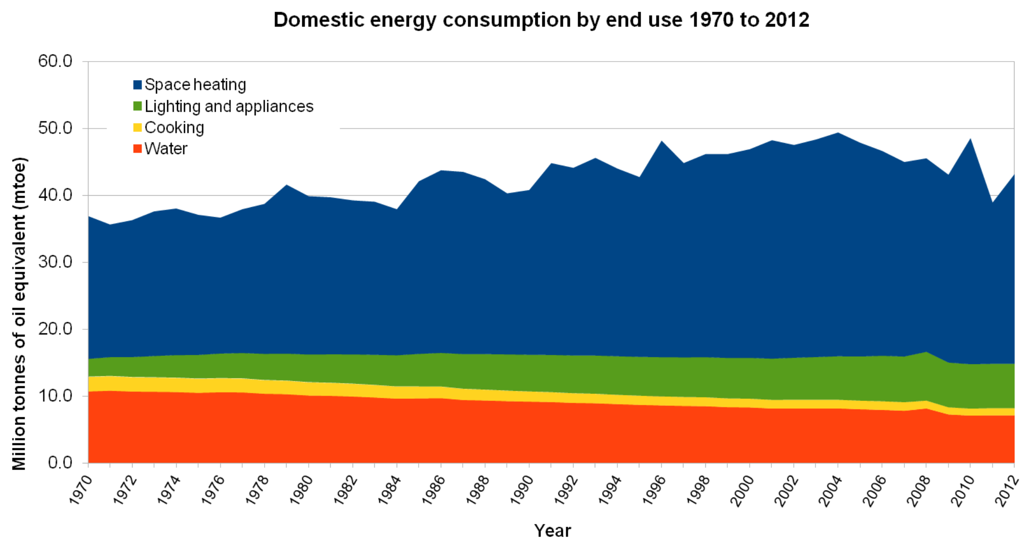

Figure 2.4: Household energy consumption by end use: 1970 to 2012
Source [Department of Energy and Climate Change, 2013a]

has remained fairly consistent, even though total energy consumption generally increased over time. Apart from space heating, the other substantial differences were a decreased use of energy for cooking followed by an increase in appliance and lighting energy use. The discontinuity in 2010 was due to a new modelling algorithm [Department of Energy and Climate Change, 2013a]. Since this breakdown of energy by final use is based on modelling, it is subject to uncertainty from the data sources, and could vary by as much as 18% [Department of Energy and Climate Change, 2013a].

The potential gains from retrofitting the domestic built environment are further underscored by its low replacement rate. Currently, the housing replacement rate is less than 1% per year [Department of Energy and Climate Change, 2012b; Kelly, 2010; Sustainable Development Commission, 2006; The Government Office for Science, 2008], resulting in an estimate that between 70% and 80% of existing homes between 2010 and 2020 will still be occupied and functioning in 2050 [Institution of Mechanical Engineers, 2009; Kelly, 2009, 2010; Ravetz, 2008; Sustainable Development Commission, 2006]. As such, today's hard to treat properties will remain the future's hard to treat homes, and without retrofitting, today's poor performing properties will remain the future's poor performing homes.

Overall, this research is focused on improving the effectiveness of retrofit programmes in a UK context. Additionally, since the studies were specifically conducted in Manchester and Cardiff, it is relevant to investigate and compare their building stock in more detail. The following sections describe and compare the current building stock in Manchester and Cardiff.

Manchester and Cardiff building stock

The Metropolitan District of Manchester is one of the UK's largest cities with an estimated population of 503k and 205k dwellings [Office for National Statistics, 2011a]. Similar in size, the Unitary Authority of Cardiff is the largest city in Wales with an estimated population of 346k and 143k dwellings [Office for National Statistics, 2011a]. Along with the UK in general, both areas share a rich and varied history dating back to Roman colonisation and were settled for millennia before their present day city form. Figures 2.5, 2.6, 2.7, and 2.8 compare the building stock characteristics for both cities using 2011 census data [Office for National Statistics, 2011a].

The Figures underscore the similarities and differences between both cities. Specifically, Cardiff has a substantially larger proportion of detached and owner occupied homes, while Manchester has a greater proportion of privately and socially rented flats. Both cities have a similar distribution for the number of people and bedrooms per household, although Cardiff has a greater proportion of 4 bedroom homes and a smaller proportion of 2 bedroom homes. This is consistent with the larger proportion of detached homes in Cardiff.

From an energy performance perspective, the building stock in both cities could greatly benefit from retrofitting. Within Greater Manchester, 25% of the housing stock is of solid wall construction and there are still 500,000 untreated lofts and cavity walls [Low Carbon Housing Retrofit, 2012]. In Wales, only approximately 18% of homes have cavity wall and loft insulation fitted [National Refurbishment Centre, 2012].

In addition to examining the building stock to understand its energy performance, it is also important to consider the building regulations that mandate home

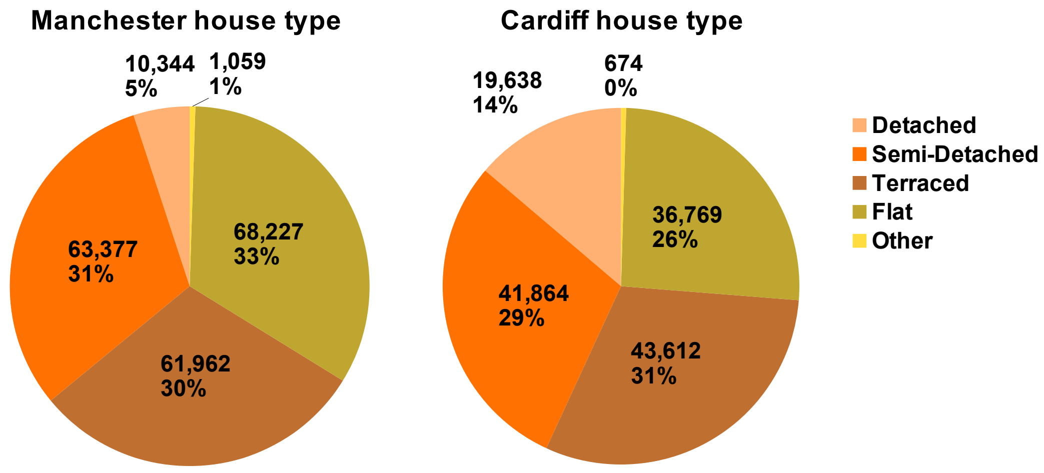

Figure 2.5: Manchester and Cardiff housing stock by type

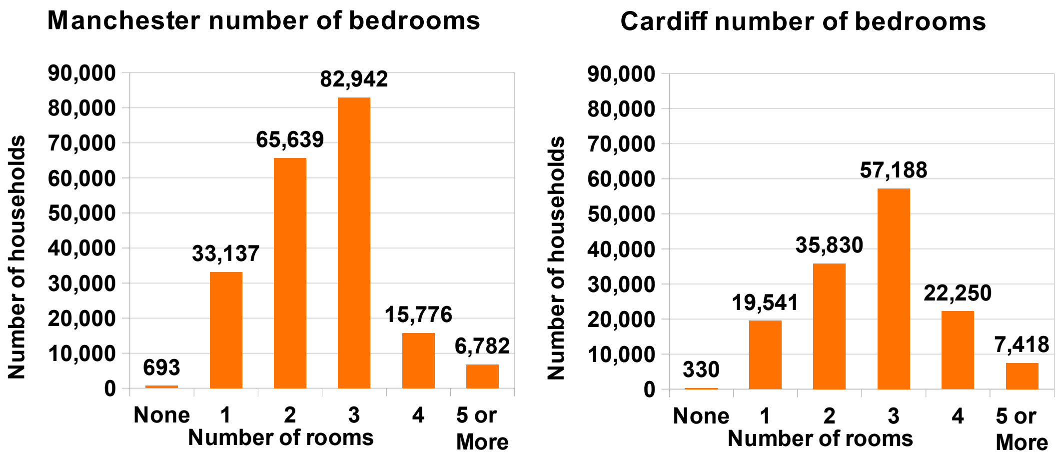

Figure 2.6: Manchester and Cardiff housing stock by number of bedrooms

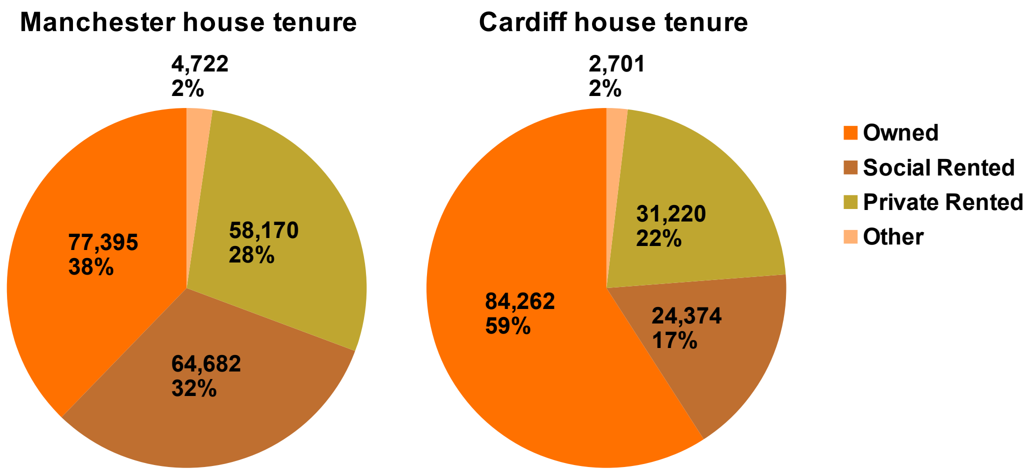

Figure 2.7: Manchester and Cardiff housing stock by tenure

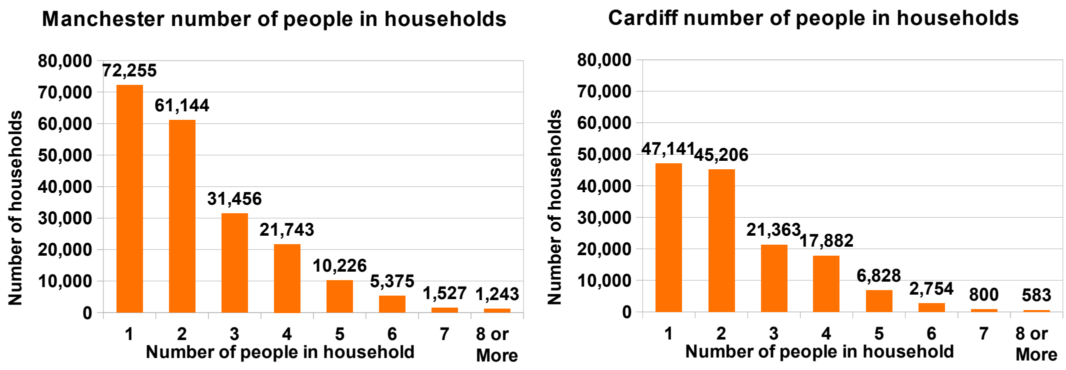

Figure 2.8: Manchester and Cardiff housing stock by number of people in household

energy efficiency standards. These regulations continue to evolve, and serve an important role in determining the minimum energy standards for new builds or heavily renovated homes.

2.1.2 Building regulations

The primary legislation addressing minimum targets for domestic energy performance is outlined in the building regulations 'Approved Document Part L: Conservation of Fuel and Power' [Planning Portal, 2011]. The concept of using Approved Documents to regulate different aspects of the built environment was only formally introduced in the Building Act (1984) [Building Act, 1984]; although previous standing national mandatory requirements were introduced in 1966. Prior to this, regulations were adoptive rather than mandatory, resulting in implementations that varied greatly across the country [Calderdale Council, 2010]. The resulting wide variety of standards, and confusion within the construction industry, often impeded energy efficiency improvements within the built environment [Calderdale Council, 2010]. Table 2.1 compares the regulated U-Values for construction elements from 1965 to 2010, where the U-Value is a measure of the heat flow through a building element. Technically, the U-Value physically describes how much thermal energy in Watts [W] is transported through a building component with the size of 1 square meter [m^2] at a temperature difference of 1 Kelvin [K]; thus the unit for U-Values is $W/(m^2K)$, and the lower the value the more efficient the element is at keeping heat inside or outside the building [BDO U-Value, 2011].

The table shows how the 2010 U-Values have improved on average by 70% since 1965, and before 1965 there was no national regulation. Using U-Values, dwelling energy performance can be estimated with the UK's Standard Assessment Procedure.

Standard Assessment Procedure

The Standard Assessment Procedure (SAP) is a methodology used to assess and compare the energy and environmental performance of dwellings [GOV.UK, 2013f]. SAP was developed by the Building Research Establishment (BRE) for the UK government in 1992, and Reduced Data SAP (RdSAP) was introduced in 2005 as a

Table 2.1: Comparison of maximum permitted U-Values for UK construction elements from 1965 to 2010

Year of building regulations	U-Value (W/m^2K)				
	Wall	Window	Floor	Roof	Door
1965	1.70	5.60	1.42	1.42	3.00
1976	1.00	5.60	1.00	0.60	3.00
1985	0.45	3.30	0.45	0.25	3.00
1995	0.45	3.00	0.35	0.20	3.00
2002	0.35	2.20	0.25	0.20	2.20
2010	0.30	2.00	0.25	0.20	2.00

Source: [Chow & Levermore, 2010; Planning Portal, 2011]

lower cost method of assessing the performance of existing dwellings [GOV.UK, 2013f]. SAP uses a number of building characteristic factors, which are independent of the occupants, to quantify the amount of energy use per unit floor area, and emissions of CO_2. The methodology produces a fuel-cost-based energy efficiency rating (the SAP rating) where a value between 80 and 90 is recommended as being acceptable [Boardman, 2012; Ward, 2008]. Currently, the average SAP rating for UK households is poor, with an average in the region of 50 - 60 [Department for Communities and Local Government, 2009; Energy Saving Trust, 2009], and approximately 5% with a SAP rating of 20 or less [Energy Saving Trust, 2009]. This is not much better than the average 1996 SAP rating of 42 [Ravetz, 2008]. In Manchester, the average SAP rating is 56 (2011), while the average rating of 62 (2009) is better in Wales [National Refurbishment Centre, 2012; Office for National Statistics, 2011a] When translated into energy consumption, the current poor SAP rating results in homes using approximately 300 kWh/m^2/year for heating, while the 2006 Building Regulations stipulated heating to use about 100 kWh/m^2 [Ward, 2008].

These poor SAP ratings are also indicative of non-decent homes, where the term 'decent' is defined as a dwelling that *"meets the statutory minimum standard, provides a reasonable degree of thermal comfort, is in a reasonable state of repair and has reasonably modern facilities"* [The Poverty Site, 2011]. Currently, just over 65% of England's housing stock are considered decent [Energy Saving Trust, 2009]. In Wales, approximately 332,000 households (25%) in 2012 were in fuel poverty

[National Refurbishment Centre, 2012]. The result is that approximately 30,000 people per year die unnecessarily because of the effects of cold in Wales [Cardiff Council, 2012b]. The ill effects from non-decent homes were also observed in a clinical randomised controlled trial in New Zealand, that investigated the link between heating systems and child asthma [Howden-Chapman *et al.*, 2008]. The study found that the installation of non-polluting, more effective heating in the homes of children with asthma significantly reduced symptoms of asthma, days off school, and healthcare utilisation [Howden-Chapman *et al.*, 2008]. Similarly, another clinical randomised controlled trial in New Zealand concluded that insulating existing houses resulted in improved self rated health, self report wheezing, days off school and work, and visits to general practitioners [Howden-Chapman *et al.*, 2007]. As such, the benefits of retrofitting aren't limited only to improving the building fabric, they also extend to improving health and thermal comfort.

Building on the development of SAP, the UK government also introduced Energy Performance Certificates to meet EU regulations, and help improve the transparency of a home's energy performance to its occupants [GOV.UK, 2013a].

Energy Performance Certificates

In 2007 the UK government introduced Energy Performance Certificates (EPC) as one effort to improve domestic energy performance transparency, as well as meet the requirements of the European Energy Performance of Buildings Directive (Directive 2002/91/EC). SAP calculations form the basis of the certification for new dwellings, while RdSAP (Reduced Data SAP) is used to assess existing properties [Department for Communities and Local Government, 2011]. Every home (and building) is required to obtain an updated EPC before they are sold or let. The intention is that this will create an incentive for owners or developers to retrofit, thereby increasing the marketability of their properties [Fuerst & McAllister, 2011]. Supporting this intent, a large scale DECC study that investigated the effect of EPC ratings on house prices found a positive relationship between energy rating and dwelling price per square meter [Department of Energy and Climate Change, 2013c]. However, in the commercial property sector, a hedonic regression study with a cross-section of 708 properties found no evidence that the EPC rating had any effect on market rent or value [Fuerst & McAllister, 2011]. A second criticism is that EPC calculations are based on generalised modern construction methods, thereby placing at a disadvantage historic and traditional homes [English Heritage, 2007]. From a purchasing decision perspective, it is also argued that EPCs are ineffective at creating behaviour change, since they may not be seen by the prospective buyer or tenant until it is too late in the purchasing process to act on the information [UKERC, 2008]. A further criticism, is that unlike Display Energy Certificates (DEC) that are based on *actual* energy performance and required for all public buildings over 1,000 m^2, EPCs are based on *likely* energy performance [English Heritage, 2007], leaving the possibility of a large gap between perceived and actual energy demand. Nevertheless, EPCs allow prospective tenants or buyers to access pertinent energy information for their dwelling, which beforehand was not freely available or easy to procure.

2.1.3 Housing Trilemma

The above review identifies three main factors responsible for today's poor performing dwellings: first, historically weak energy efficiency home standards; second, a low replacement rate for old homes; and third, physical and social building stock heterogeneity. This research proposes these three factors to be a 'Housing Trilemma', and is illustrated in Figure 2.9.

In order to overcome this Housing Trilemma and improve the energy performance of the domestic built environment, existing homes can be retrofitted with energy efficiency measures. The following section describes currently available retrofit technologies, and their potential to improve energy efficiency.

2.2 Retrofit technologies

In order to improve the energy and emission performance of homes, various passive (e.g., insulation) or active (e.g., solar photovoltaic (PV)) technologies can be retrofitted to the property *in situ*. With respect to technical solutions, the available energy efficiency technologies for domestic UK properties recognised by SAP are:

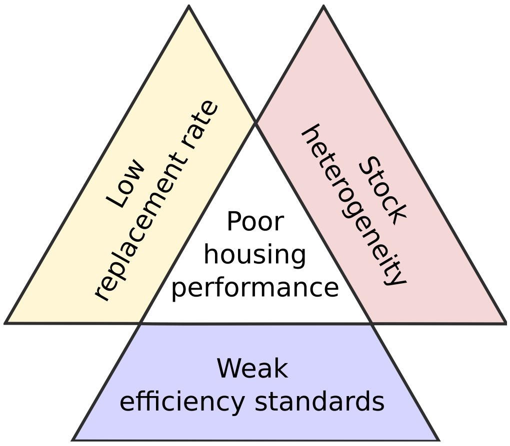

Figure 2.9: Housing Trilemma diagram of poor energy performance

- Air/ground source heat pumps (using a heat exchanger to recover or disperse heat from the environment);
- Bio-fuels/mass (if the fuel source is sustainable, biofuel can be used as an alternative to gas heating);
- Combined heat and power (using industrial waste heat for domestic heating);
- Draught proofing (doors and windows);
- Insulation (cavity, solid wall, loft, and boiler);
- Lighting (low energy lighting (LED), and passive lighting);
- Micro wind (electricity generation with wind energy);
- Modern boilers (condensing boilers);
- Solar PV (electricity generation with solar energy);
- Solar thermal (using solar energy to heat water);
- Thermal mass (seasonal or daily storage of heat);
- Window glazing (double and triple)

Despite this extensive list of available technical options, in practice only very few technologies are widely adopted by the public. Figure 2.10 shows the adoption of energy efficiency technologies in the UK since 1950, the dots represent historic or projected data points while the lines represent ideal curves.

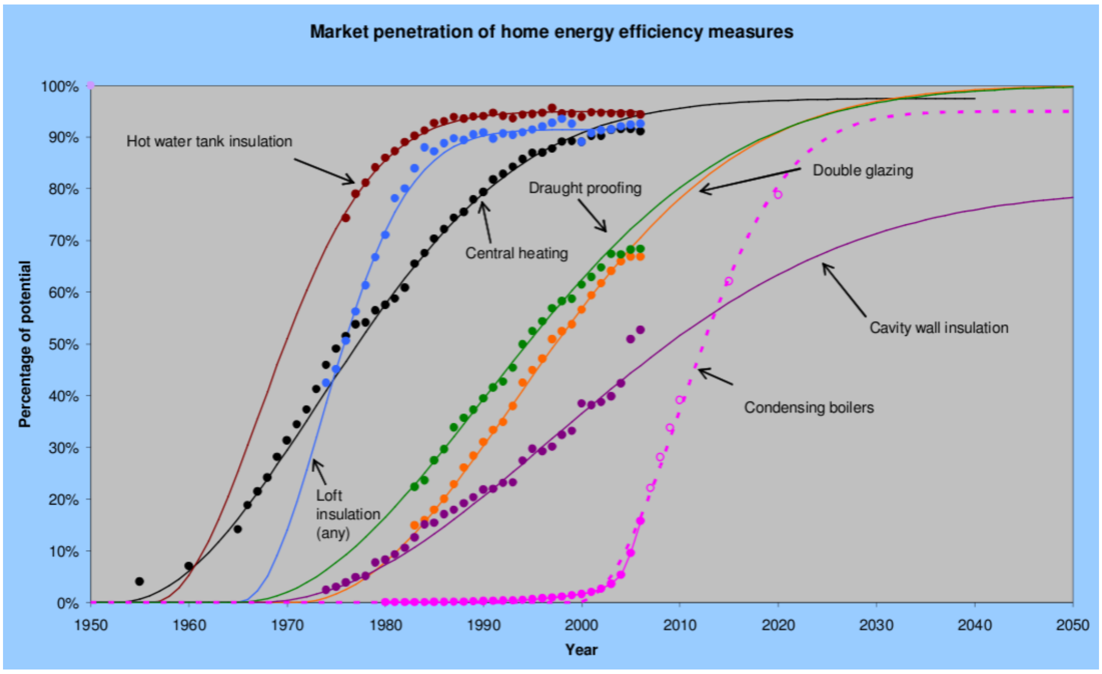

Figure 2.10: Market penetration of home energy efficiency measures in the UK
Source: [Davidson (BRE), 2009]

This Figure demonstrates that despite the available choice, mostly only passive retrofit actions are generally adopted. More so, Figure 2.10 highlights the remaining potential for these technologies.

With respect to the effectiveness of specific retrofit measures, nationwide case-study demonstration projects found that the above measures can provide significant energy savings to households. One project in York modernised approximately 250 homes (with a focus on increasing building envelope air tightness), and monitored their performance for 12 months afterwards [Bell & Lowe, 2000]. After comparing against pre-retrofit performance, Bell & Lowe concluded that their best efforts reduced household energy consumption by about 49 - 54%. Another paper presented the results of an energy and environmental assessment of retrofit actions implemented as part of the EU project "Bringing Retrofit Innovation to Application in Public Buildings (BRITA in PuBs)" [Ardente *et al.*, 2010]. By coupling life cycle analysis with monitoring equipment, Ardente *et al* found that retrofit measures produced an average of 50% energy savings for heating. In 2009, the UK Technology Strategy Board (TSB) implemented a £17m programme entitled Retrofit for the Future (RtF) to create a collection of demonstration projects in the UK's social housing stock [Low Energy Buildings, 2013]. In total, 86 projects were funded through RtF, with all the project details, including monitoring and evaluation, shared on a public database [Low Energy Buildings, 2013]. The database was created by TSB as an education and dissemination tool for retrofit professionals and the wider public.

Nationally, the UK government collected energy efficiency retrofit data and compiled it into the Homes Energy Efficiency Database (HEED) to monitor and improve the UK's housing stock [Energy Saving Trust, 2013]. HEED contains at least 1 piece of date-stamped information for approximately 13 million homes, including property characteristics, retrofit measures installed, and heating systems. A controlled study that matched HEED homes with related annualised energy demand data concluded that the presence of cavity insulation and a condensing boiler were associated with a household gas saving of 9.2% and 8% respectively [Hamilton *et al.*, 2013]. Other retrofit measures, such as loft insulation and double glazing did save energy, but were not as effective [Hamilton *et al.*, 2013]. A more detailed breakdown of potential retrofit energy savings is presented in Table 2.2.

Table 2.2 demonstrates that technical retrofit solutions have the potential to significantly improve the energy performance of the domestic built environment. However, in order to justify their financial investment, it is also informative to consider the marginal cost abatement curves for retrofit technologies alongside other measures. Figure 2.11 is a UK marginal abatement curve by McKinsey UK, while Figure 2.12 is a world wide economic mitigation curve by the Intergovernmental Panel on Climate Change (IPCC) .

Figure 2.11 shows the abatement potential on the horizontal axis and the cost on the vertical axis, with measures arranged in order of cost so that the cheapest

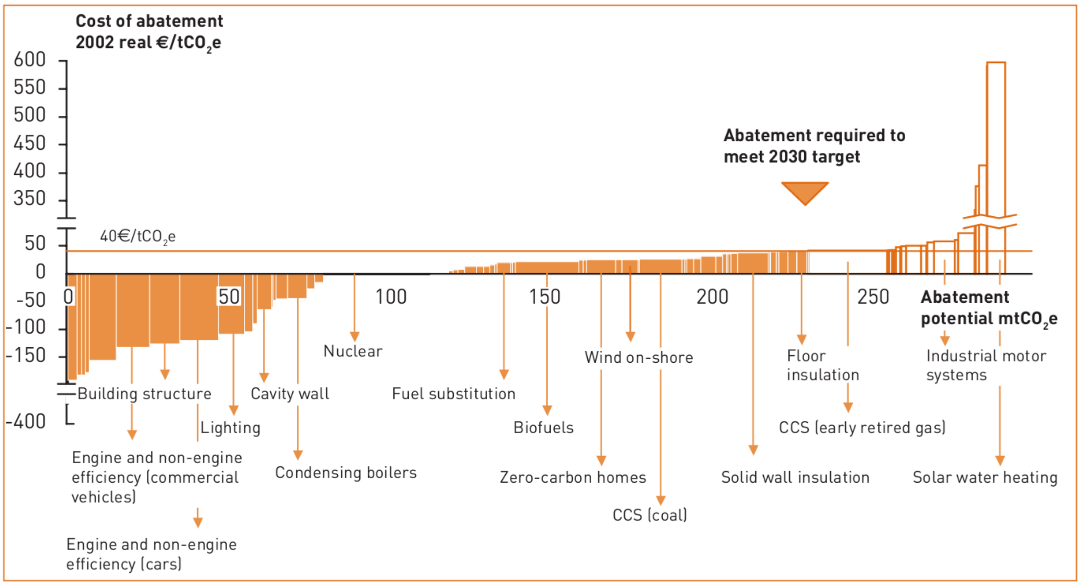

Figure 2.11: The UK cost curve for additional greenhouse gas reduction measures (source: McKinsey analysis)
Source: [Confederation of British Industry, 2007]

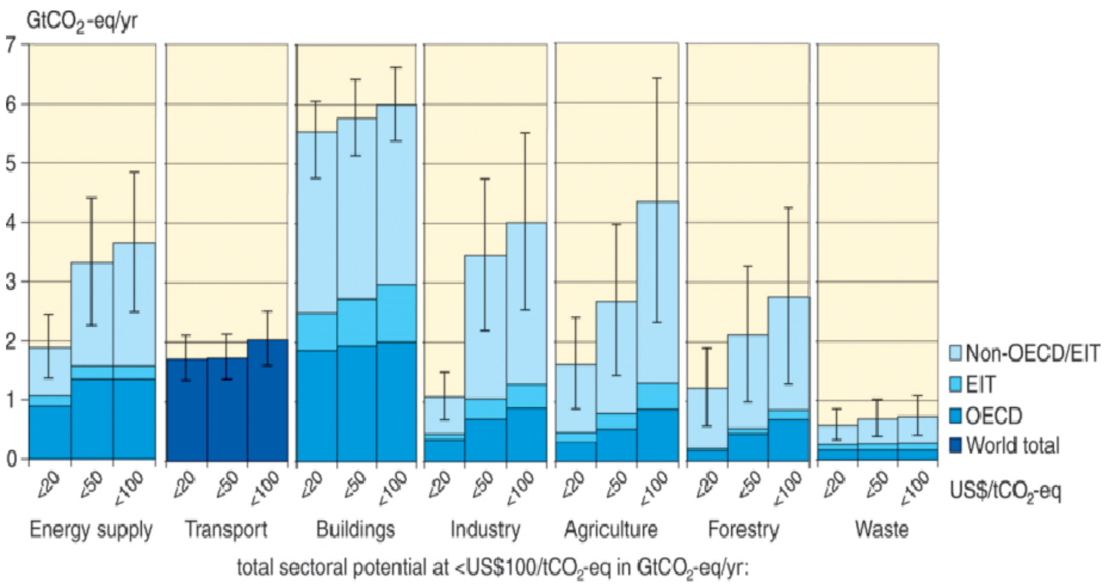

Figure 2.12: World wide economic mitigation potential by sector
Source: [Bernstein *et al.*, 2007]

Table 2.2: Energy saving potentials of individual energy efficiency measures

	Annual energy savings	
	Household (kWh)	Great Britain (TWh)
Space heating		
Cavity wall insulation*	3484	26
Solid wall insulation	12101	56
Loft insulation up to 270mm*	467	8
Floor insulation (raised timber)	1744	18
Glazing to C rated	2526	63
Insulated doors	464	12
Boiler to A-rated	4414	73
Improved heating controls	11094	19
Water heating		
Cylinder insulation to current regulations	254	4
Hot water heating controls	8276	14
Cooking		
A rated ovens	25	0.3
Induction hobs	25	0.3
Lights and appliances		
A++ rated cold appliances	259	6.5
A+rated wet appliances	200	5.0
Efficient lighting	71	1.5
Integrated digital TVs	23	0.5
Reduced standby consumption	39	1.0

* Technical savings from measures have been reduced by 50% to account for improvement in U-values achieved in practice and a 'comfort factor'
Estimate total annual domestic energy consumption = 500 TWh
Source: [OFGEM, 2009]

option is on the left. Based on this figure, all retrofit options are justified economically as effective measures towards reducing greenhouse gas emissions except solar water heating. Figure 2.12 compares buildings with other sectors and confirms that improving the performance of buildings is currently the most cost effective measure towards reducing GHG emissions.

It is important to note that this data is based on expected energy savings; however the possibility for mismatch exists between expected and actual energy demand in post-retrofit and new homes. For example, even if building standards are improved, the expected savings in energy demand may not be achieved due to unexpected occupant behaviour or poor installation/construction quality [Guerra-Santin *et al.*, 2013; Haas *et al.*, 1998; Tweed, 2013; Zero Carbon Hub, 2013]. One Austrian study found that occupant behaviour increased household energy demand by 15 - 30% beyond expected values [Haas *et al.*, 1998]. Similarly, a 3 year longitudinal study of a low energy multi-family complex in Switzerland found that the measured energy performance post-installation of solar panels exceeded expectations by 54% [Branco *et al.*, 2004]. This deviation was attributed to technology complexity and poor product quality [Branco *et al.*, 2004].

On the other hand, it may be possible to catch such performance deviations early in the project phase if rigorous monitoring and evaluation processes are put in place [Guerra-Santin *et al.*, 2013]. A study that monitored the performance of two new-build low energy homes in the UK found that their energy performance post-construction did meet expectations, due to the commitment of the design team, and the depth and breadth of performance testing and monitoring throughout the project [Guerra-Santin *et al.*, 2013]. Overall, although monitoring and evaluating the real performance of post-retrofit buildings was outside the scope of this research; it is nevertheless an important area of research requiring further investigation.

In summary, this section described the energy performance challenge facing the UK domestic built environment, and presented retrofit measures that are appropriate and capable of meeting this challenge. In order to encourage the adoption of such technologies, the following section describes UK national policies relevant to retrofitting.

2.3 Retrofit policy

A substantial driver for retrofit policies in the UK is The Climate Change Act 2008 that sets an ambitious target to cut the country's greenhouse gas (GHG) emissions from all sources by 80% (160 $MtCO_2e$) by 2050, compared to 1990 levels [Committee on Climate Change, 2011a]. The Committee on Climate Change also expects emissions from homes to fall by over a third of 2011 levels by 2022 [Committee on Climate Change, 2011b]. Simultaneously, the EU Renewable Energy Directive (2009/28/EC), introduced in April 2009, mandates that each member state in the EU shall obtain at least 20% of total energy from renewable sources by 2020 [EurActiv, 2008]. Therefore, as well as improving energy performance at the household level, retrofitting the domestic built environment also presents an opportunity to help the UK government meet its long-term renewable energy and emission goals.

In order to help meet these targets, the government tightened energy efficiency standards for buildings [Department for Communities and Local Government, 2013a] and historically introduced a range of programmes, such as: the Landlord Energy Saving Allowance; the Carbon Emissions Reduction Target (CERT); Community Energy Saving Programme (CESP); Decent Homes; and Warm Front. While these programmes are historic, the main current policies in place to encourage domestic retrofits are: the Solar Feed-in Tariff; the Renewable Heat Incentive, and the Green Deal. The Green Deal is of particular interest because it was specifically introduced to encourage the consumer adoption of energy efficiency measures in the home [GOV.UK, 2013d].

The main difference between the previous initiatives and current policies is in their scope; previous incentives targeted the most vulnerable homes, while current initiatives are targeting the entire housing stock. The following sections discuss the current government policies in more detail.

2.3.1 Green Deal

Introduced in the 2010 Energy Bill, the Green Deal is a framework and financial incentive that enables private firms to offer households energy efficiency improvements at no upfront cost, instead the costs are recouped with a charge in instalments on the energy bill [GOV.UK, 2013d]. This charge is calculated so that it is equivalent to the savings created by the installed energy efficiency measure; thereby creating a 'cost neutral' scheme to the home occupants. The financial innovation is that this scheme is attached to the property, so that if the occupant moves out and ceases to be the bill-payer, then the financial obligation will stay with the property and move to the next owner/tenant. This financial obligation is only paid while there are benefits accrued, i.e. when the properties are occupied. Finally, apart from the novel financial mechanism, the Green Deal also mandates accredited energy assessments for households (EPCs), and the use of accredited advisers and installers [GOV.UK, 2013d].

One aim of the Green Deal is to address the landlord-tenant split incentive; the phenomenon where tenants do not want to invest in the initial capital cost of retrofitting as they do not own the property, and landlords do not want to invest in retrofitting since they do not directly benefit from the reduced fuel bills. In the worst cases, owners of low value decaying property will forego proper maintenance and rent their properties to low-income people who simply cannot afford any of the needed reinvestment or upgrades [Sustainable Development Commission, 2006]. In this way, the Green Deal is similar to the Property Assessed Clean Energy (PACE) programme in the U.S., where local governments issue bonds to finance renewable energy and energy efficiency projects on private property. The bonds are secured by real property, and the bond repayments are calculated into the property tax bill [PACEnow, 2012].

Since the Green Deal was only implemented in 2013, its effectiveness has yet to be properly evaluated; however, the scheme received criticism when it was first introduced. The UK Green Building Council and the Royal Institute of Chartered Surveyors (RICS) warned that "the package of measures is incredibly ambitious, overly complex, and currently lacks the incentives necessary to drive uptake amongst households and businesses" [Nichols, 2011]. The lobby group, the Confederation of British Industry (CBI), also warned that the scheme threatens to be a 'lame duck', unless the government provided greater clarity on how it planned to fund the scheme [BusinessGreen, 2011]. An alternative measure proposed by the UK Green Building Council was to reduce the VAT rate for energy efficiency measures, which is currently set at 5% [Nichols, 2011]. Although this 5% is reduced down from the national VAT rate of 20%, it is still higher than the 0% offered for new builds. However, VAT rates are tied to EU law, which constrains how easily they can be adjusted [Sustainable Development Commission, 2006].

Also bundled with the Green Deal is the Energy Company Obligation (ECO), which is a set of policies that support the installation of energy efficiency measures in low-income households, and in hard to treat properties [GOV.UK, 2013d]. There are three specific obligations under ECO: the first is the carbon saving community obligation to provide insulation measures to households in specified areas of low income; the second is the affordable warmth obligation to provide heating and insulation measures to means-tested private tenure households; and the third is the carbon saving obligation that covers the installation of measures like solid wall and hard-to-treat cavity wall insulation that ordinarily can't be financed solely through the Green Deal [GOV.UK, 2013d]. Together, the Green Deal and ECO replace previous policies such as CERT and CESP.

Most of the efficiency measures listed in Table 2.2 are covered under the Green Deal; however, micro-generation is specifically excluded. Instead, the following two policies aim to increase the adoption of micro-renewable generation: the Feed-in Tariff; and the Renewable Heat Incentive.

2.3.2 Feed-in Tariff

The Feed-in Tariff (FIT) scheme was introduced by the UK Government on 1 April 2010 with the aim to encourage the deployment of small scale (less than 5 MW) low carbon electricity generation [Department of Energy and Climate Change, 2011a]. The intent was to encourage the domestic adoption of such technologies; however, initially the scheme was mostly adopted by larger developers. Consequently, the government reviewed the value of the FITs in 2011 to ensure that the scheme favoured domestic and other small-scale generators [GOV.UK, 2013b]. As a result of the review, the tariffs were modified to favour smaller solar PV installations and provide a rate of return of 4.5 to 8% for a typical well-sited installation [Department of Energy and Climate Change, 2012a].

In 2011/12, 498.2 GWh was reported as being generated under the Feed-in Tariff scheme from 206,851 installations [GOV.UK, 2013c]. However, this only represents approximately 0.1% of the UK's total electricity generation [Housing Energy Advisor, 2011], underscoring the potential for further penetration opportunity. The UK FITs were modelled after the success of the German Feed-in Tariffs, which included solar PV from 2000 onward, and now has over 17,000 MW of installed capacity [Hughes, 2011].

2.3.3 Renewable Heat Incentive

The Renewable Heat Incentive (RHI) was launched in November 2011, and is a financial support programme for renewable heat installations. Currently, it only provides payments to the non-domestic sector, but will be extended to households in 2014 [GOV.UK, 2013e]. This scheme is designed to complement the Green Deal and the Feed-in Tarrifs, and is the first of its kind internationally [Department of Energy and Climate Change, 2011b]. While similar to FITs in the respect that individuals are paid a fixed amount based on the output of their renewable heat source installations, there are two important differences: the first is that unlike FITs, this scheme is paid by Treasury and not by the energy users; and the second is that there is no 'National Grid' for heat, so importing/exporting heat is not relevant [RH Incentive, 2011]. Since the scheme is still under development for the domestic sector, it is difficult to predict its future effectiveness.

In summary, retrofitting the domestic built environment presents an excellent opportunity to help the UK meet its energy and emission targets, as such, the government introduced a range of policies to encourage home refurbishment. However, there is still a shortfall between the realised adoption of domestic retrofit measures and their full potential [Allcott & Mullainathan, 2010; Jaffe & Stavins, 1994; Stafford *et al.*, 2012]. The next section examines this gap in more detail and discusses the role of occupants and social factors related to domestic retrofitting.

2.4 Social factors and energy efficiency behaviours

Retrofit technologies and financial incentives are important components to improve the energy performance of the domestic built environment; however, home occupants also play a critical role in the adoption of energy efficiency measures [Janda, 2011]. Specifically, the social and cultural considerations of how domestic occupants interact with energy at home are often left unexplored by engineering professionals [Karvonen, 2013; Pelenur & Cruickshank, 2011b, 2013c]. Shifting family structures are another important social consideration. The largest growth sector in housing demand is from young and old single individuals, but there has also been a rise in flexible arrangements, such as: serial co-habitation; dual career households; third generation extensions ('granny flats'), and the return of young adults living with parents [Ravetz, 2008]. These varied living arrangements can complicate retrofit programmes and strategies [Lutzenhiser, 1993]. Additionally, changes to established and familiar built forms may be opposed by local residents for various subjective reasons, such as: aesthetics; perception of disruption to homes and gardens; and mistrust in the organisations implementing the change [The Government Office for Science, 2008]. This view is supported by extant psychological and sociological scholarship that investigated the impact of social and cultural factors on energy decisions and concluded that the lessons learned from such studies were often not considered during the design and deployment of engineering retrofit solutions [Abrahamse & Steg, 2009; Darnton, 2008; Lutzenhiser, 1992; Stephenson *et al.*, 2010; Upham *et al.*, 2009]. The result is that there exists a shortfall between the full potential and realised adoption of energy efficiency measures [Allcott & Mullainathan, 2010; Jaffe & Stavins, 1994; Stafford *et al.*, 2012], as demonstrated by the technology penetration graph in Figure 2.10. This phenomenon is termed the 'Energy Efficiency Gap', and is discussed in detail below [Allcott & Mullainathan, 2010; Jaffe & Stavins, 1994].

2.4.1 The Energy Efficiency Gap

The Energy Efficiency Gap is described as the gap that exists between the current or expected future energy use of homes, and the optimal current or future energy use [Jaffe & Stavins, 1994]. In OECD countries, this energy conservation loss due to the Energy Efficiency Gap is estimated at 30% of the total potential energy savings of the measures [Weber, 1997]. Understanding the reasons that give rise to the Energy Efficiency Gap is a well researched topic across a wide range of disciplines. In their review paper that compares multiple decision making models, Wilson & Dowlatabadi [2007] identified the following four diverse discipline approaches: conventional and behavioural economics; technology adoption theory and attitude-based decision making; social and environmental psychology; and sociology. Conclusions drawn from the review paper are that there is an unexplored potential to reconcile the theoretical preferences of different research traditions, and that a greater openness for collaboration between disciplinary approaches is required to meet that potential [Wilson & Dowlatabadi, 2007].

From a standard economic perspective, Jaffe & Stavins [1994] sought to understand why compact fluorescent light bulbs, improved thermal insulation materials, and energy-efficient appliances were not more widely adopted. In their research, they argued that the Energy Efficiency Gap is due to market failures, such as a lack of transparent information about the benefits of energy efficiency, and non-market failures, such as the transaction costs of adopting new technology or the use of inaccurate discount rates by consumers making energy efficient retrofit decisions.

Along a similar economic analysis Weber [1997] identified four main types of obstacles for the adoption of energy efficiency measures: institutional barriers (public government); market barriers; organisational barriers; and behavioural barriers. Similar to Jaffe & Stavins [1994], Stern [2006] suggested that the barriers to rational behaviour are: financially hidden costs/benefits; conflicting market signals or imperfect information; and motivation factors. However, the problem with treating occupants as rational actors or as physical entities occupying space, is that it assumes they use energy with purpose, which misses the insight that our interaction with energy is subjective and that a lot of our energy use is incidental [Lutzenhiser, 1992].

The assertion that occupants do not always act rationally with respect to adopting energy efficiency measures or their energy consumption is empirically supported by various studies. One English study (n=427) counter-intuitively found that measured living room temperatures were not correlated with the temperature settings on the central heating controls [Shipworth *et al.*, 2010]. This lack of correlation may be because occupants opened windows to regulate their indoor temperature, rather than using the heating controls correctly. Similarly, an exploratory study with 14 households in Cambridge found that installed energy efficiency measures did not necessarily change household energy consumption [Pelenur, 2010; Pelenur & Cruickshank, 2013b]. Specifically, participants that received an electricity monitor, or an active demand response system, did not show a significant change in energy demand over the course of the study (6 weeks) compared to the control group [Pelenur, 2010; Pelenur & Cruickshank, 2013b]. Another study with approximately 400 Austrian homes found that irrational occupant behaviour increased household energy demand by 15 - 30% [Haas *et al.*, 1998]. An explanation put forward for this irrational behaviour is that the general public find it difficult to understand energy because it can't physically be seen (excluding the gas flame on the stove), and people don't use energy specifically, rather they use services such as microwaves, or dishwashers [Burgess & Nye, 2008]. As such, energy can described as being 'doubly invisible' for occupants [Burgess & Nye, 2008].

Complementing the economic perspective, there is also considerable relevant extant psychological and sociological scholarship to help understand the reasons for the Energy Efficiency Gap.

In their review paper for the Living with Environmental Change programme, Upham *et al.* [2009] brought together an extensive list of psychological and sociological studies to help explain public attitudes to environmental change. Two relevant implications from the paper are that individuals' attitudes and actions were not always consistent (defined as the 'value-action' gap), and that an individual's behaviour in one context may be inconsistent with their behaviour in another context [Upham *et al.*, 2009]. Such insights may help explain why households do not adopt energy efficiency measures even though they are economically justified. From a more detailed behaviour perspective, the Behaviour Change Knowledge Review referenced over 60 relevant socio-psychological models, theories and frameworks that can be used to help understand the Energy Efficiency Gap [Darnton, 2008]. Most models presented in the paper use the variables of 'attitudes', 'norms', and 'agency' to explain behaviour, while others also include 'habit' and 'emotion' [Darnton, 2008]. To test the relative importance of such psychological variables to energy use, as well as socio-demographic variables, Abrahamse & Steg [2009] administered questionnaires and examined the energy use of 189 Dutch households. They found that household energy consumption was mainly determined by socio-demographic variables, whereas energy savings (viz., changes in behaviour) were mainly determined by psychological factors [Abrahamse & Steg, 2009]. Supporting these results, Faiers *et al.* [2007] argued that policy makers should consider a broad range of factors, such as individuals' cognitive abilities, values, attitudes, and social networks in the context of understanding consumer domestic energy use [Faiers *et al.*, 2007]. Beyond single households, community-based partnerships between occupants and retrofit delivery partners have also been proposed to take advantage of the social nature of energy use, and to promote large-scale systematic retrofits [Karvonen, 2013]. Alongside the Energy Efficiency Gap, the Rebound Effect also presents another social and behavioural challenge towards energy efficiency in the home.

2.4.2 Rebound Effect

The Rebound Effect is a phenomenon that occurs when energy efficiency improvements counter intuitively lead to higher levels of energy consumption; if held specifically to energy, the Rebound Effect is called the "Khazzoom-Brookes postulate", which was first recognised by the English economist William Jevons in the late 19th century [Madlener & Alcott, 2009]. For example, a direct Rebound Effect is higher home temperatures after the installation of insulation; while an indirect example is when a consumer purchases a larger and more inefficient vehicle based on the savings made from energy efficiency measures at home. One review examined the macro-economic rebound effect on the UK economy and found that the reduction in energy demand for 2010 was modelled to be about 11% less than expected due to direct and indirect rebound effects [Barker *et al.*, 2007]. However, such estimates are difficult to calculate, and other models expect the Rebound Effect for thermal insulation and heating systems to be much higher, in the region of 50% to 100% [Oreszczyn & Lowe, 2005].

An example of the rebound effect was observed after the introduction of appliance efficiency labels in the EU, which led to an average energy efficiency improvement of 8% for refrigerators/freezers in the UK during the first two years; however, the UK energy demand only decreased by 0.75% during the same period [EES, 1998 as cited in Burgess & Nye, 2008]. This loss of potential savings was attributed to consumers buying larger fridges rather than similar or smaller sized units, this is an example of an indirect rebound effect [Burgess & Nye, 2008]. Another example is the continuous increase in domestic thermal comfort expectations. In 1970 the average temperature within the home was 12°C, however with the introduction of new cheaper and more efficient heating technology, the average temperature in 2002 increased to 18°C, and this is predicted to rise to 21°C within the next decade [Oreszczyn & Lowe, 2005]. Such increases to thermal comfort reduce the total savings seen from installing new energy efficient technologies.

As such, without a broad understanding of how households interact and use energy, it is possible that well-intentioned energy policies backfire, resulting in the Rebound Effect and leading to more energy use rather than less. In order to visualise occupant decision making in the context of home energy use, Wilson & Dowlatabadi [2007] present an overarching integrated model for pro-environmental behaviour as shown in Figure 2.13 (adapted from [Stern, 2000]).

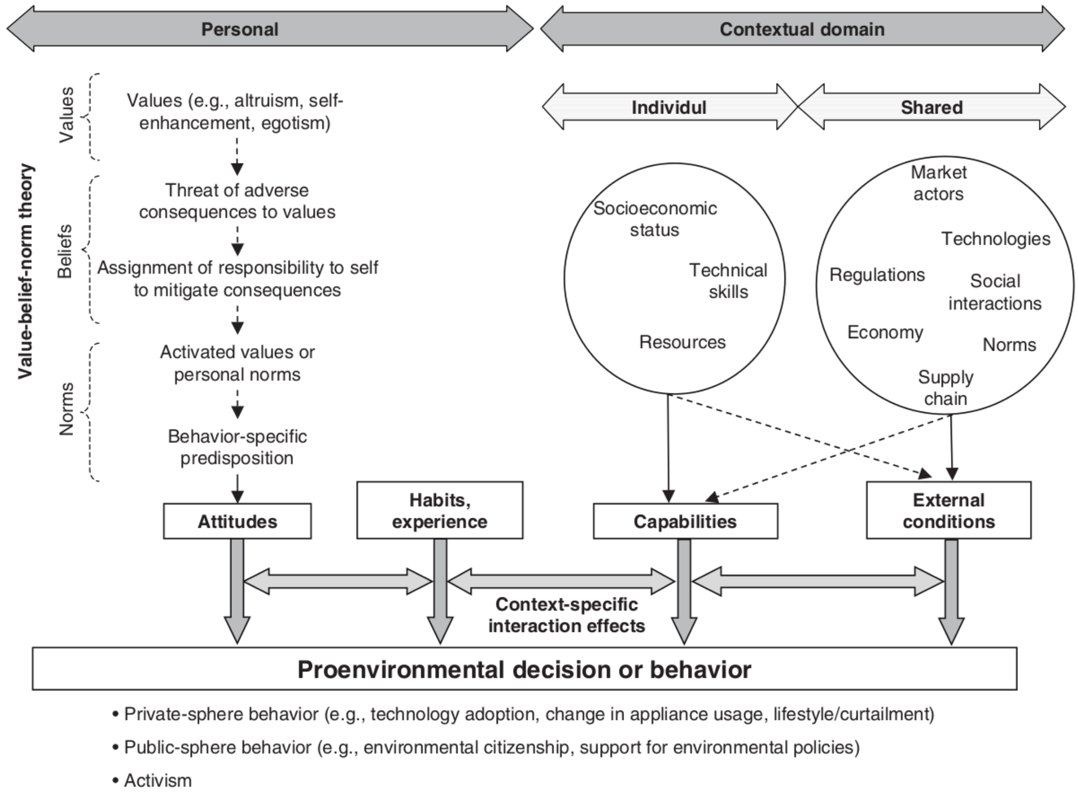

Figure 2.13: An integrated model of pro-environmental behaviour

The model in Figure 2.13 distinguishes between personal and contextual domains while recognising interactions between them [Wilson & Dowlatabadi, 2007]. Although comprehensive, the model is also not straight forward to apply to specific behaviours [Wilson & Dowlatabadi, 2007]. In parallel and from a sociological perspective, Lutzenhiser introduced the idea of a simpler integrated Energy Culture framework to understand behaviour, that considers social norms and culture alongside the more traditional econometrics [Lutzenhiser, 1992].

2.4.3 Energy Culture framework

The Energy Culture framework was introduced by Lutzenhiser [1992], who argued that in order to understand energy consumption in the home, researchers should consider social norms and culture alongside the more traditional econometrics [Lutzenhiser, 1992]. Lutzenhiser supported this approach by highlighting complex personal psychological attitude models that failed to predict intention to conserve [Lutzenhiser, 1992]. This result is supported with an exploratory study by Pelenur & Cruickshank [2011a] that applied the Technology Acceptance Model to investigate behavioural intent. In that study, two types of energy efficiency measures were fitted to Cambridge households for a period of 6 weeks. The exploratory results found that the perceived enjoyment, ease of use, and usefulness of the energy efficiency measures did not indicate behavioural intent [Pelenur & Cruickshank, 2011a].

More recently, Stephenson *et al.* [2010] applied the Energy Culture framework to consumer energy behaviour, by specifically examining the interactions between cognitive norms (e.g. beliefs, understandings), material culture (e.g. technologies, building form), and energy practices (e.g. activities, processes). Stephenson goes on to suggest that the Energy Culture framework can be used to identify areas of deficiency for interventions to target. This framework can be applied to individuals and households, as well as neighbourhoods and communities. Figure 2.14 is an example of using the Energy Culture framework to model home heating behaviours; where the left-hand side model characterises the home heating behaviours, and right-hand side model reflects some of the wider systemic influences.

The Energy Culture framework is congruent with other research that demonstrates how our collective norms, cultural practices, and shared expectations are all factors that may aid or obstruct our energy efficiency potential [Hargreaves *et al.*, 2010; Rayner & Malone, 1998]. For example, windows in continental European buildings generally open inwards, while British windows open outwards, constraining the options for shutters and shading to help with cooling [The Government Office for Science, 2008]. Other examples of social factors are: lifestyle

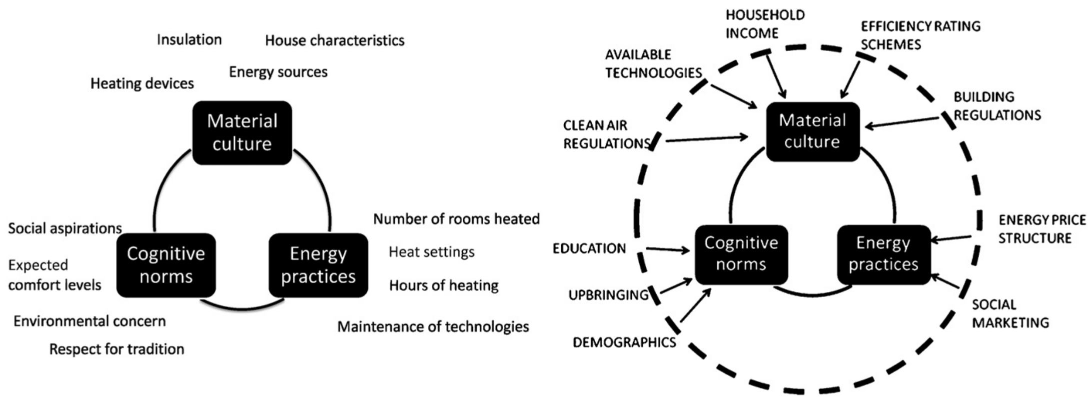

Figure 2.14: Energy Culture framework example
Source: [Stephenson *et al.*, 2010]

choices (choosing to live in a rural property without gas mains); perceived aesthetics of technology (solar panels or double glazing too obtrusive); and desire to minimise disruption (hassle to clear loft) [Pelenur & Cruickshank, 2011b]. Adopting a more holistic approach towards improving our understanding of domestic energy consumption is further justified by a growing body of evidence that non-monetary interventions, such as social approval, feedback, and community goal settings are effective at changing behaviour [Allcott & Mullainathan, 2010], and that changing occupant behaviour can lead to a 10 - 30% reduction in energy consumption [Yohanis *et al.*, 2008]. As such, retrofitting can be approached as a set of socio-technical issues [Tweed, 2013]. For example, one case study in south Wales used phenomenology (the study of structures of consciousness as experienced from the first-person point of view [Smith, 2011]) and ecological psychology to examine occupants' experience of a retrofitted home. The study highlighted social practices that might have otherwise been overlooked in a traditional technical or economic assessment, such as leaving doors open to allow free passage for the family dog [Tweed, 2013]. Therefore, the challenge to change energy habits or make retrofit decisions should not be informed only by single analytical models or incentive policies; rather, inter-disciplinary approaches should be encouraged to create long lasting change [Stephenson *et al.*, 2010].

In summary, this section described the Energy Efficiency Gap and presented the argument that this gap can best be overcome by adopting an inter-disciplinary research approach. Specifically, this review identified a knowledge gap within the engineering profession for more socio-technical research that empirically considers both social and cultural retrofit factors alongside traditional technical and econometric measures [Abrahamse & Steg, 2009; Darnton, 2008; Lutzenhiser, 1992; Stephenson *et al.*, 2010; Upham *et al.*, 2009]. As such, the following section presents the socio-technical Energy Culture model developed to guide this research. This model is based on the general Energy Culture framework, and specifically links household barriers and motivations to adopt retrofit measures, with retrofit technologies and social attitudes towards energy.

2.5 Research model

The socio-technical Energy Culture model used to guide this research was adapted to theoretically represent components of the Energy Efficiency Gap. Specifically, the model places households at the centre, internally influenced by three broad areas: cognitive norms (social viewpoints and attitudes towards energy), material culture (retrofit technologies and building fabric), and energy practices (energy efficiency behaviours), the model is shown in Figure 2.15. Motivations to change any of those areas are represented as arrows outward, while barriers preventing change are represented as a dashed circle. It is important to note that the model is a unique contribution of this research, developed from the preceding literature as a way of both summarising and interpreting the literature findings.

The model illustrates how a holistic approach can be adopted to address the Energy Efficiency Gap, as opposed to simply targeting one area, such as barriers. Without considering all the factors together, efforts to address specific areas may not be as effective. For example, improving a household's material culture (i.e. installing retrofit technologies or upgrading the built form), may not produce optimal energy savings if the household energy practices are not also made more efficient. Similarly, without understanding the cognitive norm within a household, efforts to change energy practices may not work. As such, the areas in the model are interlinked (inner circle) and are affected by motivations and barriers (arrows outward and dashed outer circle). By investigating the areas outlined in the model, this

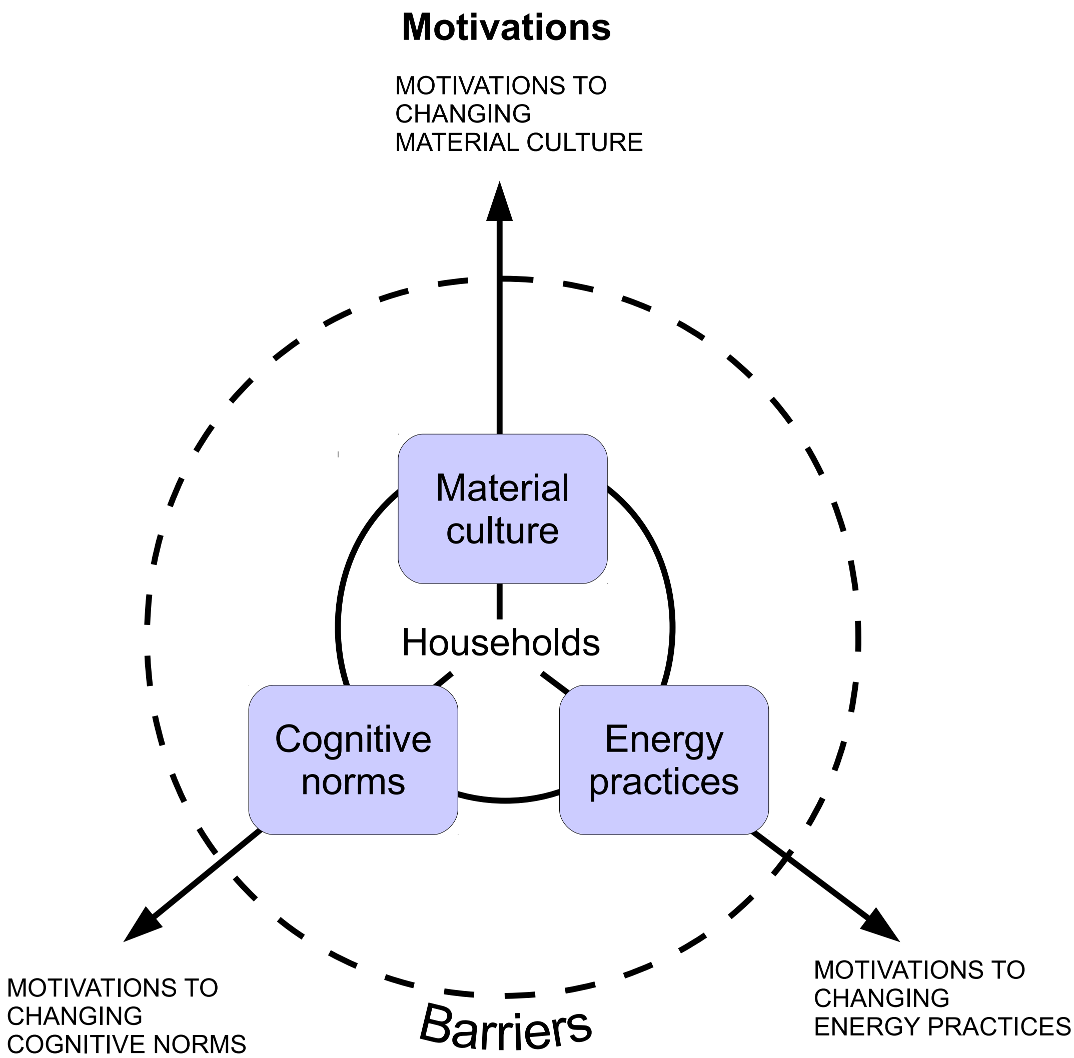

Figure 2.15: Research model based on Energy Culture

research aims to help address the Energy Efficiency Gap and improve the energy performance of the built environment. Further review of the barriers, motivations, and attitudes towards energy use are discussed in the following sections.

2.5.1 Barriers to adopt energy efficiency measures

As previously discussed within the Energy Efficiency Gap, there is a wide range of identified barriers that prevent or hinder the adoption of domestic energy efficiency measures. Empirically, this study inductively identified the following seven barrier themes: upfront cost; physical property constraints; personal behaviour/lifestyle; landlord-tenant/housing association split incentive; family/partner/housemate dynamics; beliefs/information/attitude; and institutional (government, energy companies) [Pelenur & Cruickshank, 2012a]. These barriers span a diverse range of perspectives from purely economical (upfront cost) to social (family relationship dynamics). From a market/economic perspective Jaffe & Stavins [1994], Stern [2006], and Sutherland [1991] argue that consumers apply an inaccurate discount rate to energy efficiency measures, i.e. they do not correctly assess the cost-benefits of energy retrofits. An Irish economic study also focused on monetary and institutional barriers, citing retrofit costs, lack of disposable incomes, and fragmented government policies as barriers preventing the adoption of energy efficiency measures [Clinch & Healy, 2000]. Supporting the regulatory perspective, Lowe & Oreszczyn [2008] present their review of barriers that UK policy needs to overcome to improve building energy performance. Specifically, Lowe & Oreszczyn cite the following institutional barriers: regulatory confusion; lack of energy performance data; absence of coherent energy supply policies for housing; and lack of construction industry skills [Lowe & Oreszczyn, 2008].

Along similar lines, a UK national survey and focus group identified a substantial disparity between households' willingness to pay for renewable energy and their adoption of such tariffs [Diaz-Rainey & Ashton, 2008]. The study concluded that consumer confusion, lack of supply, and institutional complexity all contributed to the disparity [Diaz-Rainey & Ashton, 2008]. Supporting these results, an OECD report based on the Environmental Policy and Individual Behaviour

Change survey carried out in 2011 with 12,000 households across various countries found that 60% of respondents were willing to pay more for renewable energy, but that they did not have the option to do so [OECD, 2013]. Focusing on one specific technology, a further study that investigated the adoption of air-source heat pumps (ASHP) in East Yorkshire also concluded that consumer confusion and technology complexity were barriers affecting the adoption of ASHPs [Owen *et al.*, 2013]. Complementing these technical, institutional and economic factors, there is also a wide range of psychological and sociological barriers that affect the uptake of energy efficiency measures.

Within the UK, the Department for Environment Food and Rural Affairs (DEFRA) commissioned a large social science study to develop a framework for pro-environmental behaviour [Defra, 2008]. As part of this study, DEFRA identified social barriers that prevented the adoption of domestic energy efficiency measures, specifically: external constraints (working patterns, demands on time); individual habit; scepticism; and dis-empowerment [Defra, 2008]. In addition, Lutzenhiser [1993] presented a review of social science research concerned with human factors in domestic energy use. The review identified a breadth of research that highlighted how social processes, such as neighbourhoods and family relationships, influence energy consumption [Lutzenhiser, 1993]. Other identified examples of social processes are personal habits; lifestyle choices; and social norms/values [Blumstein *et al.*, 1980]. Along with the traditional economic and market barriers, these identified social barriers highlight the complexity of the retrofit challenge and underscore the need for inter-disciplinary research.

While barrier research alone may may help decision makers overcome obstacles, it typically lends itself to energy conservation positive actions and favours technical solutions [Weber, 1997]. As such, research into the motivations or drivers of adopting energy efficiency measures complements barrier research, and may help decision makers better understand how to more effectively *overcome* these barriers.

2.5.2 Motivations to adopt energy efficiency measures

From a UK perspective, Mills & Rosenfeld [1996] identified the following drivers to improve household energy performance: improved competitiveness; energy security; net job creation; and environmental protection. While from the consumer level, Mills & Rosenfeld [1996] found that it was often non-energy benefits that motivated households to be energy efficient, since households stood to gain only relatively small financial savings from adopting energy efficiency measures. For example: improved comfort; reduced noise; labour and time savings; improved process control; increased convenience; waste minimisation; and direct or indirect economic benefits from downsizing of equipment [Mills & Rosenfeld, 1996]. These motivations presented by Mills & Rosenfeld highlight the range of drivers that may exist outside pure economics; although their study did not directly engage with households and instead relied on secondary sources.

Empirically, this study inductively identified the following seven motivation themes: save money, environmental/emissions, resource efficiency, warmth and comfort, aesthetics and space, health and safety, and time and convenience [Pelenur & Cruickshank, 2013a]. Using another more direct research method, a UK study that interviewed 53 social housing tenants also found that comfort habits were substantial factors affecting domestic energy consumption [Huebner *et al.*, 2013]. Similarly, the Design Innovation Group in the Open University Sustainable Technologies Group used on-line questionnaires and in-depth telephone interviews to survey UK households about the factors influencing the adoption of four established energy efficiency measures (loft insulation, condensing boilers, heating controls, and energy efficient lighting) [Caird *et al.*, 2008]. In total they gathered nearly 400 responses with the questionnaire and 111 in-depth telephone interviews, although they reported that their sample may suffer from self-selection bias. In their study, Caird *et al.* found that the motivations fell into three broad categories: save energy; save money; and save the environment [Caird *et al.*, 2008]. For loft insulation, another driver was the desire for a warmer home and comfort [Chappells & Shove, 2005]. Other studies have explored these motivations in finer detail. One such study carried out in-depth interviews, lasting about 30 mins, with a representative sample of about 1,000 UK households and found the following drivers: perceived cost of the measure; the perceived amount of disruption its installation would cause; the presence and awareness of any accreditation regime; and whether the measure had been recommended to the household [Oxera, 2006].

International studies also identified a similar range of motivations. Looking at one technology in particular, Fischer [2004] examined the motivations of pioneer users of MicroCHP [1]in Germany. Three group discussions were held with 26 volunteers, and an additional 464 postal questionnaires were sent out (returned = 142). The results revealed the following motivations to adopt this technology: government support scheme; produces electricity; reliability; needed new heating; independence from oil; a new technology; cost advantages; saving energy; and the environment [Fischer, 2004]. On a wider scale, an Indian study that examined the Energy Efficiency Gap in India's household sector found that households wanted to be convinced of technical soundness, cost effectiveness, and have access to the necessary finances before adopting energy efficiency measures [Reddy, 2003].

In summary, the above research identified a wide range of barriers and motivations for adopting energy efficiency measures, many of which did not relate directly to cost or energy savings (such as convenience, personal habits, and time savings). However, none of the studies investigated which types of households were associated with each barrier/motivation. Therefore, as well as identifying retrofit barriers and motivations in a large UK city context, this research also investigated potential demographic variables associated with these barriers/motivations. The aim of using demographics was to enhance the contextual data for each barrier/motivation, and thereby improve the the practicality of the final recommendations.

2.5.3 Attitudes towards energy use

In the wake of the 1970s oil crisis, there was a surge of research that investigated attitudes towards energy use, conservation, and environmental beliefs. In his study, Olsen [1981] found that during the oil crisis, Americans personally felt responsible for solving the problem and held a broad environmental ethic; although less than a quarter felt completely unconvinced of the problem. Another psychological study,

[1]Small combined heat and power plants based on fuel cell technology

also conducted during the height of the crisis, investigated what effect fear had on attitudes towards energy [Hass *et al.*, 1975]. The results concluded that increasing the perceived likelihood of an energy shortage did not affect attitude, but that increasing the perceived noxiousness or severity of an energy crisis strengthened intention to reduce energy consumption [Hass *et al.*, 1975]. With respect to technology attitudes, a small study in Los Angeles found no link between general attitudes towards technology and conservation behaviour [Anderson & Lipsey, 1978]. The 1970s oil crisis highlighted how large global events can influence attitudes towards energy use, with the Fukushima Daiichi nuclear disaster as a more recent example that resulted in stronger anti-nuclear sentiments [Visschers & Siegrist, 2013].

Whether it is large global events or local culture, context is an important factor to consider when investigating attitudes towards energy [Lutzenhiser, 1992; Owens & Driffill, 2008; Shove *et al.*, 1998]. For example, a study in Canada examined the relationship between homeowners' attitudes and their winter gas consumption, and found that thermal comfort was the most important determinant of household energy use [Becker *et al.*, 1981]. On the other hand, other studies found a wide range of socio-demographic variables more significant in determining household energy use [Abrahamse & Steg, 2009; Guerin *et al.*, 2000; Ritchie *et al.*, 1981]. For example, a large scale Texas study investigating viewpoints towards energy use in the southwestern United States also found that thermal comfort and health was the prevailing attitude [Samuelson & Biek, 1991]. However, even though the Canadian and Texas study conclusions were broadly similar, the interpretation of the results was quite different given that thermal comfort in Canada is largely defined by heating, while air conditioning determines thermal comfort in Texas. Another cultural difference example was revealed in a US study that politically conservative individuals were less likely to adopt energy efficiency measures than were those who were more politically liberal [Gromet *et al.*, 2013]. Gromet *et al.* [2013] concluded that the results were driven primarily by the reduced psychological value that more conservative individuals placed on reducing carbon emissions. However, such politically-based psychological value depends heavily on the political context, and may not be applicable across political borders or successive governments. Such studies highlight the need to understand and present both physical and temporal context before attempting to interpret social attitude research.

In the UK, the Department of Food and Rural Affairs (Defra) conducted a series of environmental attitude studies to investigate three areas: first, to understand pro-environmental behaviour and attitudes; second, to investigate how those attitudes can be used to encourage sustainable energy consumption at home; and third, to outline a framework to generally encourage pro-environmental behaviour [Defra, 2007, 2008]. Their results segmented the population into seven major groups according to their environmental values, namely: Greens; Consumers with a Conscience; Wastage Focused; Currently Constrained; Basic Contributors; Long-Term Restricted; and Disinterested [Defra, 2007]. While thorough, these studies focused only on environmental attitudes as opposed to general attitudes on energy use. With respect to energy, numerous studies have investigated attitudes toward specific issues such as wind or solar power [Eltham *et al.*, 2008; Faiers & Neame, 2006; Jones & Eiser, 2009; Krohn & Damborg, 1999], but very few studies have sought to specifically identify attitudes towards home energy use more generally. Instead, some studies solely investigated environmental attitudes with the implicit assumption that only those attitudes were related to domestic energy use [Mansouri *et al.*, 1996; Zhang *et al.*, 2012]; while other studies treated attitudes/behaviour as a poorly defined nebulous variable in a statistical or engineering model [Druckman & Jackson, 2008; Swan & Ugursal, 2009]. Therefore, to address this gap in extant scholarship, this study aimed to clearly identify general household viewpoints/attitudes towards energy use and link them to technical retrofit preferences and energy efficiency behaviours in a UK context.

2.6 Summary

In summary, this literature review highlighted the importance of addressing the Energy Efficiency Gap in the UK. In order to improve the understanding of this phenomenon, the literature review also identified a knowledge gap for more interdisciplinary research that considers both social and cultural factors alongside traditional technical and econometric measures. Hence, this chapter introduced a socio-technical Energy Culture model that links household barriers and motivations to adopt retrofit measures with retrofit technologies and social attitudes towards energy. The relevant literature underpinning the model was also reviewed, and based on these insights, the following chapter presents the research design and overall methodology used by this research.

3 | Research design

This chapter presents the overarching research philosophy, methodology, and design. The research was carried out to address the identified knowledge gap of inter-disciplinary research into the Energy Efficiency Gap. As such, the research questions were crafted to gain a broad insight into the social and technical factors affecting the adoption of retrofit measures. Specifically, this research investigated household retrofit barriers/motivations, viewpoints towards energy use, and retrofit technology and behaviour preferences.

To answer the research questions, an overarching interpretivist paradigm and mixed-method methodology were adopted [Ponterotto, 2005]. Broadly, the research was conducted in two phases. The first phase applied thematic analysis and a modified chi-square test of association to investigate the barriers and motivations of retrofitting; while the second phase applied Q Methodology and a questionnaire to investigate household viewpoints towards energy use, and retrofit technology and energy efficiency behaviour preferences.

This chapter is divided into two halves: the first half outlines the theoretical underpinnings of the research philosophy and methods; while the second half discusses the practical implementation of the methods.

3.1 Research philosophy

This research adopted a broad interpretivist paradigm as its philosophy. Within this paradigm, the research design and interpretation of the results were guided by a relativist ontology and constructivism epistemology. Essentially, interpretivism maintains that reality is constructed in the mind of the individual based on meanings, context, and shared experiences, and only to a lesser extent determined by fixed physical structures [Ponterotto, 2005; Robert Wood Johnson Foundation, 2008; Routledge, 2000]. In other words, individuals construct their knowledge and truth as the result of perspectives, and create a world around them through a process of social exchange [Crotty, 1998, p. 57 - 59]. For example, can a Picasso masterpiece be enjoyed by simply reading a description of its colours, the intensity of each shade, the size of the details and the dimensions of the frame [Black, 2006]?

As a result of this philosophy, data was primarily collected by speaking to individuals; although objective data such as household demographics was also collected to aid in the interpretation of the results. Consequently , the identified motivations, barriers, attitudes, and technology preferences were taken as subjective beliefs valid in their own right. For example, if an individual stated that they did not have enough space in their loft for insulation, that belief was considered valid even though that may not have been the objective truth.

This approach is congruent with the perspective that people use energy, not buildings [Janda, 2011], and the Energy Culture framework that describes how our cognitive norms, such as upbringing and education, are linked to our energy practices and material culture [Hargreaves *et al.*, 2010; Rayner & Malone, 1998; Stephenson *et al.*, 2010].

3.2 Methodology

Based on an interpretive paradigm, this research was conducted using a concurrent mixed-method methodology, i.e. a mix of parallel qualitative and quantitative approaches. Using mixed-methods, three of the research questions were answered primarily with qualitative approaches supplemented by quantitative data, specifically, the motivations for retrofitting, the barriers for retrofitting, and household viewpoints towards energy use. The remaining research question was answered primarily with a quantitative method supplemented with qualitative data, specifically, retrofit technology and energy efficiency behaviour preferences, and investigating the relationships between the viewpoints and stated preferences. For example, the questionnaire included open response boxes, and demographics were statistically linked with qualitative barriers/motivations. The aim of using mixed-methods was to facilitate the inclusion of social context and participant subjectivity, as well as increase the breadth and depth of data to aid in the final interpretation.

In detail, the motivations and barriers for retrofitting were identified through the thematic analysis of street interview transcripts, and household viewpoints towards energy use were identified through Q Methodology. Likewise, a quantitative questionnaire was used to measure retrofit technology/behaviour preferences, and multiple statistical tests of association were applied to investigate the relationship between the stated preferences and viewpoints.

Figure 3.1 is a visualisation of the adopted research philosophy, methodology, and design.

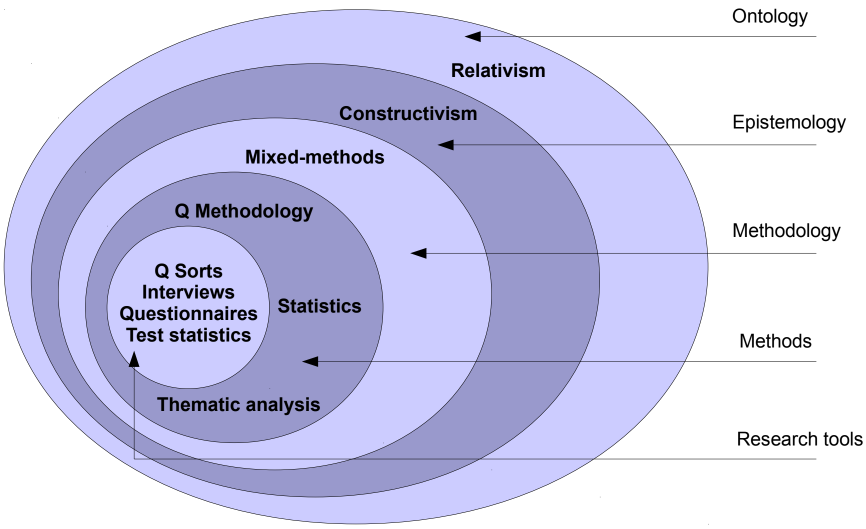

Figure 3.1: PhD research philosophy and methodology
Adapted from [Saunders *et al.*, 2009, p. 108]

3.3 Methods

The selected research methods are discussed below, followed by their practical designs.

3.3.1 Thematic analysis

Thematic analysis was applied to answer the first two research questions: what are the barriers preventing households from adopting retrofit technologies and energy efficiency behaviours, and conversely what are their motivations? This involved identifying important information in semi-structured interview transcripts and encoding it prior to a process of interpretation [Boyatzis, 1998; Pelenur & Cruickshank, 2012b]. The identified codes were then used to organise the data in order to identify and develop the barriers and motivations [Fereday & Muir-Cochrane, 2008]. As such, the results represented specific patterns found in the data, and were identified inductively [Marks & Yardley, 2004]. A strength of this approach is that it provides flexibility for the researcher to define their own criteria that best answers their specific research question [Braun & Clarke, 2006]. However, an important point to address in terms of coding is what counts as a pattern/theme? Generally, a theme captures something important about the data and represents some level of meaning within the data. Therefore, since this research aimed to identify a wide range of possible retrofit motivations and barriers, no quantitative prevalence threshold was set, i.e. there was no minimum number of responses required before identifying a theme. Instead, the coding process was inclusive and comprehensive, identifying all unique motivations stated by participants to provide a rich thematic description of the entire data set [Braun & Clarke, 2006]. An advantage of this approach was that it provided a flexible method for the systematic detailed analysis of qualitative data. The flexibility, inclusiveness, and comprehensiveness of thematic analysis is why it was selected over other more quantitative methods, such as content analysis. Conversely, this flexibility can also be viewed as a disadvantage since it does not provide specific guidelines of analysis for the researcher [Braun & Clarke, 2006].

Once the barriers and motivations were identified, interviewee demographics were then used to enhance the context and interpretation of the results. For example, was the initial purchase price of a retrofit measure consistently stated as a barrier more often in Manchester than in Cardiff? In order to investigate such possible associations, contingency tables were formed between demographic variables and all the motivations and barriers were identified by thematic analysis. A modified first-order corrected Rao-Scott chi-square statistic was then used to identify significant associations [Pelenur & Cruickshank, 2012b].

3.3.2 Modified chi-square test statistic

The test of association for contingency tables with categorical data, such as motivations and barriers to retrofitting, is normally done with a Pearson's chi-square test of association. However, it was not possible to apply a standard test to this data because the interviewees were asked to list ANY barriers and motivations towards retrofitting rather than a SINGLE barrier or motivation. Hence, it was possible for individual interviewees to state multiple barriers/motivations, i.e. the categorical data (barriers and motivations) was *multi-response*. As such, a traditional Pearson chi-square was inappropriate since there was within-participant dependence among responses, thereby invalidating the independence of observation assumption underpinning the test [Bilder & Loughin, 2004]. Table 3.1 is an example of this multi-response data, shown as a contingency table between the demographic variable of Sex and 8 barriers (B1 - B8).

Table 3.1: Contingency table of demographic variable Sex versus barriers

Sex	Barriers								Total number of	Total number of
[D1]	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	responses	participants
Female	12	34	18	4	10	13	19	25	135	88
Male	4	31	7	11	18	17	14	15	117	85
Total	16	65	25	15	28	30	33	40	252	173

Table 3.1 highlights the within-participant dependence problem. Note that since some interviewees mentioned multiple barriers, the total number of responses for females was 135 with only 88 females interviewed. As such, instead of a standard singly-by-single test, a single-by-multiple (SM) response test was required.

Categorical multiple response survey data

Despite the historic use of multiple response surveys, tests for association for this type of data were only recently proposed during this last decade. As listed by Thomas & Decady [2004], current tests fall into two classes: the first, 'bootstrapping' a suitable test statistic when its distribution is not known exactly [Loughin & Scherer, 1998]; and the second, approximating chi-squared tests [Decady & Thomas, 2000]. The latter were of particular interest because of their familiarity and close relation to the classical Pearson chi-square test [Thomas & Decady, 2004], which is widely understood and recognised as a standard statistical test. In order to retain intuitive familiarity with the results, this research used a modified first-order corrected Rao-Scott chi-square statistic [Rao, 1984; Rao & Scott, 1981], denoted as $X^2_{SM}(AL)$, proposed by Agresti & Liu [1999], and Thomas & Decady [2000, 2004]. As well as testing for association, the strength of the resulting association was also examined with a corresponding odds ratio table, as per Thomas & Decady [2004].

Briefly, the test statistic $X^2_{SM}(AL)$ is calculated for a $r \times c$ data table by summing up the individual Pearson chi-square statistics for each of the c marginal $r \times 2$ tables relating the single response variable to the multiple response variable with $df = c(r-1)$ [Agresti & Liu, 1999]. Agresti & Liu [1999] found that this approach yielded a chi-square test statistic numerically similar to those produced by other asymptotically correct procedures [Agresti & Liu, 1999]. Thomas & Decady [2000], and Bilder *et al.* [2000] also independently showed that $X^2_{SM}(AL)$ can be regarded as a member of the familiar Rao-Scott corrected chi-squared family of tests for complex surveys [Thomas & Decady, 2004]. As such, the $X^2_{SM}(AL)$ statistic is a simple and parsimonious approach to apply to categorical multiple response data. For example, in Table 3.1, the eight marginal Pearson statistics are 4.11, 0.09, 5.22, 3.85, 3.07, 0.82, 0.73, and 2.82, each having $df = 1$. Therefore, the resulting $X^2_{SM}(AL)$ statistic is the summation of these values and equals 20.71 with $df = 8$, $p = 0.008$.

This approach can be re-written as a single equation by considering a single by multiple response data table with n participants, and with row and column variables which consist of lists of items of length r and c. Thomas & Decady [2004] and

Bilder *et al.* [2000] showed that with the above notation and definition, $X^2_{SM}(AL)$ can be calculated simply as:

$$X^2_{SM}(AL) = \sum_{i=1}^{r}\sum_{j=1}^{c} \frac{(m_{ij} - n_i m_{.j}/n)^2}{(n_i m_{.j}/n)(1 - m_{.j})} \tag{3.1}$$

In Equation 3.1, let m_{ij} denote the number of participants (out of a total n) who selected item i on the first variable and item j in the second. The number of participants responding in row i of the table is denoted by n_i for the single response variable $i = 1, \ldots, r$, and the marginal count, $m_{.j}$, $j = 1, \ldots, c$ denotes the number of participants selecting item j in the multiple response variable column (irrespective of row selection) [Thomas & Decady, 2004].

The probability π_{ij} that a participant will respond positively to item i of the row variable, and item j of the column variables is defined and estimated as $\pi_{ij} = E(m_{ij})/n$ and $\hat{\pi}_{ij} = m_{ij}/n$ respectively, where E(.) denotes expectation [Thomas & Decady, 2004]. Similarly, the one-way marginal probabilities π_i and $\pi_{.j}$ are defined as $\pi_i = E(n_i)/n$, $\hat{\pi}_i = n_i/n$ and $\pi_{.j} = E(m_{.j})/n$, $\hat{\pi}_{.j} = m_{.j}/n$. Therefore, the hypothesis for row by column marginal independence is expressed as:

$$H_o : \pi_{ij} = \pi_i \pi_j$$

$$H_1 : \text{At least one equality does not hold}$$

The above hypothesis of marginal independence is equivalent to the odds ratio hypothesis $\Phi_{ij} = 1 \forall i, j$ so that as well as applying the $X^2_{SM}(AL)$ test statistic, the data can also be displayed in terms of odds ratios, which can be used to examine the strength of association [Thomas & Decady, 2004].

Analogously, the approach for single response versus multiple response variables ($X^2_{SM}(AL)$) can also be extended to multiple response versus multiple response ($X^2_{MM}(AL)$) [Thomas & Decady, 2004]. Algebraically, the equation to calculate $X^2_{MM}(AL)$ using the marginal counts for both rows and columns is:

$$X^2_{MM}(AL) = \sum_{i=1}^{r}\sum_{j=1}^{c} \frac{(m_{ij} - m_{i.} m_{.j}/n)^2}{(m_{i.} m_{.j}/n)(1 - m_{.j}/n)(1 - m_{i.}/n)} \tag{3.2}$$

Thomas & Decady [2004] demonstrated that the multiple by multiple modified first-order corrected Rao-Scott chi-square statistic ($X^2_{MM}(AL)$) yields good control of Type I errors, similar to $X^2_{SM}(AL)$. The hypothesis of row by column marginal independence for two multiple-response variables is the same as for one multiple-response variable [Thomas & Decady, 2004].

Using the modified test statistic, it was possible to statistically identify associations between interviewee demographics and the identified barriers and motivations to retrofitting. Such associations improve the inclusion of interviewee context in the analysis and discussion. Alongside the identified barriers and motivations to retrofitting, this research also used Q Methodology to investigate the underlying general public viewpoints and attitudes about household energy consumption. The aim of investigating retrofit barriers, motivations, and viewpoints towards energy consumption was to improve our contextual understanding of how households view energy, in order to create a set of balanced and holistic recommendations to improve the effectiveness of future retrofit initiatives.

3.3.3 Q Methodology

Q Methodology (Q) was developed by psychologist William Stephenson in 1952 as a research method used to study the 'subjectivity' or viewpoints of specific topics [Stephenson, 1952]. Since then, it has been adopted by multiple disciplines as a robust tool to help researchers investigate a wide range of subjective topics such as: teen pregnancy; divorce; and residence proximity to nuclear power plants. The research presented in this thesis was the first to apply Q to energy use in the UK built environment, specifically by investigating the public's viewpoints towards their household energy use.

As presented by Barry & Proops [1999], the general steps to a Q Study are shown below. These steps should not be used in isolation, rather the seminal books by Brown [1980] and Watts & Stenner [2012] provide a more detailed overview of the application of Q.

1. Identify the area of subjective 'discourse' one wishes to explore, where the term 'discourse' is used to represent the collective viewpoints on a given

topic. In this study, the discourse under study was household viewpoints relating to domestic energy use.

2. Research existing viewpoints through the use of interviews, focus groups, or discussions with the relevant population. Other sources of opinions, such as newspaper items or magazines, can also be used to supplement the interviews. The main objective of this step is to create a comprehensive and representative list of viewpoints that broadly encompass the discourse under study [Brown, 2004; Watts & Stenner, 2005]. This step is performed as carefully as participant selection for a normal survey [Brown, 2004].

3. With the data, make a selection of single idea statements (Q-set) that will later be ranked by participants during the Q-sorts. The same participants that were part of the statement interviews may also be selected for the Q-sorts.

4. Perform Q-sorts with individual participants, where the statements (Q-set) are presented to them and then typically ranked using a Likert-type scale into a quasi-normal forced distribution. Although the shape of the distribution is not significant [Watts & Stenner, 2012]. During this ranking stage, the participants are asked to comment on their decisions, and these responses are used to qualitatively inform the final analysis.

5. Perform a statistical by-person factor analysis with the rank ordered statements.

6. Qualitatively interpret the resulting factors, which represent the emergent viewpoints.

The forced quasi-normal distribution used as part of the Q Study is shown in Figure 3.2, and an illustration of a participant performing the Q-sort is shown in Figure 3.3.

Instead of a quasi-normal distribution, it is possible to use other forms such as a 'free' distribution where the participants have no ranking limit, as the distribution effects are virtually nil [Brown, 1980; Watts & Stenner, 2005]. This is due to the cognitive challenge faced by participants when ranking statements. Brown [1980]

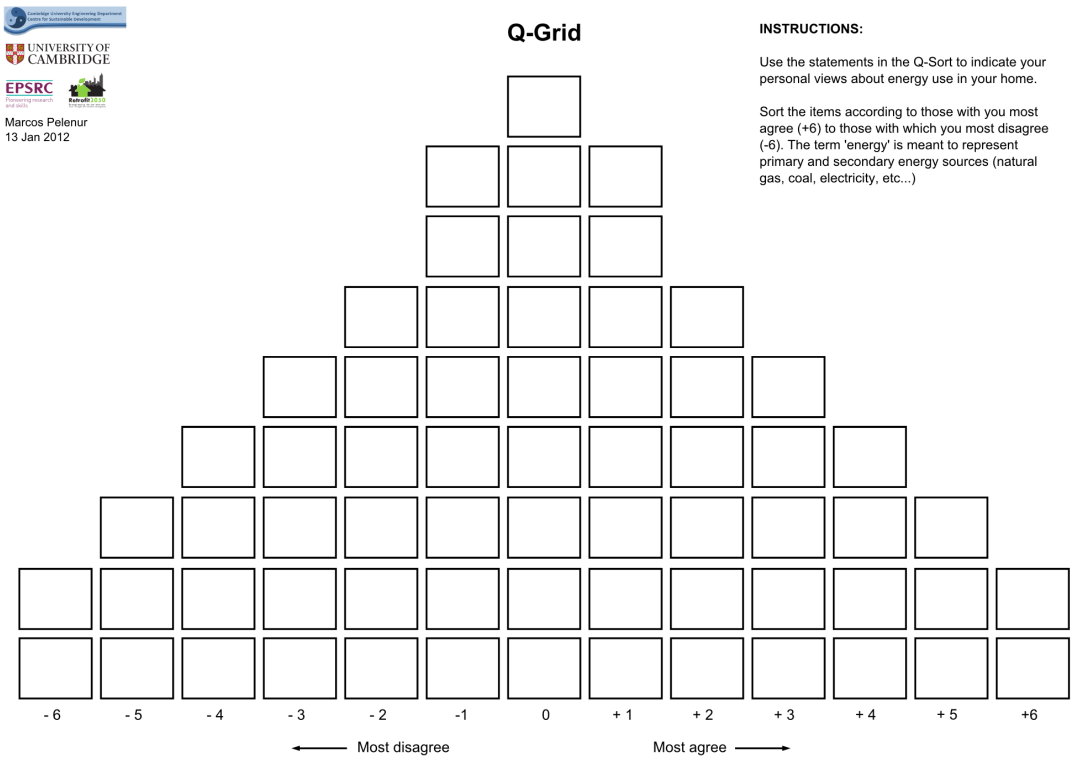

Figure 3.2: Q Study quasi-normal distribution

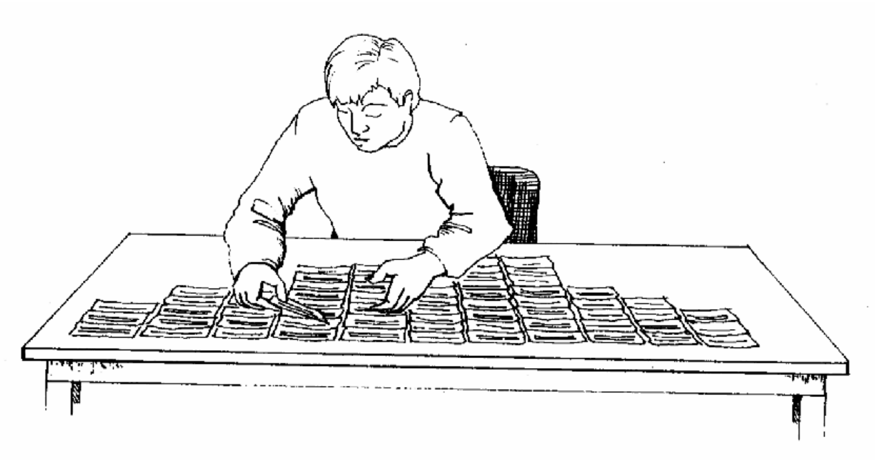

Figure 3.3: Example of a participant performing a Q Sort with cards

showed that with a relatively small Q set of only 33 statements, the cognitive ranking task still presented participants with *"roughly 11,000 times as many [sorting] options as there are people in the world"*; in other words, a *"hyperastronomical"* number of combinations.

Although Q uses a type of statistical analysis, it should not be confused with the commonly used quantitative R Methodology (example: questionnaires), which seeks to identify and combine sets of dependant variables to statistically correlate relationships between similar things. Instead, Q uses a by-person factor analysis in order to identify groups of participants who rank and make sense of statements in a comparable way [Watts & Stenner, 2005]. By supplementing the factor analysis with interview transcripts, Q allows the researcher to interpret the statistical results through a qualitative lens, thereby "establishing patterns within and across individuals rather than patterns across individual traits, such as gender, age, class, etc" [Barry & Proops, 1999]. As such, Q offers the advantage of using a small sample to parsimoniously explore subjective topics and identify complex viewpoints, while R offers the advantage of generalisability to larger populations of people, and an explanation of a perspective's relationship to other variables [Danielson, 2009]. It is also important to recognise that Q is an inherently exploratory technique, meaning that it cannot prove hypotheses. However, it can help "bring a sense of coherence to research questions that have many, potentially complex and socially contested answers" [Smith *et al.*, 1995].

At the same time as the Q-Sorts were being conducted, a questionnaire was also administered to measure retrofit technology and energy efficiency behaviour preferences. The results of the questionnaire were linked to the energy viewpoints to provide context and assist in the Q Methodology factor interpretation.

3.3.4 Questionnaire to measure retrofit technologies and energy efficiency behaviour preferences

The questionnaire investigated stated intent and desire to install various energy efficiency technologies and/or behaviours in the home. The questionnaire design was influenced by the Theory of Reasoned Action (TRA) and Theory of planned behaviour (TPB), which both suggest that the level of 'intentions' shown by an individual is the best predictor of their behaviour [Jackson, 2004; Kaiser *et al.*, 1999; Kalafatis *et al.*, 1999]. TRA was developed by Fishbein and Ajzen in the late 1970s as a model which assumes that people behave according to their beliefs about the outcomes of their behaviour, and the values they attach to those outcomes. As Jackson [2004] explains, "my intention to act in a certain way is, in this circumstance, likely to be a reliable indicator of my actual behaviour". In their model, intention is the key determinant of behaviour, however many examples exist where intention and behaviour are often at odds, as the saying goes, "the road to hell is paved with good intentions" [Jackson, 2004]. In order to address this point, the theory was extended in the 1980s to TPB by Fishbein and Ajzen. The new model included an additional indicator of both intention and action, known as perceived behavioural control (PBC). PBC is defined as "the person's belief as to how easy or difficult performance of the behaviour is likely to be" [Ajzen & Madden, 1986].

Since their introduction, TRA and TPB have been widely applied to understanding behaviour in a range of different contexts, particularly to explore pro-environmental behaviour [Jackson, 2004]. However, TRA and TPB have both been criticised for not specifically measuring behaviour or accounting for affective or emotional behaviour [Fitzmaurice, 2005].

For this research, the questionnaire was influenced by TRA/TPB but did not formally apply the models, specifically the questionnaire measured the desire to install or adopt a range of energy efficiency technologies and/or behaviours as well as the participant's stated intent to do so. The distinction between 'desire' and 'intent' was intentional, in order to capture situations when a participant wanted to install/adopt a certain technology/behaviour ('desire'), but could not do so ('intent'). For example, some participants wanted to install solar photovoltaic systems to generate electricity (high 'desire'), but could not do so because of the cost or due to being a tenant (low 'intent'). Therefore, a response box was also placed next to each technology/behaviour in the questionnaire so that the participant could note the reason for any difference between intent and desire, and to note any motivations or barriers to adopting the technology/behaviour. The questionnaires were completed after the participants finished the Q-sort.

Importantly, even though intention to act is often a reliable indicator of behaviour [Jackson, 2004], this study did not infer that the stated answers on the questionnaire necessarily led to behaviour change. Instead, the purpose of the questionnaires was to reveal potentially interesting relationships between the Q study factors (viewpoints) and the stated intent and/or desire to install/adopt energy efficiency technologies/behaviours. Such relationships help ground the Q factors within an engineering and technological context, and help with the possible interpretation of the factors.

The remaining sections describe the practical implementation of each of the research methods.

3.4 Research scope

As part of the EPSRC RETROFIT 2050 programme, this research was geographically centred in the UK city regions of Cardiff and Greater Manchester. Cardiff and Manchester were selected by the RETROFIT 2050 project because "both have long industrial histories, both have suffered decline in recent decades and both are seeking to overcome this decline, regenerating themselves into modern, vibrant cities" [RETROFIT 2050, 2012]. In support of this geographical selection by the research programme, the building stock in Manchester and Cardiff also stands to benefit by systematic retrofitting, since there are still approximately 500,000 untreated lofts and cavity walls in Manchester [Low Carbon Housing Retrofit, 2012], and only approximately 18% of homes in Wales have cavity wall and loft insulation fitted [National Refurbishment Centre, 2012].

The research methods were applied separately in both cities, but the results analysed together to identify similarities and differences. Similarly, research participants were selected as individuals, however, when possible the analysis was conducted at the household level, i.e. retrofit motivations/barriers, energy viewpoints, and technology/behaviour preferences were related back to households. Households were a practical means of capturing important social context relevant to retrofitting, for example inter-occupant relationships and how households view themselves within their neighbourhood. Social context, such as collective norms or shared expectations, are important factors to consider in order to better understand energy consumption in the home [Hargreaves *et al.*, 2010; Lutzenhiser, 1992; Rayner & Malone, 1998; Stephenson *et al.*, 2010].

Temporally, this research applied a snapshot rather than longitudinal approach. Specifically, the results reflected present conditions, so there is a risk that the relevancy may diminish if there was a sudden change in the make-up of the physical housing stock, or in how households view energy. For example, public opinion towards nuclear energy noticeably shifted after the Fukushima Daiichi nuclear disaster [Visschers & Siegrist, 2013]. However, the UK housing stock has a very slow demolition and re-build rate [Boardman *et al.*, 2005], so it is unlikely that the neighbourhood housing stock will dramatically or quickly transform. Similarly, from a social perspective, the Energy Efficiency Gap was identified over 30 years ago, yet survived all the subsequent cultural evolutions [Scheraga, 1994]. Therefore, it is also unlikely that short-term external events will dramatically or quickly alter our social and cultural norms towards energy use. More likely, seasonal shifts in the weather may affect subjective viewpoints towards household energy use. Hence, the subjective research was carried out twice, once in the summer and once in the winter, to compare and contrast results.

3.5 Research model

Based on the Energy Culture model [Stephenson *et al.*, 2010], Figure 3.4 outlines how the methods and broad sources of data fit into the theoretical model for this research.

3.5.1 Cognitive norms

The cognitive norms component of the model refers to the attitude/value/belief system that the household holds towards energy use [Stephenson *et al.*, 2010]. For this research the following three methods were used to investigate household cognitive norms: Q Methodology; interviews; and a questionnaire.

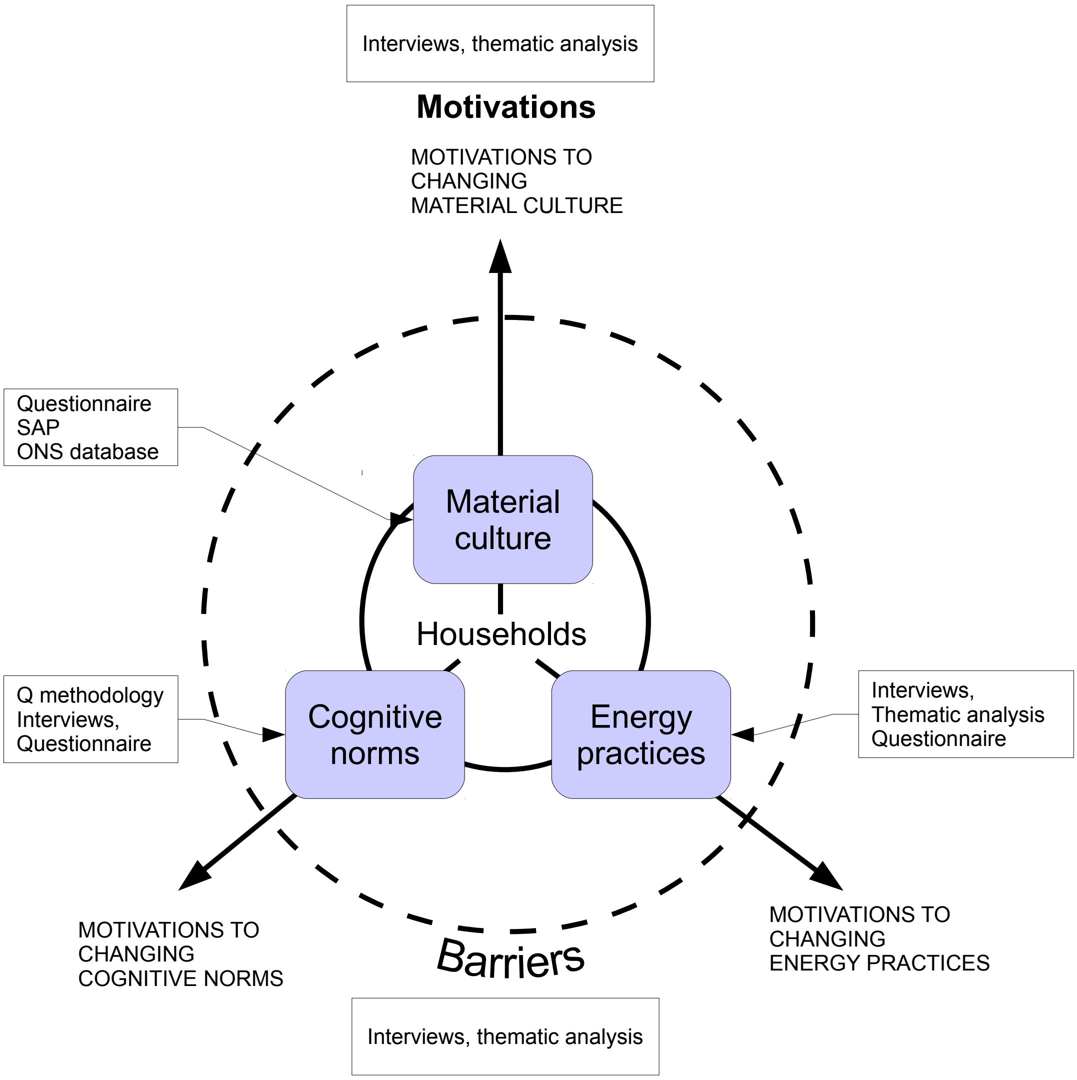

Figure 3.4: Theoretical research design and data sources

3.5.2 Material culture

The material culture of a household can be understood as a technical system in its own right [Stephenson *et al.*, 2010]. For this research context, the material culture represented retrofit technologies and the household building fabric. This data was collected through the use of a questionnaire and the ONS Neighbourhood Statistics database.

3.5.3 Energy practices

Energy practices can be systematically understood as the interactions between individual, social, and institutional behaviours [Stephenson *et al.*, 2010]. In this model, energy practices referred to household energy efficiency behaviours and were collected through thematic analysis of interview transcripts, and a questionnaire.

All the components of the model are highly interactive and linked, but also systematically rest within a wider context [Stephenson *et al.*, 2010]. For this research, barriers were represented as a shared factor that encircles and affects all the core components. Similarly, motivations affect all the core components and are represented as directional arrows that can be used to overcome the barriers.

The following section describes the practical implementation used to investigate each of the model components.

3.6 Research approach

3.6.1 Barriers and motivations for retrofitting

The retrofit barriers and motivations were identified from general population interviews in Manchester and Cardiff. The interview questions were first piloted twice in Cambridge to ensure that the wording of the questions were easily understood by participants, yet open enough to allow for varied responses [Pelenur & Cruickshank, 2011b]. The first pilot took place in winter 2011 with 40 randomly selected members of the public using street interviews in the city centre. The second pilot tested the questions in a questionnaire that was distributed to an evening public lecture held at the University of Cambridge. From the 315 questionnaires distributed, 118 were sufficiently completed to be analysed. As a result of the pilots, the wording of the two questions and probing questions were selected as follows: the first question asked, *"Is there anything you would like to change about how your household uses energy? If yes, what? And why? And how would your household go about making the change? What are the drivers?"*; the second question asked, *"What are some of the barriers preventing your household from making the change?"* The questions were worded to encourage the interviewee to adopt a 'household' perspective, rather than simply an 'individual' viewpoint. This was a deliberate phrasing of the question so that the results would not only include individual behaviours, but also insights about how relationships between family members or multi-tenanted homes affect consumption.

The interviews were conducted in three different locations in each city, so that as many divergent viewpoints as possible could be captured. The Manchester set of interviews took place over three days of a bank holiday weekend in April 2011, and elicited 100 interviews in three locations. On day one, the interviews were conducted in front of an ASDA store in the neighbourhood of Hulme; on day two, in the Trafford Centre (up-scale retail); and on day three, in the city centre. The Cardiff set of interviews followed the same pattern and also took place over three days of a bank holiday in May, and elicited 98 interviews in the following three locations: day one, in front of a Super ASDA; day two, in front of a suburban Tesco; and day three, in the city centre. The varied locations were selected in order to reduce the sample bias from a single location and the interviews were conducted over bank holiday weekends to increase the range of demographics capable of participating (since the majority of people were off work).

After transcribing the interviews, the barriers and motivations were coded using the online qualitative research and mixed methods package, Dedoose. The coding process followed a thematic analysis three stage approach: first, each transcript excerpt that described a barrier or motivation was summarised by an axial code; second, the codes were analysed and grouped by sub-theme; third, the analysis was repeated in an iterative process that eventually grouped the sub-themes into an emergent theme code representing an identified barrier or motivation [Pelenur & Cruickshank, 2012b]. This process allowed for interviewees to state all the salient barriers or motivations to retrofitting affecting their household; instead of limiting them to select from a pre-defined list. As such, this approach was inductive and exploratory in nature, as opposed to explanatory.

Demographics associated with barriers and motivations

In order to include interviewee context in the analysis, each of the identified barriers and motivations were linked to their respective interviewee demographics, and statistically analysed by examining the subsequent contingency tables between demographics and barriers/motivations. For the analysis, all the demographic variables were treated as categorical, i.e. levels were assigned to each variable, in order to allow for consistent tests of association. The threshold values that defined each level were selected in order to ensure as closely as possible that "no more than 20% of the expected counts [in the resulting contingency tables] are less than 5, and all individual counts are 1 or greater" [Yates *et al.*, 1999, p. 734].

The tests of association for the resulting multi-response contingency tables with categorical data were done with the first-order corrected Rao-Scott chi-square statistic ($X^2_{SM}(AL)$). The strength of the resulting associations were also examined with a corresponding odds ratio table [Thomas & Decady, 2004].

3.6.2 Household viewpoints towards energy consumption

After identifying household motivations and barriers to retrofitting, a Q-study was undertaken to investigate the subjective viewpoints households hold towards their energy consumption.

Q-set design and content

The Q-set (range of single idea statements) for the Q-study were derived from the same general public semi-structured transcripts used to identify the motivations and barriers in Manchester and Cardiff, as well as from the transcript of a multi-day workshop with energy retrofit professionals. In total, approximately 200 suitable single idea Q statements were identified after removing obvious duplications. This list of 'raw' statements was then grouped into themes according to an inductive and structured Q-set approach as described by [McKeown & Thomas, 1988]. As such, statements were selected to cover a range of topics in order to avoid biases in over-or-undersampling particular subject areas [Steelman & Maguire, 1998]. The topics themselves were defined inductively after the statements were identified, as opposed to being deductively pre-defined based on theory [McKeown & Thomas, 1988, pp 28-30]. While it is impossible to truly separate the researcher's own subjectivity from affecting an inductive process, efforts were made to reduce possible bias by asking four colleagues to independently repeat the theme identification process. Afterwards, all the identified topics were compared together, and common themes emerged based on overlapping statements. In total, all the raw Q Statements were grouped within the following 8 themes representing different sub-topics of domestic energy consumption:

1. Economics and finance;
2. Information, awareness, and education;
3. Environment and the future;
4. Energy supply/generation;
5. Heating, home and technology;
6. Other people's behaviour;
7. My energy efficient behaviour;
8. I don't want to change/my inefficient behaviour.

In order to select only the most salient statements from each theme to ensure an approximately equal distribution, the complete list of Q Statements (grouped by theme) was shown to four non-academic volunteers unfamiliar with Q methodology. The statements that the volunteers felt were the easiest to understand and relevant to the topic (energy consumption in the home) were selected. The final Q-set consisted of 65 statements and is shown in Appendix A.

Ideally, the goal of the Q set is to capture the broadest rage of viewpoints based on the discourse, in this case energy use in the home [Durning & Brown, 2007; Karim, 2001]. However the Q set does not depend on traditional issues of validity because a viewpoint expressed by an individual is just as valid as any other expressed viewpoint and cannot be deemed invalid [Brown, 1980; Durning & Brown, 2007]. Even when individuals interpret the same statements differently, the important insight is what meanings the participants themselves derived from the statement in comparison to all the other statements [Brown, 1980; Durning & Brown, 2007]; as opposed to any *a priori* meanings imposed by the researcher.

Participants (P-set)

The participants (P-set) for this study were drawn from four areas in Cardiff and four areas in Manchester, shown in Figure 3.5. The area boundaries were defined by the Office for National Statistics (ONS) Middle Layer Super Output Area (MSOA) geographies. MSOAs were designed to improve the reporting of small area statistics and are geographically consistent with between 2,000 to 6,000 homes in each area [Office for National Statistics, 2011b]. Using a list of census and demographic variables, the four areas in each city with respect to the built form and energy use were selected to most closely match the average for the city as a whole. This was achieved by standardising the census data within each MSOA and then taking the difference between the MSOA data and the corresponding city variable. The differences for all the variables were then summed, and the four areas with the smallest total (i.e. smallest difference from city average) were selected. As such, these areas represented typical neighbourhoods in Manchester and Cardiff, as opposed to randomly selected neighbourhoods. The census variables are shown in Table 3.2 and the calculations are shown in Appendix B.

Table 3.2: Variables used to select MSOA samples

Demographic variables	
Household tenure (KS18)	Age structure (KS02)
Dwelling stock by council tax band	Household composition (KS20)
Household spaces and accommodation type (KS16)	Domestic energy consumption
Rooms, amenities, central heating and lowest floor level (KS19)	

All the variables in Table 3.2 related to MSOA level statistics, with parenthesis indicating a census variable. The data was collected from the Office for National

Statistics, Neighbourhood Statistics Database, and since the 2011 census data was not available at the time of this research, the 2001 census was used instead. Each variable is briefly described in the following list:

- Household tenure referred to the proportion of homes that were owned outright versus rented (private, council, or housing association).
- Age structure referred to the median and mean age of the population in the MSOA.
- The dwelling stock by council tax band, which listed properties by council tax rating, was data compiled from Valuation Office Agency.
- Household composition referred to the family structure within households. For example, the proportion of pensioners, married couples, or lone parents.
- Household spaces and accommodation type specified the type of home, such as detached, terraced, or flat (commercial building, purpose built, or converted).
- Domestic energy consumption data was collected from the Department of Energy and Climate Change, and included both gas and electricity.
- Rooms, amenities, central heating and lowest level floor was a compound variable that included: average household size (number of occupants); average number of rooms per household; occupancy rating; with/without central heating; lowest floor level.

These variables included all the physical built form and demographic variables relating to homes available at the MSOA level. By standardising them and comparing to the city average, it was possible to select the 4 most typical MSOAs in each city. This was deliberate sampling in order to meet the research objective of investigating general viewpoints about household energy use in 'normal/typical' neighbourhoods. This type of non-probabilistic sampling is the norm in Q [Brown, 1980; Watts & Stenner, 2012], where participants are usually chosen based on *a priori* theoretical design, rather than representativeness or quantity [Eden *et al.*, 2005]. As such, since this study investigated the general public's viewpoints, participants were purposely drawn from typical neighbourhoods in each city. However, it may be interesting for future research to investigate and contrast attitudes from fringe communities.

In total, there were 10,908 households in the 4 areas of Cardiff and 12,667 households in the four areas of Manchester. Leaflets offering a chance to win £250 in grocery vouchers for participating in the study were delivered to all the homes, followed by 2 days of door knocking in each of the areas. The leaflet distribution, door knocking, and Q-sorts in both cities occurred over the Summer of 2012. The goal was to recruit at least 10 participants from each of the areas. In total, 46 participants were recruited in Manchester and 45 in Cardiff. Figure 3.5 highlights the specific locations of the MSOAs in each of the cities.

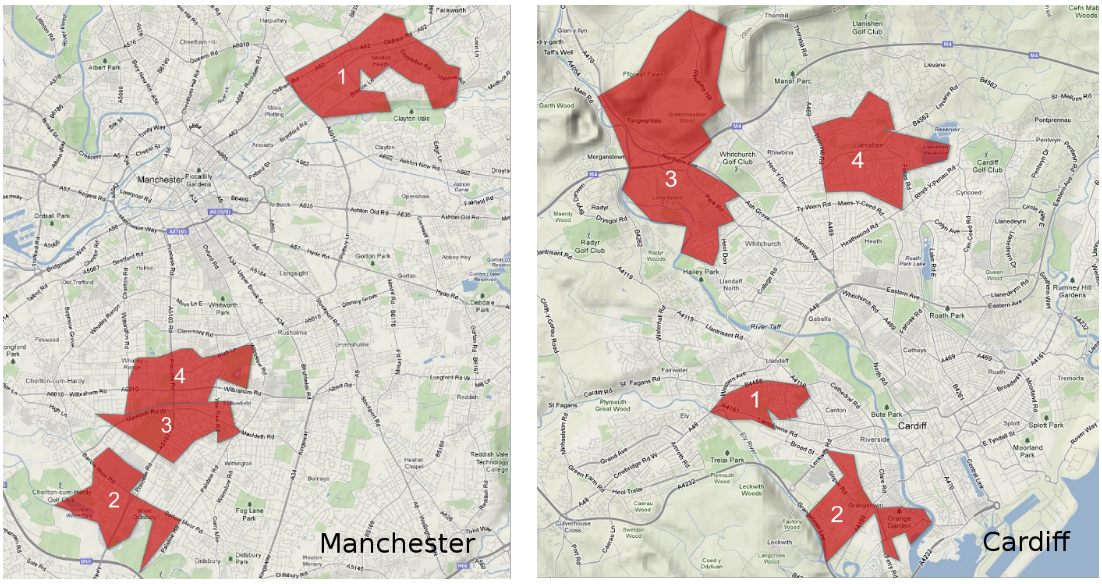

Figure 3.5: Geographic maps with highlighted sample areas in Manchester and Cardiff
Maps from Google Maps 2013

Administering the Q-sort

Prior to administering the Q-sorts in Manchester and Cardiff, two pilot tests were conducted with 14 participants in Cambridge and London. The aim of the pilots was to test the Q-set and retrofit technology/behaviour questionnaire. Following their Q-sort, each participant was asked the following questions:

- Did you understand the condition of instruction?
- Did you feel there were any statements missing, and if so, which statements would you add?
- Did you understand all the statements?

After this feedback, each participant completed the questionnaire and answered a similar set of questions. Feedback from the pilot study indicated that the Q-set was comprehensive and easy to understand, although a few minor wording changes were recommended. The Q-set and questionnaire were modified accordingly.

For the main study, the Q-sorts in each city were individually conducted in either the participant's home or in a public location, with the 65 Q Statements provided on separate and numbered cards for each participant to sort. During the Q-Sort, the participant was instructed to first sort the items into three piles: "disagree"; "neutral"; and "agree". After this coarse sort, the participant was then instructed to sort the piles one at a time (using "neutral" as the last pile) onto a quasi-normal forced distribution using a scale from -6 (most disagree) through 0 to +6 (most agree) [Watts & Stenner, 2012]. The specific condition of instruction was, "use the statements in the Q-Sort to indicate your personal views about energy use in your home. Sort the items according to those which you most agree (+6) to those with which you most disagree (-6). The term 'energy' is meant to represent primary and secondary energy sources (natural gas, coal, electricity, etc)."

After performing the Q-sorts, a semi-structured interview was conducted with each participant. The aim of the interview was to understand why participants sorted the statements the way they did, and to ensure that their viewpoint was adequately represented in the Q-sort. The interview transcripts were used to aid the final interpretation of the results. The specific questions asked were:

- Do you feel there were any statements missing, if so which statements would you add?
- Can you please explain the reasoning for choosing the extreme (+/- 6) statements?

- What do the extreme statements mean to you?
- In general, can you sum up your thoughts around this topic, specifically how you feel about energy use in your home?
- Did anything surprise you from the process?

After the interview, the participants completed the questionnaire that measured their preferences towards energy efficiency technologies and behaviours. The researcher was present to explain the instructions, answer any queries, and ensure that no questions were accidentally missed.

3.6.3 Retrofit technology and energy efficiency behaviour preferences

The questionnaire was created in order to measure the preference, as defined by intent and desire, of installing energy efficiency technologies in the home and/or adopting energy efficiency behaviours. In total, 18 energy efficiency technologies and 7 behaviours were included in the questionnaire. The technologies were selected based on their inclusion in the UK's Standard Assessment Procedure (SAP), that is the methodology used by the UK government for assessing and comparing the energy and environmental performance of dwellings [Department of Energy and Climate Change, 2012c]. The behaviours were inductively identified from the 198 general population interviews conducted in Manchester and Cardiff [Pelenur & Cruickshank, 2011b]. Table 3.3 lists the specific technologies and behaviours included in the questionnaire.

For each technology and behaviour, the questionnaire used a 7 point Likert Item (from "strongly disagree" to "strongly agree") to measure the response of the following questions: "I want to fit/adopt this measure/behaviour in my home"; and "I intend to fit/adopt this measure/behaviour in the next 12 months." Participants were also asked to tick a box if they had already installed/adopted the technology/behaviour in their home and to comment on any differences between their 'intent' and 'desire' responses, such as barriers, or motivations. If there were any technologies or behaviours unfamiliar to the participant, they were asked to

Table 3.3: Technologies and behaviours included in the questionnaire

Technologies	
Loft insulation	Wall insulation
Floor insulation	Boiler insulation
Double glazing	Triple glazing
Condensing boiler	Draught proofing
Ground source heat pump	Domestic Combined Heat and Power (CHP)
Air source heat pump	Energy efficient lighting
Passive lighting	Micro-wind
Solar PV	Solar thermal
Improved heating controls	Radiator thermometers
Behaviours	
Seek energy saving advice (from energy companies or government)	
Coordinate the time-of-use of appliances in order to minimise peak demand	
Turn appliances off completely rather than leave on stand-by	
Get rid of unnecessary gadgets or appliances	
Consciously use less	
Use lower temperature for washing machine	
Put on a jumper before turning up the heating	

skip the question. Finally, the questionnaire asked a series of personal and household demographic questions. At the end, each response was reviewed together by the researcher and the participant to ensure that they understood the difference between 'intent' and 'desire' for installing/adopting energy efficient technologies/behaviours. Similar to the Q-set, the questionnaire was also piloted in Cambridge.

Linking the questionnaire with the Q-study

In order to link the results of the questionnaire with the Q sorts, tests of associations were carried out between the numerical Q factor loadings and the questionnaire responses. For this purpose, other studies have used ANOVA, MANOVA, Pearson's correlation, and Path Analysis [Kubier, 2010; Thomas & Baas, 1996; Thomas *et al.*, 1982, 1993]. However, since the questionnaire variables consisted of multiple data types, a range of correlation measures and test statistics were used to investigate the relationship between the numerical Q factor loadings and the questionnaire responses. For example, the technology intent and desire Likert Items were interpreted as ordinal while the type of home (a demographic variable) was categorical (nominal). While there is considerable debate around the interpretation of Likert Scales (which are composed from Likert Items), it is generally recommended that individual Likert Items should be analysed as ordinal data [Carifio & Perla, 2007; Jamieson, 2004]. Table 3.4 summarises the data types associated with each of the questionnaire variables, and the test of association or test statistic used to correlate each variable with the numerical (interval/scale continuous) factor loadings from the Q study.

Table 3.4: Tests of associations with interval continuous variable

Questionnaire variables	Data type	Test of association
Technology/behaviour desire	Ordinal - Likert Item	Spearman's rho
Technology/behaviour intent	Ordinal - Likert Item	Spearman's rho
Installed/adopted (yes/no)	Dichotomous nominal	Point-biserial
Sex	Dichotomous nominal	Point-biserial
Age	Ordinal	Spearman's rho
Education level	Nominal	Anova (F Test)
Marital status	Nominal	Anova (F Test)
Household income	Ordinal	Spearman's rho
Tenure	Nominal	Anova (F Test)
Type of home	Nominal	Anova (F Test)
House age	Ordinal	Spearman's rho
Number of bedrooms	Interval	Pearson correlation

For all the listed tests of association, the null hypotheses H_o was no significant correlation between any of the questionnaire variables and the factor loadings, while the alternative hypothesis H_1 was the existence of any correlation between the variables. Since there were multiple hypothesis testing between variables, the resulting p-values from each test were adjusted to correct for multiple comparisons. For this study, the Benjamini-Hochberg procedure (BH step-up) was used to adjust the final p-values and control the false discovery rate (FDR) , i.e. the expected proportion of incorrectly rejected null hypothesis ("false discovery"). FDR procedures are widely used in data rich fields such as: physics; weather mapping; and genetics, because the procedures have been shown to more powerful than comparable methods that control for the traditional familywise error rate (such as the Holm or Bonferroni method) [Abramovich & Benjamini, 1996; Weller *et al.*, 1998; Yekutieli & Benjamini, 1999]. The adjusted p-values help correct for errors introduced by multiple comparisons, and are a more accurate reflection of significance.

3.6.4 Seasonality

The Q-study and questionnaire were both conducted during summer; however, subjective viewpoints towards energy use may change in the winter, when the heating is on and outdoor temperatures have dropped. As such, a winter survey was carried out after the summer research with all 91 participants (46 in Manchester, and 45 in Cardiff). The aim of the survey was to investigate how the change in seasons affected viewpoints towards household energy use.

The survey was administered as a posted questionnaire with an introductory letter, and an offer to win £50 in Amazon vouchers for participating. In order to increase the returned response rate, the questionnaires were kept as simple as possible. In total, 5 questions were asked. All the questions except the fifth were repeated from the Q-study or the street interviews. Specifically, the first 4 questions were:

- In general, can you sum up your thoughts about energy use in your home (electricity/gas)? [Open ended answer]

- Is there anything you would like to change about how your household uses energy? If yes, what? Please include motivations for the change and/or barriers stopping you. [Open ended answer]

- How frequently do you think about your household energy use? [5 point Likert Item]

- Thinking about your home in the winter, how easy or difficult is it to keep your home warm when the heating is on? [4 point response scale]

The fifth question asked participants to read through the original 65 statements used in the Q-study and select the 5 statements they most agree with, and the 5 statements they most disagree with. Finally, a response box was provided for participants to explain the reasoning for their selections. This approach was selected since it was somewhat analogous to a Q-study but much more simplified; as opposed to administering a second full Q-study by post, which may have been too onerous and unreliable for the participants.

In total, 91 winter surveys were posted and 34 were returned, 19 from Cardiff and 15 from Manchester, resulting in an overall response rate of 37% . This response return rate was within one standard deviation of a normal average for mailed out questionnaires, as identified by review papers employing response rate meta-analysis [Baruch, 1999; Baruch & Holtom, 2008]. From the 34 returned surveys, 3 were incorrectly filled out and could not be used.

The results from the winter survey were compared against the main summer study, and differences identified in order to enhance the discussion of the main study conclusions. However, since the winter survey was not a full Q Study, it was not possible, nor desirable, to verify the test-retest reliability with the summer survey. Test-retest reliability asses the consistency of a measure from one time to another, i.e. administering the same test to the same sample on two different occasion [William Trochim, 2006]. For Q methodology, the Q-sort reliability coefficients of a person with himself have been shown to normally range from 0.8 upward [Brown, 1980; Dennis, 1992; John Nicholas, 2011].

3.6.5 Research ethics

As part of this research, the ethics and implications of using human participants for the interviews, questionnaires, and Q-sorts were carefully considered in the design. This research design respects the ethical code for research set out by the School of Technology, University of Cambridge [School of Technology, 2011], and followed the specific guidelines prescribed by Blackwell [2013]. The ethical code and guidelines were applied to the recruitment of participants, anonymity, data retention, incentives, and permission.

At each stage of the research, and with each method, informed consent was obtained from all participants. Consent was given with a signed form outlining the research purpose, outcomes and clearly stating that participants could opt out at any point. Once collected, the data was made anonymous and kept secure. All information that allowed participants to be identified was kept in a separate place, with only the anonymous data used during the analysis.

3.7 Summary

In summary, this chapter presented the research philosophy, methodology, and design. Specifically, a broad interpretivist paradigm and mixed-method methodology was adopted to investigate household retrofit barriers/motivations, viewpoints towards energy use, and retrofit technology and behaviour preferences. The methods used were: first, thematic analysis and a modified chi-square test of association to investigate the barriers and motivations of retrofitting; and second, Q Methodology and a questionnaire to investigate household viewpoints towards energy use, and retrofit technology and energy efficiency behaviour preferences.

The overarching aim was to answer the research questions, and address the knowledge gap for more inter-disciplinary research into understanding the Energy Efficiency Gap. To this effect, a socio-technical approach was adopted that considered both social and technical factors affecting the adoption of retrofit technologies and energy efficiency behaviours in the home. Overall, this research aimed to improve the understanding of household energy use in the UK.

4 | Results

This chapter presents the overall research results in broadly two parts. The first identifies the barriers and motivations to retrofitting, along with their associated demographics. While the second part discusses household viewpoints towards energy use, and corresponding technology/behaviour preferences.

4.1 Barriers and motivations to retrofitting

In total, 198 general public semi-structured interviews were conducted in Manchester and Cardiff. During the interview, if the topic of barriers or motivations was not discussed then it was not used in the analysis. As such, 25 interviews were excluded from the identification of barriers, and 49 for motivations. Table 4.1 shows the summary demographics from all the interviewees (percentages do not always sum to 100 due to rounding).

Table 4.1 highlights how the interviews captured a broad distribution of demographics. Based on the interview transcripts and an iterative thematic analysis procedure, a total of eight barriers and eight motivations were identified. The barriers and motivations are discussed individually in the following sections, and summarised as frequency graphs in Figure 4.1 and 4.2. However, these frequencies should not be used to signify population prevalence or importance, as the thematic analysis was exploratory in nature, not explanatory.

4.1.1 Barriers to retrofit

A total of eight barriers were identified from the study. The barriers included the traditional economic and technical perspectives (cost, limitations imposed by

Table 4.1: Summary demographics

Demographic variables	Percent of participants	Demographic variables	Percent of participants
Sex		**Location**	
Female	50%	Manchester	51%
Male	50%	Cardiff	49%
Age		**Income**	
Under 30	19%	£20k and less	23%
30 - 45	35%	Between £20k to £40k	29%
45 - 60	30%	Between £40k to £60k	19%
Greater than 60	16%	Greater than £60k	15%
		Refused	14%
Education		**Marital Status**	
Degree or more	51%	Single/widowed	46%
High school/Trade	49%	Married/common law	54%
Number of bedrooms		**Type of dwelling**	
1 - 2	39%	Flat/apartment	25%
3	36%	Terrace (end or mid)	25%
Greater than 4	25%	Semi/detached house	50%
Number of occupants		**Type of tenure**	
1 - 2	52%	Own	56%
3 - 4	37%	Rent/live with family/friends	44%
Greater than 4	11%		

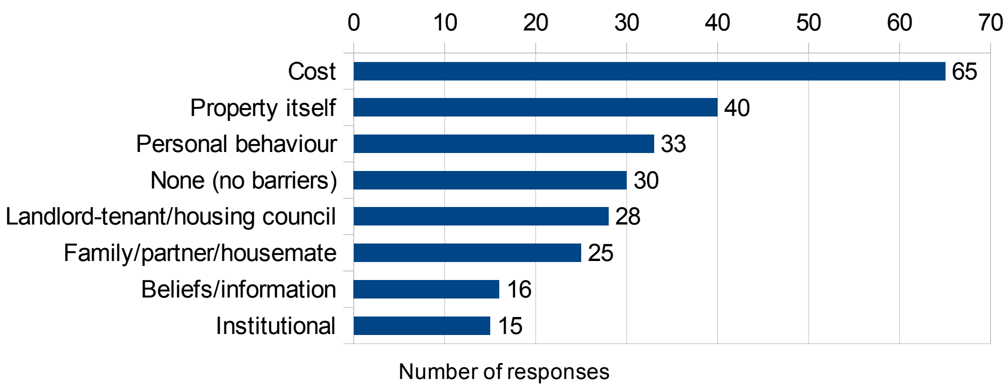

Figure 4.1: Barriers towards the adoption of energy efficiency measures in the home

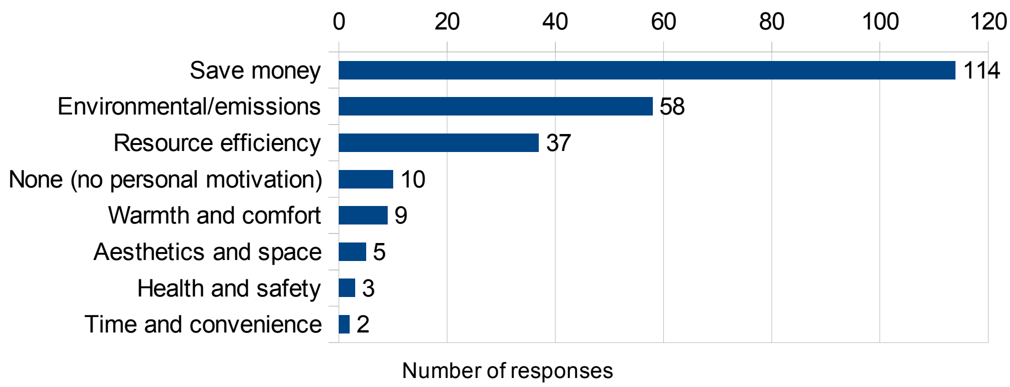

Figure 4.2: Motivations towards the adoption of energy efficiency measures in the home

the property itself), but also underscored important social factors, such as family disputes and personal behaviour/beliefs [Pelenur & Cruickshank, 2012a].

Cost

The upfront cost of energy efficiency measures is the economic barrier that receives the most attention in similar studies and policy [Pelenur & Cruickshank, 2012b]. However, there was some complexity within this barrier, for example, the idea of discounted costs versus perceived benefits. Specifically, if the benefits of the retrofit measure are not correctly valued by the household, then reducing the upfront price may not necessarily increase its up-take. Likewise, if the price is incorrectly perceived as too expensive, then the challenge lies not in reducing cost but in adjusting perception. Two illustrative quotes highlight this point,

> "The thing is, if you double glaze your house and everything, it is an awful lot of money, and how many years is it going to take before you get your money back?"; "... Maybe cost, even though we don't know how much [energy efficiency measures] cost."

Therefore, even though cost is a traditional economic barrier, households may not act as rational actors.

Property itself

This barrier encompassed the sub-barriers of the physical property, and conservation & heritage. The property sub-barrier referred to the limitations that the property structure itself imposes on residents, for example the space available in the home, its age, or unsuitable loft space roofs. The conservation & heritage sub-barrier captured the case in which owners were unable to install energy efficiency measures because of planning issues, specifically if they were either listed buildings or in a conservation area. It is interesting to note, that some respondents mentioned the aesthetics of the home as a barrier, for example,

> "we've got original windows in our house, which aren't secondary double glazed, so that's a huge loss of heat, but secondary double glazing isn't ideal for aesthetics ... so this is something we know is not helpful in terms of energy efficiency, but we haven't changed it."

The conservation & heritage sub-barrier is particularly challenging, since there is a natural tension between preserving the heritage value of the built environment and retrofitting it for energy efficiency [Friedman & Cooke, 2012; Tweed & Sutherland, 2007]. For example, approximately 17% of all households are in conservation areas in London [Boardman *et al.*, 2005]; thereby restricting their retrofit options. In addition, cultural heritage is an important part of societal and community well-being [Tweed & Sutherland, 2007]. Therefore, if the UK is committed to improving the energy performance of its built environment, it will need to carefully reconcile retrofit and heritage policies, while minimising impact to society well-being.

Personal behaviour

This is a complex barrier that conflated behaviour and attitudes, two variables that are often separated from a psychological perspective but combined in this research as a social norm [Lutzenhiser, 1992; Shove *et al.*, 1998; Stephenson *et al.*, 2010]. Specifically Stephenson *et al.* [Stephenson *et al.*, 2010] defines 'energy practices' as activities and processes relating to energy use. Based on the interview transcriptions, this barrier was subdivided into the following areas: a feeling by interviewees that they have already done everything possible; current lifestyle choices; and interviewees who consciously do not want to adopt energy efficiency measures. Lifestyle in itself included the themes of laziness; lack of time; convenience; and forgetfulness, as well as ideas that highlighted the rebound effect, such as: keeping up with appearances, and a desire for more gadgets. The following illustrative quotes highlight some of these issues,

> "I have the telly on myself ... especially in the bedroom when I'm doing the ironing, but I've got 4 children and each one has a television, playstation, and a laptop ... it's keeping up with the Jones as they say, have to keep up with every child. A lot of kids would get bullied if they haven't got what they say"; "Haven't thought about it to be honest with you, such a busy lifestyle you see."; "Well one thing I suppose is I can get rid of my Aga, it's on 24/7 365 days a year, [but] for me, that is a luxury."

This barrier, along with the family/partner/housemate relationship barrier were both socially rooted and may not be easily overcome with traditional incentives, such as price subsidies. Instead, incentives should be carefully designed to address these social concerns. For example, offering home owners a loft-clearance service was shown to significantly increase the odds of installing loft insulation by over a factor of 4 [Behavioural Insights Team, 2012]. This result highlights the importance of addressing non-monetary barriers to retrofitting, in this case, the hassle factor of loft clearance [Behavioural Insights Team, 2012].

None (no barriers)

This is the non sequitur barrier of none (representing no barriers). It captured interviewees who felt there were no barriers for them to adopt energy efficiency measures.

Landlord-tenant/housing associations

This barrier referred to the split-incentive between landlords/housing associations and their tenants. Specifically referring to the dilemma that landlords do not want to invest in energy efficiency measures, since they do not benefit from the corresponding reduced energy bills. Similarly, tenants are unwilling to invest in energy efficiency measures for homes they do not own.

This barrier was recognised by the UK government and is currently addressed through the Green Deal scheme. However, it is not yet possible to determine the long term effectiveness of the policy since it was recently rolled-out in 2013.

Family/partner/housemate

This barrier is often ignored by the pure technical/economic perspective, but was frequently mentioned in inter-disciplinary scholarship, and represented a significant proportion of responses in this study [Darby, 2010; Hargreaves *et al.*, 2010; Shove *et al.*, 1998]. This barrier included inter-occupant opposition towards energy efficiency measures, specifically from husbands/wives/partners, as well as apathy from other family members, particularly children. The challenge of reaching consensus in multi-tenanted homes was also captured within this barrier. Illustrative quotes highlight these issues: with regard to children,

> "It doesn't occur to them [children]. They just don't think. You encourage them to switch off but they forget, there's far more, many more important things going on, like what they can eat next, who they are going to see."

With regard to partners,

> "She [wife] rather have it look good than save on cost" and "I wish my husband turned off the lights and the television. (Interviewer): Why doesn't he? (Interviewee) because he's a lazy sod."

These quotes highlighted how poor energy efficiency behaviours are sometimes blamed on others. Such a shift in responsibility may weaken personal liability and create a self-reinforcing environment of poor behaviour, as illustrated in this quote,

> "when you live in a shared house ... people can't really be bothered to put in any effort, myself included. Obviously when you have your own place, then you're much more keen on finding new solutions or controlling energy waste".

This quote is interesting since it highlighted how personal energy habits between tenants were more important than the price of the wasted energy.

Similar to personal behaviour, this barrier presents a complex challenge that may not be easily overcome with traditional incentives. How to specifically address inter-occupant relationships, such as between parents and children, with regard to energy was outside the scope of this research. However, this result highlights how simply designing interventions from a purely technical or economic perspective may be inadequate. Instead an inter-disciplinary approach should be considered.

Beliefs/information

This barrier related to information (or lack of) about energy efficiency measures, and beliefs that affect the adoption of such measures. Examples cited in the interviews: a lack of expertise/knowledge of what to do; unclear or lack of trustworthy information from government; and mistrust of energy companies or contractors. This type of barrier was also suggested by Stern [Stern, 2006] and described as a cognitive norm factor affecting energy use [Lutzenhiser, 1992; Stephenson *et al.*, 2010]. The following illustrative quotes highlight these perceived issues:

> "Knowledge ... you wouldn't know that unless you've looked into it and studied it, so need more info."; "I'm concerned with these people who cold call me about having loft insulation and pumping the walls full of junk ... I want to feel comfortable with the contractor, know that they will do what they say they will do."

Institutional

Institutional barriers related to the perception from some interviewees that the government and/or energy companies were the main barrier towards adopting energy efficiency measures. Examples cited in the interviews: government incentives are incorrectly targeted; energy companies are unwilling to sincerely promote energy efficiency; and that consumer choice is being actively hampered by government and energy companies. This type of barrier was also suggested by Weber [Weber, 1997]. An example quote, *"Energy companies restricting research, look at short term profit over long term interests."* On the other hand, evidence shows that social housing providers, who manage housing estates, are strongly driven by government-funded programmes [Swan *et al.*, 2013]. Although this is not unexpected since social housing providers are often government owned or run.

Summary of barriers

These identified barriers were consistent with other results from scholarship and industry. For example, in their framework for pro-environmental behaviours, the Department for Environment Food and Rural Affairs (DEFRA) identified the following common barriers: external constraints (working patterns, demands on time); habit; scepticism; and dis-empowerment [Defra, 2008]. In addition, the UK Green Building Council identified the following occupier/landlord relevant barriers: fear of the 'hassle' factor; occupiers with poor knowledge of energy use; no requirement for homes to meet standard of energy efficiency; and perception that low carbon homes cost too much [UK-GBC, 2008]. While the identified barriers from the two previous reports supported the results of this research, they differ in that they were based solely on secondary literature reviews or workshop transcripts, rather than primary individual interview data.

From an academic perspective, Dowson *et al.* [2012] cite the barriers of meeting building regulations, increased use of heating following refurbishment ('take-back'), and an historic shift of thermal comfort expectations (i.e., warmer homes). Again, the identified barriers are from a secondary source review. Professionally, Lowery *et al.* [2012] describe the barriers encountered while delivering a social housing retrofit project by a registered social landlord in Sunderland, North East of England. During the project, the team encountered the following barriers: communication between partners; procurement and supply chain training; internal expertise; energy consumption monitoring; and type of retrofit technology to install [Lowery *et al.*, 2012]. This professional perspective highlights how retrofitting the built environment is not simply about overcoming household level barriers, but rather also addressing the barriers encountered by installers and other retrofit professionals.

Complementary to barriers are the motivations to install retrofit measures, and adopt energy efficiency behaviours. By investigating both barriers and motivations, the aim was to create a more balanced set of recommendations to help overcome the Energy Efficiency Gap.

4.1.2 Motivations to retrofit

Similar to barriers, eight motivations were identified; however three motivations were the most often cited, accounting for 88% of total responses. They were the same three broad categories as identified by Caird *et al.* [Caird *et al.*, 2008]: save money; save the environment; save resources (energy) [Pelenur & Cruickshank, 2013a].

Save money

Saving money was the most commonly mentioned motivation for installing energy efficiency measures in the home. While the idea of simply saving money and increasing disposable income were mentioned, this theme also included the more nuanced ideas of avoiding the outright need to pay for energy, and the perceived view that fuel prices are too high. Two illustrative quotes highlight this point,

> Interviewer: "What was the motivation [for installing energy efficiency measures]?" Respondent: "Well we've only got one world is the primary one, and secondary is knowing how much we're getting ripped off for everything." The second quote, Interviewer: "Why do you [want to install energy efficiency measures]?" Respondent: "Because once you have it you don't need to pay for fuel . . . ."

Environmental/emissions

Environmental and green issues were the second most mentioned motivation. This theme covered a broad range of ideas such as: minimising harm to the local ecosystem; avoiding fossil fuel and nuclear energy due to environmental concerns; and reducing carbon emissions (by using less energy) to address climate change. The following illustrative quotes highlight these ideas:

> "Trying to do our bit to save the planet . . . "; "Because we're quite into green issues."; "For long term environmental reasons. Anything that's

> more natural than the alternatives which include nuclear."; and "I'm concerned about the effects [of energy use] on the atmosphere."

Resource efficiency

Resource efficiency was a nuanced theme identified by probing respondents who stated that 'saving energy' was their motivation to install energy efficiency measures. Specifically this theme covers the following ideas: conserving energy out of a general principle of reducing waste; being more self-sufficient with resources; increasing national energy security; and being conscious about future resource needs. The temporal nature of this theme (protecting the future) was also shared by the environmental theme; however the responses here specifically only focused on ensuring future resource abundance as opposed to protecting the environment for future generations. Some illustrative quotes:

> "Well just as a general principle, we use too much of certain things."; "Just basically being conscious about the future ... you see these companies and the amount of money they're investing in R&D which just shows you how important it is to not neglect the fact we will have to change in the future."; "Because there's a shortage of gas, and we don't have gas always in this country." and "I'd rather use less energy because there's not a lot of it being generated in a renewable way."

None (no personal motivation)

This non-motivation specifically included respondents who did not want change their household energy use because they either: had no motivation (apathy); were content with the status quo; or because they were not responsible for energy in their home. Illustrative examples of these ideas:

> "I don't see there's much I can do about it [household energy use] anyway."; "My husband did it [install energy efficiency measures], I didn't have anything to do with it."; and "I leave [energy efficiency] up to my husband."

It's interesting to note how this theme touched on the feelings of helplessness, apathy, and shifting personal responsibility. While this study identified *existing* motivations, this theme highlighted how some households may require further information about energy efficiency measures, in order to spark an *initial* motivation to change.

These motivations, apart from the non-motivation of apathy, related to the saving of measurable physical items (save money, save the environment, save resources); however, the interview transcripts also highlighted other non-physical drivers to improve energy efficiency. The following motivations supported the hypothesis that it is often non-energy benefits that drive the adoption of energy efficiency measures [Mills & Rosenfeld, 1996].

Warmth and comfort

This motivation centred around the idea of installing energy efficiency measures in order to improve home comfort and heating. Particularly relevant given that this aim does not necessarily align with the government energy demand reduction targets. The following two quotes illustrate this point:

> "Better insulation on the walls means I can keep the heating on for a long time.", and"If I want to turn the heating up, I'm not going to sit there and put on a jumper. They say instead of turning the heating up put on a jumper - no way! I like to be comfortable."

This motivation highlighted how even though personal comfort can drive the adoption of energy efficiency measures, the end result may not lead to a reduction in energy use (i.e. the "Rebound Effect" [Madlener & Alcott, 2009]).

Aesthetics and space

While most energy efficiency measures are often invisible to the household (examples: loft insulation, cavity wall insulation, central heating), some energy efficiency measures are adopted for their aesthetic value, as well as their practical value. This motivation captured this idea, as well as the idea that saving space can drive households to adopt smaller energy efficiency solutions. Illustrative quotes,

> Interviewer: “Why did you get … double glazing and wall insulation?” Respondent: “To keep [house] warm and looks good. That’s it basically.” Interviewer: “What are the reasons that you want to change the boiler and explore [solar thermal]?” Respondent: “… Trying to utilise some space, because the old fashion [boiler] uses a lot of space, so I have to have this big tank in the ironing cupboard, [which] is bad.”

Health and safety

Relating more to energy efficiency behaviours as opposed to retrofit technologies, health and safety was a reason a few households gave when asked why they changed their household energy use. The following quote illustrates this idea,

> Interviewer: “Why try to keep [energy use] to a minimum? What motivates you?” Respondent: “Well, especially with televisions on, stuff that comes off the TV, waves that rattle your brain don’t they, too much [adverse health affects] going on. … We have flat screen TVs in all the rooms, [because we] want to reduce the transmission of the waves that come off the TV … because they get hot … [and] some can give you headaches.”

Another idea captured by this motivation is with respect to energy supply safety, specifically to reduce our energy consumption and reliance on nuclear, not for resource efficiency or the environment, but because of safety. An example quote,

> “look what’s happened in Japan … there’s a nuclear power plant about 100 miles from here, it could just easily happen there too, it’s on a fault line [also].”

Time and convenience

This final motivation related to households who felt that being energy efficient can help them save time or increase convenience, for example by reducing the time needed to do house chores or heat water. When asked what motivates one household to save energy, one respondent said, *“It’s time consumption, with the* *combination boiler you switch the tap on and it's hot water rather than waiting 30 min for the water to heat."*

Summary of motivations

While the majority of motivations fell into one of the three main themes, save money, save the environment, or save resources (energy) [Caird *et al.*, 2008]; there were other non-conventional motivations identified, such as saving time and aesthetics/space. This result was consistent with Mills & Rosenfeld [1996] who found that it was often non-energy benefits that motivated households to be energy efficient, such as improved comfort, reduced noise, labour and time savings, and increased convenience. Similarly, another study found that the perceived amount of disruption; the presence and awareness of any accreditation regime; and whether the retrofit measure had been recommended to the household were important drivers for the adoption of retrofit technologies [Oxera, 2006].

Taken together, the barrier and motivation results from this research underscore the need for policy makers, engineers and retrofit professionals to move beyond simple economic based incentives or initiatives. Instead, a more holistic approach should be adopted to overcome barriers, utilise motivations, and increase the effectiveness of future policies and retrofit programmes.

4.1.3 Demographics with barriers/motivations

As well as identifying household retrofit barriers and motivations, it was also informative to investigate which demographics were associated with each barrier or motivation. All the barriers were used for the statistical analysis; however the following motivations were grouped together as 'Other' in order to meet the criteria that no more than 20% of the expected counts in the contingency tables between demographics and motivations should be less than 5, and all individual counts are 1 or greater [Yates *et al.*, 1999, p. 734]. The motivations grouped into 'Other' were: none; warmth and comfort; aesthetics and space; health and safety; and time and convenience. The tests of association were done with the modified first-order corrected Rao-Scott chi-square test statistic for single by multiple response data, $X^2_{SM}(AL)$.

Based on the null hypothesis for two-tail marginal independence with $\alpha = 0.05$ and the test statistic of $X^2_{SM}(AL)$, the following demographic variables shaded in Table 4.2 were found to be significantly associated with specific barriers and motivations.

Table 4.2: Highlighted demographic variables significantly correlated with barriers and motivations ($p < 0.05$)

Demographic variables	Motivations $X^2_{SM}(AL)$	Motivations df	Motivations p value	Barriers $X^2_{SM}(AL)$	Barriers df	Barriers p value
[D1] Sex	3.67	4	0.452	20.71	8	0.008
[D2] Age	16.78	12	0.158	29.38	24	0.206
[D3] Household income	26.32	8	0.001	17.14	16	0.377
[D4] Marital status	16.49	4	0.002	15.51	8	0.050
[D5] Education level	5.86	4	0.210	20.57	8	0.008
[D6] Type of dwelling	18.90	8	0.015	29.21	16	0.018
[D7] Number of bedrooms in household	11.16	8	0.193	25.40	16	0.063
[D8] Number of occupants in household	7.59	4	0.108	19.64	8	0.012
[D9] Residence (own, rent, live with family/friends)	6.57	4	0.160	66.89	8	0.000
[D10] Location (Manchester/Cardiff)	3.21	4	0.524	37.92	8	0.000

Table 4.2 underscores how most of the demographic variables were associated with either barriers or motivations, with the exception of occupant age and number of bedrooms in the household. Other studies found that age and house size (number of bedrooms as a proxy) were factors typically associated with energy consumption [Abrahamse & Steg, 2009; Guerin *et al.*, 2000; Lenzen *et al.*, 2006]. However, the results from this study imply that even though those variables were associated with energy consumption, they were not associated with any barrier or motivation for retrofitting.

All the individual relationships between the demographic variables and the specific barriers/motivations are presented in the Discussion (Section 5.1).

4.1.4 Relationship between barriers and motivations

Using the $X^2_{MM}(AL)$ test statistic for multiple-by-multiple response data, it was also possible to investigate the relationship between barriers and motivations, i.e. were any specific barriers or motivations associated with each other? The data was considered multiple-by-multiple response since interviewees were able to list multiple barriers or motivations to retrofitting their household. While this type of data obfuscated the statistical analysis slightly, the results may be more relevant since in practice households likely face multiple retrofit barriers or motivations.

Based on the null hypothesis for two-tail marginal independence with $\alpha = 0.05$ and the test statistic of $X^2_{MM}(AL)$, specific motivations were found to be significantly associated with barriers ($X^2_{MM}(AL) = 106.3, df = 32, p < 0.001$). It is informative to examine the strength of such associations using the odds-ratio (Φ); where an odds-ratio of greater than 2 was considered a strong association [Thomas & Decady, 2004]. For clarity, the odds-ratio results and contingency table proportions are visually shown with a shaded mosaic plot. Mosaic plots essentially visualise the data as "tiles" representing the cells of the table, such that the area of each tile is proportional to the cell frequency. Specifically, the vertical height of each row represents the barrier frequency proportion and the horizontal width of each column represents the motivation frequency proportion [Friendly, 1994]. The "tiles" in all the mosaic plots are also shaded for significant odds ratio results. Specifically, heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2. As such, the mosaic plot in Figure 4.3 shows the following associations:

- Motivation [M1] Save money was strongly associated with barriers: [B3] Family/partner/housemate; [B5] Landlord-tenant/housing associations; and [B8] Property itself.
- Motivation [M2] Environmental/emissions was strongly associated with barriers [B1] Beliefs/information; [B2] Costs; [B4] Institutional; and [B5] Landlord-tenant/housing associations.
- Motivation [M3] Resource efficiency was strongly associated with barriers [B1] Beliefs/information; [B2] Costs; and [B5] Landlord-tenant/housing associations.
- Combined motivation of [M4-8] Other was strongly associated with barrier [B2] Costs.

These associations highlighted the relationships between barriers and motivations to adopting domestic retrofit technologies. Considered together, they enabled

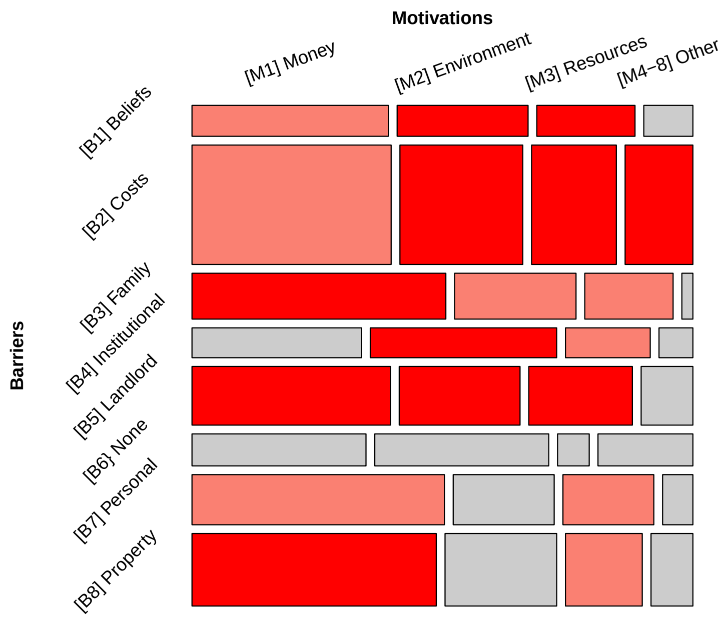

Figure 4.3: Mosaic plot for retrofit motivations versus barriers

a more thorough discussion of how certain motivations can be used to tailor specific incentives to help overcome the barriers to retrofitting.

4.1.5 Summary of barriers and motivations

In summary, a wide variety of barriers and motivations were identified to retrofitting the domestic built environment. They ranged from the standard economic predicted theme of saving money, to the more social themed barrier of family/partner opposition, and motivation to increase convenience and save time.

As well as investigating the relationship between the barriers and motivations themselves, the association with demographics was also analysed. The results revealed multiple associations that when considered together, help inform the discussion and recommendations.

Overall, the barrier and motivation results highlight the need for retrofit programmes and policies to adopt a more inclusive design. An approach that considers economic, engineering, and social themes together. Further to the stated barriers and motivations, this research also investigated the subjective viewpoints that individuals hold towards energy consumption in their home. By considering both the external retrofit barriers/motivations and internal viewpoints held towards energy consumption, the aim was to recommend holistic solutions that help overcome the Energy Efficiency Gap.

4.2 Household viewpoints towards energy

This phase of the research investigated household viewpoints towards energy consumption. The drive to do so was based partly on the principle of stakeholder engagement. If reducing domestic energy demand is the goal, and households are viewed as the primary stakeholders, then their viewpoints and attitudes should be considered as important elements in the design of retrofit policy and interventions. Without considering the needs or attitudes of stakeholder groups, there is a risk that the retrofit intervention may have unintended consequences, such as overheating or inter-occupant conflict [Burgess & Nye, 2008]. Hence, to better understand household viewpoints towards energy use in a large UK city context, an explorative Q-study was conducted that identified viewpoints naturistically from households themselves, instead of being guided by *a priori* theory. The results allow for better tailored policy and interventions.

4.2.1 Q-study results

A total of 45 Q-sorts were completed in Cardiff and 46 in Manchester. Table 4.3 shows the summary demographics for the participants in each city, as well as the percentages and averages for each city where available (percentages do not always sum to 100 due to rounding).

The sample demographics between Manchester and Cardiff were broadly similar, but there were some expected deviations between the sample and city averages. Most notably, there were many more married/common law Q sort participants than the city averages. This was expected given that partners were often recruited for the Q Study in tandem, in line with the goal of investigating how inter-household dynamics affect attitudes towards energy use. The other notable difference was

Table 4.3: Q Study demographics

Demographic variables	Cardiff sample	Manchester sample	Cardiff city	Manchester city
Sex				
Female	60%	52%	51%	50%
Male	40%	48%	49%	50%
Age				
Under 30	7%	7%	45%	50%
30 - 45	33%	39%	20%	22%
45 - 60	36%	39%	17%	14%
Greater than 60	24%	15%	18%	13%
Marital Status				
Single/widowed	33%	35%	61%	70%
Married/common law	67%	65%	39%	30%
Type of dwelling				
Flat/apartment	11%	11%	27%	35%
Terrace (end or mid)	36%	48%	30%	30%
Semi/detached house	53%	41%	42%	35%
Tenure				
Own	76%	65%	59%	38%
Rent/live with family/friends	24%	35%	41%	62%
Number of bedrooms				
1 - 2	13%	28%	(average)	(average)
3 - 4	82%	67%	2.8	2.5
Greater than 4	4%	4%		
Number of occupants				
1 - 2	58%	46%	(average)	(average)
3 - 4	33%	50%	2.3	2.3
Greater than 4	9%	4%		
Education level				
Degree or more	67%	67%		
High school/trade	33%	33%		
Income				
£20k or less	29%	24%		
£20k - £40k	20%	26%		
£40k - £60k	13%	17%		
Greater than £60k	22%	26%		
Refused	16%	7%		

Source for city data: [Office for National Statistics, 2011a] that not many participants under 30 were recruited, and due to the difficulty of recruiting in purpose built flats, there were more owner occupied non-flat residents recruited. Nevertheless, Q Study sample still captured households from all the key demographics, and was representative of the areas selected.

The Q-sorts for each city were analysed using PQ Method, a software package used to facilitate the analysis of Q-studies [Schmolck, 2012]. The resulting factors that emerged in each city were interpreted into viewpoints and compared for similarities/differences. For Cardiff, the factor extraction was done using centroid factor analysis (CFA), which is commonly used by Q practitioners because of the "permissiveness it allows in relation to data exploration" [Watts & Stenner, 2012]. Objectively, there was one dominant factor that emerged from Cardiff; however, in Q Methodology statistical criteria alone may not yield a factor that is important contextually or theoretically [Brown, 1980, pp. 40 - 43]. Therefore, based on the examination of the data, interview transcripts, and experiences in the field, judgement rotation was used to identify other important factors while also preserving the dominant first factor. In total, the dominant factor, a specificity of it, and a secondary factor were identified in Cardiff. A specificity is defined as a factor where respondents that load significantly on it also agree with the main dominant factor [Brown, 1980]. In this way, specificities allow the researcher to examine a dominant theme from multiple sub-perspectives. The Cardiff specificity was also bi-polar, meaning that it was defined by both positively and negatively loading Q-sorts [Watts & Stenner, 2012]. Hence for analysis, the single bi-polar factor was separated into two unique factors to represent each of the poles, as per Brown [1980] and Watts & Stenner [2012]. In order to identify statistically significant Q-sorts for each factor at $p < 0.05$, the Q-sort loading value had to be greater than $|0.243|$ [Brown, 1980, pp. 223]. A higher significance level of 0.4 was used for the secondary factor in order to avoid conflating Q-sorts (Q-sorts that load onto more than one factor), while a significance level of 0.25 was used for the bi-polar specificity. The final result was four factors identified in Cardiff: a dominant factor; a positive specificity; a negative specificity; and a secondary factor [Pelenur & Cruickshank, 2013c].

As well as the four common Cardiff factors identified through CFA, a single participant (C13) was also visually identified as being of interest because their Q-sort was diametrically different from the others in the sample. Q-Methodology is admirably suited to the analysis of interesting single cases [Brown, 1980], which are generally viewed as advancing knowledge about the process by which wider subjective worlds are constructed and experienced [McKeown & Thomas, 1988]. As such, the single Q-sort from participant C13 was analysed qualitatively and used to inform the discussion of the Cardiff results.

For Manchester, the data was less homogeneous and therefore simpler to isolate and separate factors. For comparison, the Manchester analysis was initially conducted using CFA/judgement rotation as well as a Principal Component Analysis (PCA)/varimax rotation. The PCA factor extraction method is a more mathematically precise solution but offers less flexibility with data exploration [Watts & Stenner, 2012]. Both approaches yielded two clear factors, but the PCA solution with varimax rotation was selected because the factors were easier to isolate. In total, two factors were identified with a raised Q-sort significance level of 0.37 to reduce the instances of conflating sorts [Pelenur & Cruickshank, 2013c]. The rotated factor loadings for each factor with flagged Q-sorts are shown in Appendix C.

Following a Q Methodology narrative style [Watts & Stenner, 2012], the following narratives describe each of the factors for Cardiff and Manchester and were constructed through the interpretation of the factor arrays and post-sort interview comments. Q Statements used in the narratives are followed by their number and factor score in parenthesis. For readability, the phrasing of some statements were switched from positive to negative or vice-versa signified by square brackets in the statement.

4.2.2 Cardiff Factor 1: I think about being energy efficient for the environment and greater good

26 participants' Q-sorts exemplified this factor, making this the dominant factor in the Cardiff study that accounted for 40% of the variance. The main theme of this factor was the link between energy use and the environment, as well as a concern about its long-term impacts on society. As such, being energy efficient was viewed

as normal and necessary to protect the environment.

> **Narrative** 'I'm concerned about the effect of energy use on the atmosphere' (21: +6) and can't understand how some people 'don't believe in climate change' (42: -6). Therefore because 'protecting the environment is important to me' (27: +6), I strongly believe 'it's our responsibility to look after the next generation's future' (49: +5), which is why 'parents should ensure that their kids are taught how to be energy efficient at home' (9: +3). From a wider perspective, 'I'd like there to be more environmentally friendly sources of energy' (13: +5) since 'we are too dependent on fossil fuels' (16: +4), but 'the government is not doing enough about improving energy use' (24: +5).
>
> To do my bit at home, 'I rather use multiple blankets or put on more layers than turn up the heating' (6: +1) but 'I believe the ever increasing number of gadgets is a problem for energy efficiency' (54: +3). However, even though gadgets in the home are a problem for people in general, 'modern technology, such as plasma screens, are [not] more important to me than being energy efficient' (59: -5). Definitely 'the appearance of my home is [not] more important than being energy efficient' (17: -5) nor is 'trying to keep up with the neighbours ...' (19: -6)'. All in all, 'being energy efficient is [not] a disruption to my lifestyle' (52:-5), it's about the environment and the greater good.

Summary of Cardiff Factor 1

This factor highlighted the viewpoint that conserving household energy should be driven by broader issues, such as protecting the environment or climate change, with an emphasis on safeguarding the next generation's future. Similarly, energy efficiency was not viewed as an inconvenience but simply as a normal and important part of life, without the need to consider social norms (i.e. keeping up with the neighbours). As such, this factor draws heavily from statements within the 'Environment and the future' theme. Mostly missing from the extreme ends of the factor array are statements regarding economics, finance, and inefficient behaviours.

4.2.3 Cardiff Factor 2: I want to be more energy efficient to save money, but I don't really know how

5 participants' Q-sorts strongly exemplified this factor, that accounted for 10% of the variance. Conserving energy to save money was the main theme, but this factor also highlighted a lack of knowledge about energy efficiency and measuring energy use in general.

> **Narrative** Even though 'I can afford my energy bills, [I'm still motivated to] conserve energy' (60: -6) because 'I'm [not] happy with my energy costs' (50: -6), which is why I really 'try and reduce my energy use to save money' (23: +6). As such, 'I would like my household energy use to be more cost effective' (44: +6), but while 'I [really] think about my household energy use' (28: -5) and 'try and conserve energy, sometimes it's difficult to get other people to do the same' (36: +3). 'I think other people should be more aware about their energy use' (43: +4), but I believe that 'families waste energy because of convenience' (40: +5) and that 'woman use most of the energy at home' (11: +3).
>
> Unfortunately, while I try and conserve energy to save money, 'I don't know if my energy use is above average or below average' (58: +5), nor do I 'know how much heating I use' (8: +3). It really doesn't help that 'the energy and utility tariffs are complicated to understand' (2: +4). Personally, 'modern technology, such as plasma screens, are [not] more important to me than being energy efficient' (59: -5), but I would rather heat the whole home instead of just one room (31: -5). I want to conserve energy to save money, but I don't really know how.

Summary of Cardiff Factor 2

This factor highlighted a clear desire to conserve energy to save money, without mention of other possible motivations. However, even though saving costs was a priority, households exemplified by this viewpoint did not particularly understand their energy use, let alone how to start being more energy efficient. Therefore, education and information campaigns that promote saving energy to save money with specific practical examples, may be very effective at spurring energy efficiency in these households.

4.2.4 Cardiff Factor 3 (specificity of Factor 1): I'm consciously and actively energy efficient because it's plain common sense

3 participants' Q-sorts exemplified this factor, which was the positive bi-polar specificity of Factor 1 accounting for 4% of the variance. The main theme was about conserving energy for the sake of reducing waste, and personal responsibility. This viewpoint embodies direct action to being energy efficient, for the environment, but also out of general principle.

> **Narrative** 'I try and conserve energy out of general principle' (39: +5), for example 'I turn off lighting when not in the room' (51: +6), I 'heat one room rather than the whole home' (31: +4), and 'I make a conscious effort to turn things off at the socket' (48: +5). Basically, 'I was raised to not waste energy' (30, +3). However, 'I try and conserve energy, but sometimes it's difficult to get other people to do the same' (36: +3). That's why I think 'schools should be teaching more about energy efficiency to kids' (57: +5) and that 'parents should ensure that their kids are taught how to be energy efficient at home' (9: +3); in general,'not enough communication is being done within households about energy issues' (41: +4).
>
> I take an active approach to being energy efficient, 'I [always] turn off the lights or TV' (3: -5), 'I [know] how to control my heating efficiently' (12: -6), and 'I [don't] forget to turn the heating off' (46: -6). We can all be doing a bit more though, for example 'I think solar panels should be built into all new properties' (29: +6) and that 'energy efficient bulbs [are] good' (55: -5); 'trying to keep up with the neighbours is [not] more important than being energy efficient' (19: -6). I take an active and conscious approach to being energy efficient, because what's the point of waste?

Summary Cardiff Factor 3

While this factor was a specificity of factor 1 (I think about being energy efficient for the environment and the greater good), it clearly highlighted the view that energy conservation isn't just about the environment, but also about avoiding waste on general principles. This factor also takes personal responsibility for conserving energy, listing specific examples of energy efficient behaviours, instead of using broad statements about the general welfare or supply of electricity.

4.2.5 Cardiff Factor 4 (specificity of Factor 1): I don't really think about energy efficient behaviours, but I want my energy supply to be renewable and greener

5 participants' Q-sorts exemplified this factor, which was also the negative bi-polar specificity of Factor 1 accounting for 4% of the variance. Unlike factor 3 that focused on direct action and personal responsibility, the main theme in this viewpoint was more focused on passive action and indirect responsibility. This viewpoint identified with protecting the environment, but shifted the responsibility of being energy efficient from the household to the energy suppliers.

> **Narrative** 'Protecting the environment is important to me' (27: +5), which is why 'I'd like there to be more environmentally friendly sources of energy' (13: +5). Specifically, I believe 'we're not using sunlight or wind effectively as a nation' (25: +6), and that 'solar panels should be built into all new properties' (29: +6). Ideally I 'want my energy use to be greener' (12: +5) and that 'as a society, we should be self sufficient with our energy' (53: +4).
>
> However, 'I [don't always] make a conscious effort to turn things off at the socket' (48: -3) or 'use as little energy as possible' (5: -2). But definitely 'the appearance of my home is [not] more important than being energy efficient' (17: -5) nor is 'trying to keep up with the neighbours ...' (19: -6). I also think that 'modern technology, such as plasma screens, are [not] more important to me than being energy efficient'

> (59: -5). Even though 'I can afford my energy bills, [I still care] about conserving energy' (60: -6). I may not always think about conserving energy, but for the sake the environment, I wish my energy supply was renewable and green.

Summary Cardiff Factor 4

This factor was the bi-polar viewpoint of factor 3; therefore, instead of espousing personal responsibility for energy conservation, this viewpoint shifted the responsibility to the energy suppliers. Protecting the environment and being green was important to this viewpoint, but such beliefs did not always reflect in personal actions at home. As such, even though these households cared about the effects of energy use on the environment, it may not be enough motivation for them to be energy efficient.

4.2.6 Cardiff Single Case Q-Sort C13:

Participant 13's Q-Sort did not significantly load on any one factor, but was so substantially different from the sample that it warranted a more detailed analysis. This single case exemplified a diametrically different viewpoint compared to the other perspectives; one that did not prioritise energy efficiency, saving money, or environmental issues. Instead, this viewpoint identified a more casual perspective towards energy use in the home; not completely apathetic nor interested.

> **Narrative** When it comes to energy use in my home, I don't really care. I especially don't want '... more information about my household's energy use' (38: -6). To be fair, as a man it's not my problem since 'woman use most of the energy at home' (11: +5), although 'families waste energy because of convenience' (40: +3). Regardless, I think '[too much] communication [is] being done within households about energy issues' (41: -5). If anything, 'schools should be teaching more about energy efficiency to kids' (57: +3), not me.
>
> While I strongly agree that 'it's our responsibility to look after the next generation's future' (59: +6), 'it's a balance between what you pay for

> energy and what it costs you to improve energy efficiency' (37: +5). For example, I admit that 'trying to keep up with the neighbours is more important than being energy efficient' (19: +3) and that 'modern technology, such as plasma screens are more important to me than being energy efficient' (59: +6). Even though I agree that 'the ever increasing number of gadgets is a problem for energy efficiency' (55: +4). I guess I just don't agree with the importance of conserving energy.
>
> For me, 'being energy efficient is about saving time' (47: +4), which is why 'it's better to heat one room rather than the whole home' (31: +5). Although, 'my house is [not] very hard to heat' (64: -4), which means that 'I [do not really] want to reduce my heating' (10: -3), nor do I care about '... my household energy use [being] more cost effective' (44: -3)
>
> When it comes to the environment, 'I don't [particularly] believe in climate change' (42: +3) and 'protecting the environment is [not that] important to me' (27: -2). I don't really think 'we are too dependent on fossil fuels' (6: -2) and I especially would not '... like there to be more environmentally friendly sources of energy' (13: -4), for example 'I [don't] think solar panels should be built into all new properties' (29: -4). We should just leave homes as they are, I don't want to see 'old homes ... improved to modern building standards' (7:-6). As a society, we're making a big deal about nothing important.

Summary Single Case Q-Sort C13

This Q-Sort represented a detached viewpoint about energy use in the home. Examining the post-sort interview revealed that participant C13 did not pay any of the bills, instead his wife managed all the household finances. As a result, the participant admitted that not paying the bills made him complacent towards household energy use. In the interview he said that household energy use "doesn't impact anybody else's life" and that "if people want to waste [energy], they can because they pay for it." Understanding this context helps explain the perspective exemplified by the viewpoint. As a unique single case, this participant was worth analysing further for the discussion, but with only one defining Q-Sort, this viewpoint was not quantitatively compared to the other factors.

4.2.7 Cardiff correlations between factor scores

Even though the emergent factor arrays represented viewpoints as a whole, they were created by analysing a composite of all the individual participant Q-sorts. As such, since every participant Q-sort loads somewhat on each factor, the resulting arrays will always *intercorrelate* to some extent [Watts & Stenner, 2012]. The size of the correlations determines to what significance the factors are related. If the correlations are high, it may mean that they are manifestations of a single viewpoint [Watts & Stenner, 2012]. Table 4.4 shows the correlations between Cardiff factor scores.

Table 4.4: Correlations between Cardiff factor scores

Correlations between Cardiff factor scores				
	1	2	3	4
1	1.0000	0.4800	0.7112	0.8343
2	0.4800	1.0000	0.4374	0.5719
3	0.7112	0.4374	1.0000	0.4830
4	0.8343	0.5719	0.4830	1.0000

Because Factors 3 and 4 were specificities of Factor 1, it was consistent to observe significantly high correlations between them. These high correlations do not invalidate the interpretation of the viewpoints, rather it reinforces the need to consider them as alternative manifestations of the dominant viewpoint [Watts & Stenner, 2012]. The correlation between Factor 1 and 2 was also high; however, a qualitative interrogation of the factor arrays confirmed that they were holistically different from each other and could be interpreted individually.

The Q-sorts can also be diagrammatically mapped onto a two axis plot for visual inspections. In Figure 4.4 the vertical axis represents Factor 1, while the horizontal axis represents Factor 2 (the non specificity Factor). The distance from the null origin represents the size of the factor loading for each Q-sort.

Figure 4.4 highlights the mix of Q-sorts on both Factor 1 and Factor 2, but more importantly the visual inspection allowed the diametrically different single case viewpoint (C13) to be clearly identified.

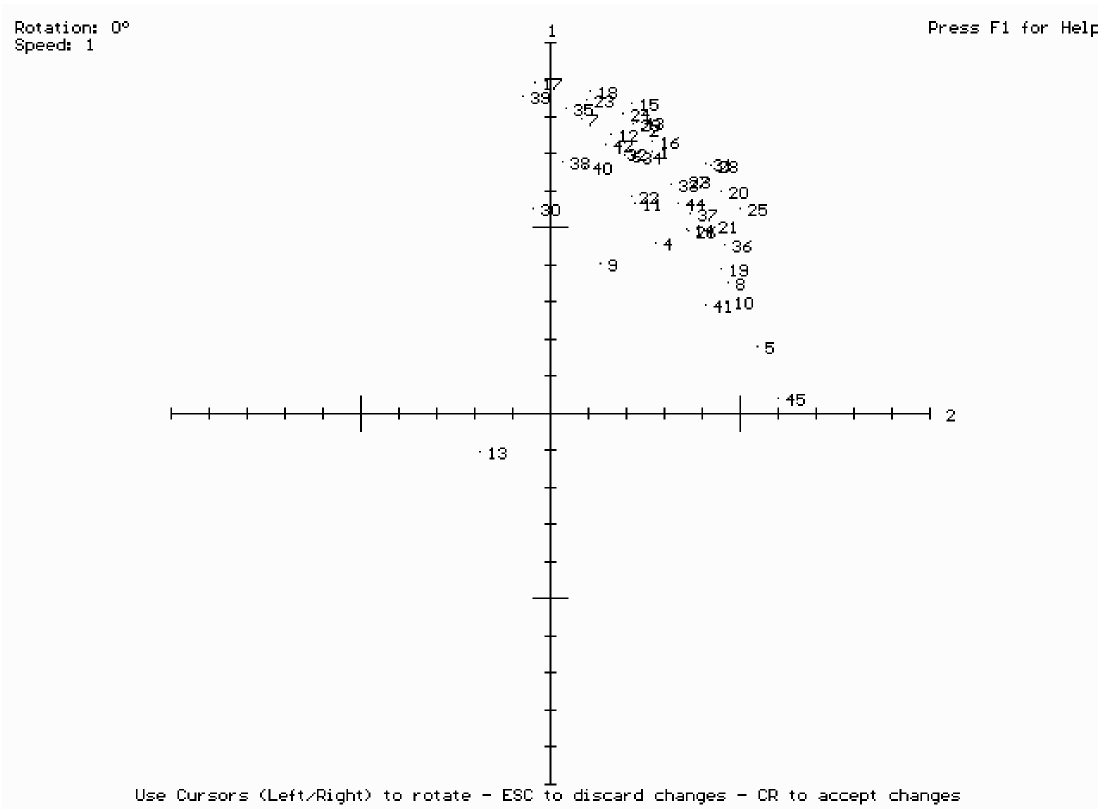

Figure 4.4: Cardiff Factor 1 versus Factor 2

4.2.8 Manchester Factor 1: I think about being energy efficient and the environment is important to me, but I reduce energy to save money

25 participants' Q-sorts exemplified this factor accounting for 33% of the variance. There were two main themes in this factor, conserving energy to save money and protecting the environment.

> **Narrative** 'It's our responsibility to look after the next generation's future' (49: +6) and 'protecting the environment is important to me' (27: +6), but 'I try and reduce my energy use to save money' (23: +5) as opposed to just the environment. If 'I [do] think about my household energy use' (28: -5) it's because 'I would like my household energy use to more cost effective' (44: +5), which is why 'I turn off lighting when not in the room' (51: +4), '[don't] leave lights on for appearances' (33: -4), and 'I'm [not] too lazy to always turn off the lights or TV' (3: -5). Aside from just saving money, 'I use as little energy as possible' (5: +3) because 'I was raised to not waste energy' (30: +3), I basically 'try and conserve energy out of general principle' (39: +5).
>
> Of course, 'I [do] believe in Climate Change' (42: -6) and 'I'm concerned about the effect of energy use on the atmosphere' (21: +4), so as well as taking personal responsibility, 'I'd like there to be more environmentally friendly sources of energy' (13: +4) and 'think solar panels should be built into all new properties' (29: +4). Especially, since 'the appearance of my home is [not] more important than being energy efficient' (17: -5), nor is 'trying to keep up with the neighbours more important than being energy efficient' (19: -6). 'Being energy efficient is [not] a disruption to my lifestyle' (52: -4) and the environment is important to me, but I reduce energy to save money.

Summary Manchester Factor 1

This factor presented a balanced viewpoint that considered reducing energy use for both the environment and saving money. As such, this viewpoint included multiple energy efficiency themes in a single factor, highlighting the complexity of understanding energy use at home and ultimately the Energy Efficiency Gap. This viewpoint was similar to a combination of Factors 1 and 2 from Cardiff, which were both uni-themed.

4.2.9 Manchester Factor 2: I don't really know how much energy I use, nor do I really care. I'm too lazy to change my lifestyle

5 participants' Q-sorts exemplified this factor accounting for 14% of the variance. The main theme was an honest admission that energy use in the home was not an significant issue. More specifically, that lifestyle and comfort were more important than trying to conserve energy either to save money or the environment. This is a particularly interesting factor since households with this viewpoint may not be motivated to conserve energy through traditional financial or altruistic incentives. Instead, households with this viewpoint may need to see a personal gain in comfort or lifestyle before adopting energy efficiency measures.

> **Narrative** Energy use at home is just not that important to me. 'I don't know how much heating I use' (8: +5) and I'm not ashamed to say that 'I'm too lazy to always turn off off the lights or TV' (3: +6). Fundamentally, 'being comfortable is more important than saving energy' (56: +4), that's why 'I [leave] lights on when not in the room' (51: -5), '[don't] make a conscious effort to turn things off at the socket' (48: -6), and 'sometimes forget to turn my heating off' (46: +4). Although I do agree that 'it's better to heat one room rather than the whole home' (31: +5).
>
> From a broad perspective, 'I [do] believe in climate change' (42: -6) and I do think that 'we are too dependent on fossil fuels' (16: +6) since 'we're not using sunlight or wind effectively as a nation' (25: +5) but I don't let it affect my lifestyle. 'I [don't] use as little energy as possible' (5: -4) and 'when I buy and appliance, I [don't] check the energy ratings' (18: -5), I just buy what I want. I'm not really

> that fussed about thinking about my energy use, but I do agree that 'the energy and utility tariffs are complicated to understand' (2: +2), although I feel strongly that 'people should [not] pay the same per-unit-cost of energy regardless of how much they use' (20: -5). I don't really know how much energy I use, nor do I really care. I'm too lazy to change my lifestyle.

Summary Manchester Factor 2

This factor was a candid insight into households that admit to using as much energy as they like. Comfort and lifestyle were the primary concerns of this viewpoint, despite still considering the environment and wider issues. Traditional financial incentives may not be effective on these households, if the energy efficiency measure is perceived to cause a disruption to their lifestyle. While the themes in Manchester Factor 2 were not revealed in the general factors identified in Cardiff, there was some similarity with the Cardiff single case viewpoint.

4.2.10 Manchester correlations between factor scores

The two factors that were identified for Manchester are independent of one another as demonstrated with the low correlation value in Table 4.4.

Table 4.5: Correlations between Manchester factor scores

Correlations between Manchester factor scores		
	1	2
1	1.0000	0.1785
2	0.1785	1.0000

Although they were statistically independent, Manchester Factor 1 still represented a conflation of multiple themes within itself, such as conserving energy to save money and the environment. In this case for Manchester, there was no meaningful factor rotation solution that was able to separate those themes.

As per Cardiff, the Q-sorts can also be diagrammatically mapped onto a two axis plot for visual inspections. The Q-sorts for Factors 1 and 2 are mapped in Figure 4.5.

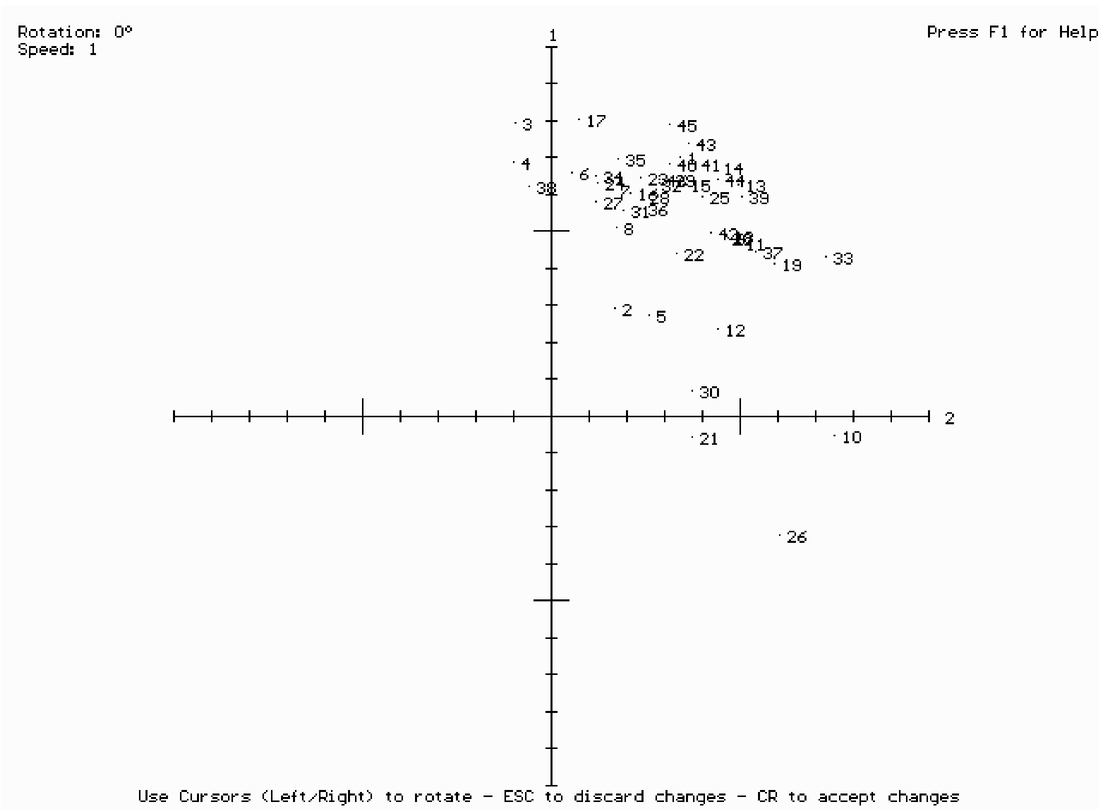

Figure 4.5: Manchester Factor 1 versus Factor 2

Figure 4.5 highlights a cluster of Q-sorts exemplifying Factor 1 and a handful of Q-sorts clearly exemplifying Factor 2 (21, 30, 12, 10, 26).

4.2.11 Summary of household viewpoints towards energy consumption

The Q-study identified multiple household viewpoints towards energy in Cardiff and Manchester. The viewpoints can be mapped onto three axes grouped by theme: saving the environment; saving money; and apathy. However, while it is tempting to simply restrict the analysis and discussion to those three axes; that would be an over-simplification that ignores the insights gained from each distinct viewpoint.

The dominant viewpoint in Cardiff was being energy efficient for the environment and greater good; however within this theme two distinct perspectives emerged. The first, was a conscious and active approach to energy efficiency; while the second exemplified a desire for clean energy sources but with a passive personal role of responsibility. The second viewpoint in Cardiff described households motivated to save money but who lacked information. Overall, the viewpoints highlighted awareness and engagement with energy use, although the responsibility of action was not always with the household. As a balance, a unique single case was also identified that highlighted a detachment towards energy use, as a result of the participant being removed from managing the household finances.

The themes in Manchester shared many of the characteristics with the viewpoints identified in Cardiff. For example, Manchester Factor 1 exemplified households that valued the environment as well as saving money through energy efficiency. Although the distinct difference between household and government responsibility that was clearly identified in Cardiff, was obfuscated in Manchester. On the other hand, Factor 2 in Manchester was a candid expression of households' apathy and disinterest. Such households may present a challenge towards retrofitting the built environment; conversely they may also present the greatest potential for realised energy savings.

As well as identifying distinct energy viewpoints in Cardiff and Manchester, a questionnaire was also administered to participants that measured their stated intent/desire to install retrofit measures and adopt energy efficiency behaviours.

Analysed together, the results provided a richer context to the viewpoint discussion and insights.

4.3 Retrofit technology and energy efficiency behaviour preferences

Using the statistical software package R, the results from the questionnaires were correlated with the Q Study factor loadings according to the tests of associations described in Table 3.4, and their p-values adjusted to compensate for multiple comparisons using the BH Step-up procedure. These tests were used to investigate the relationship between the viewpoints identified by Q and the desire/intent to install/adopt various energy efficiency technologies and behaviours. Specifically, the numerical factor loadings in Cardiff and Manchester were independently tested for association with each of the technologies, behaviours, and demographic variables. Any responses that were purposely left blank because of unfamiliar technologies or behaviours were given a 'neutral' score on the Likert item. The results shown in Table 4 and 5 are the variables that were found to be significantly correlated ($p < 0.05$) with each of the factor loadings (note the sign of the correlation to determine direction of relationship).

Since the Cardiff Factor 4 loadings were the inverted loadings from Factor 3, it was expected to find an inverse relationship between the variable associations of Factor 3 and 4.

Overall, there were not many significant relationships between retrofit technologies and the identified viewpoints. Explicitly, only wall insulation, radiator thermostats, and combined heat and power boilers were associated (either positively or negatively) to viewpoints. While it was reassuring to find that Cardiff Factor 3 (I'm consciously and actively energy efficient because it's plain common sense) was associated with the adoption of effective retrofit technologies, it was consistent with expectations since this was the most 'pro-active' viewpoint. However, the distinct lack of associations between installed retrofit measures and the other energy aware viewpoints highlighted the psychological value-action gap, which in this context is the Energy Efficiency Gap, i.e. individuals who expressed

Table 4.6: Significantly correlated technologies, behaviours, and demographic variables for Cardiff Factors

Questionnaire variables	p value	Statistic	Test of association
Factor 1: I think about being energy efficient for the environment and greater good			
Technologies			
Combined heat and power (intent)	0.032	-0.509	Spearman rho
Behaviours			
User lower washing machine temp.(adopt)	0.032	0.51	Point-biserial
Factor 2: I want to be more energy efficient to save money, but I don't really know how			
Demographics			
Energy awareness	0.041	12.321	F-Statistic
Factor 3: I'm consciously and actively energy efficient because it's plain common sense.			
Technologies			
Wall insulation (installed)	0.039	0.493	Point-biserial
Radiator thermostats (installed)	0.019	0.556	Point-biserial
Factor 4: I don't really think about energy efficient behaviours, but I want my energy supply to be renewable and greener			
Technologies			
Wall insulation (installed)	0.039	-0.493	Point-biserial
Radiator thermostats (installed)	0.019	-0.556	Point-biserial

Table 4.7: Significantly correlated technologies, behaviours, and demographic variables for Manchester Factors

Questionnaire variables	p value	Statistic	Test of association
Factor 1: I think about being energy efficient and the environment is important to me, but I reduce energy to save money			
Behaviours			
Turn off appliances completely (desire)	0.004	0.566	Spearman rho
Turn off appliances completely (intent)	0.017	0.488	Spearman rho
Turn off appliances completely (adopt)	0.004	0.578	Point-biserial
Consciously use less (desire)	0.017	0.488	Spearman rho
Consciously use less (intent)	0.017	0.482	Spearman rho
Consciously use less (adopt)	0.004	0.554	Point-biserial
Factor 2: I don't really know how much energy I use, nor do I really care. I'm too lazy to change my lifestyle.			
Behaviours			
Turn off appliances completely (adopt)	0.017	-0.5	Point-biserial

energy conservation attitudes were not significantly correlated with any of the installed retrofit technologies.

Conversely, Manchester Factor 1, *I think about being energy efficient and the environment is important to me, but I reduce energy to save money*, was the only viewpoint associated with multiple energy efficiency behaviours. As such, while the results from the questionnaires helped with the discussion and interpretation of the factors; the explicit lack of associations between technologies and viewpoints may again be a re-affirmation of the Energy Efficiency Gap.

4.4 Winter survey results

The winter survey was carried out in order to investigate how the change in season may affect household viewpoints towards energy use. Naturally, it was expected that attitudes towards energy may have shifted when the temperature dropped and heating was turned on. However, since the aim of this research was not explicitly to investigate how the weather affected attitudes towards energy use, a simplified postal questionnaire was employed, instead of a second full Q-study. As a result, the data from the questionnaire was not as rich as the summer Q study, but still allowed for meaningful comparisons while being more practical to administer and less onerous for the participants.

In total, 91 winter surveys were posted and 34 were returned, 19 from Cardiff and 15 from Manchester, resulting in an overall response rate of 37% . From the 34 returned surveys, 3 were incorrectly filled out and could only be partially used. In the winter survey, participants were given the same 65 Q statements used in the summer study and asked to select the 5 statements they agreed with the most, followed by the 5 statements they disagreed with the most. The results were compared quantitatively, but more importantly, also qualitatively with the summer study; as participants were asked in open ended questions to sum up their thoughts about energy use in their home, and if there is anything they would like to change about their household energy use.

Quantitatively, the agree and disagree statements in the winter survey were compared with the ±6, ±5, and ±4 agree/disagree statements from the summer survey. The total number of repeats were then calculated for each participant, and a one-sample statistical t-test used to determine if there was a significant difference between the seasonal results. The Null Hypothesis was no significant difference between seasons, i.e. the mean number of repeats was equal to 10 (complete overlap with the 5 agree and 5 disagree statements); while the one-sided Alternative Hypothesis was that the mean was less than 10. Figure 4.6 shows the total number of repeated agree and disagree statements for each returned winter survey.

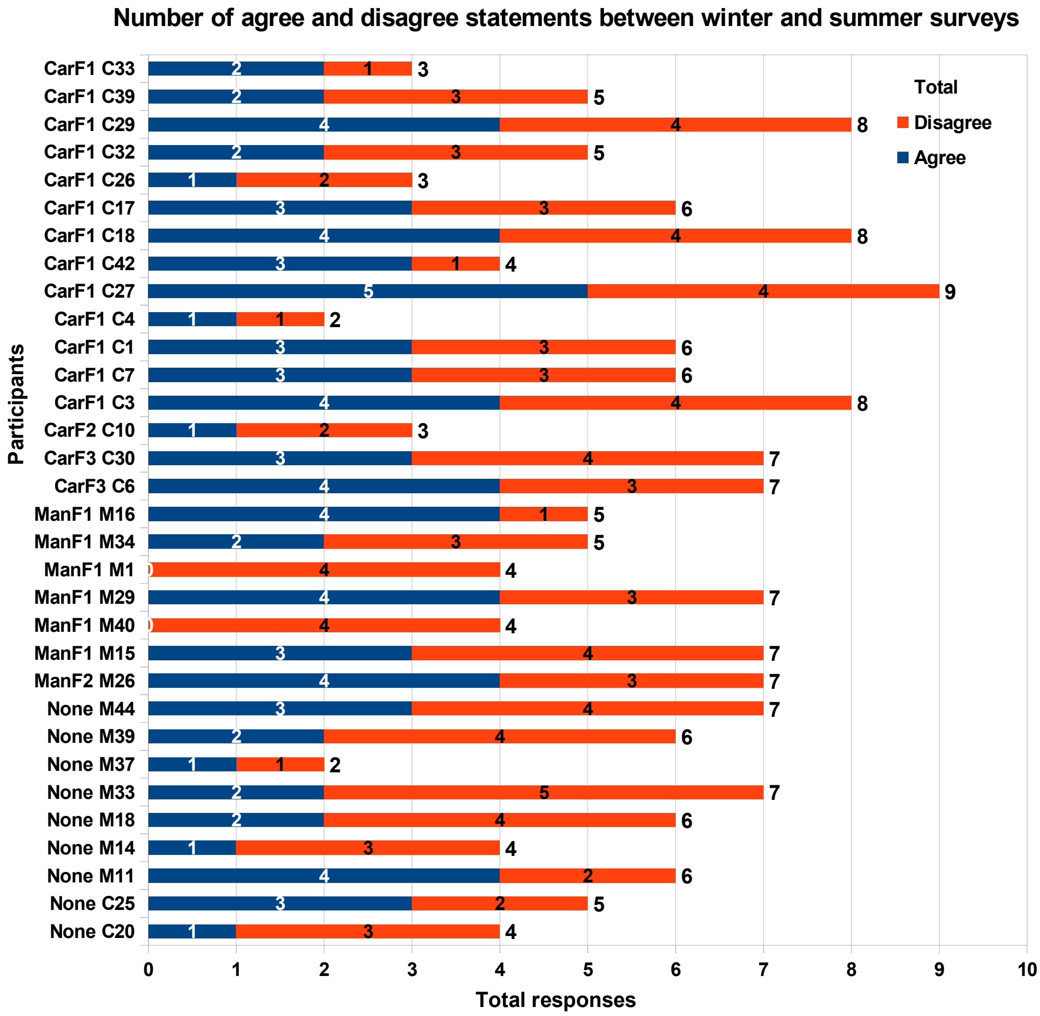

Figure 4.6: Number of repeated agree and disagree statements between winter and summer surveys

The total mean for repeated statements was 5.5 with a standard deviation of 1.83. The one-sample two tail t-test ($t = -13.90, df = 31, \mu = 10, p < 0.001, \alpha =$

0.01, single-tail) rejected the Null Hypothesis, indicating a significant difference between summer and winter agree/disagree statements. Given the change in temperature and corresponding heating use, this result was not surprising in itself. More useful, was examining the data qualitatively to investigate the new agree/disagree statements in order to extend and enhance the interpretation of the identified viewpoints.

The participants with the least number of repeats (3 or less) summer and winter were: C33; C26; C4; C10; M37. The C and M prefix represent Cardiff and Manchester participants respectively. Their different statement selections and questionnaire results are discussed below, but the full statement selection between winter and summer participants is presented in Appendix D. When comparing the Q-study Factors with the winter results, it is important to remember that the Factors are composites created by combining all the significantly loaded Q-sorts. Therefore, even though individual participants may significantly load on a Factor, it does not necessarily imply that their statement selections completely exemplify the final Factor interpretation.

Participant C33

Participant C33 loaded onto Cardiff Factor 1 (I think about being energy efficient for the environment and greater good) with a significant loading score of 0.6194; however, the winter statement selections reflected a shift in priorities. For example, participant C33 agreed with statement 23, *"I try and reduce my energy use to save money"* in the winter survey but not the summer survey. Although some environmental statements were still selected, such as 14 (*"I want my energy use to be greener"*) and 25 (*"we're not using sunlight wind effectively as a nation"*).

When asked to sum of their thoughts about energy use in the home, C33 responded by writing, "more aware of cost, heating used to a minimum, thermostat regularly turned down." Similarly, when asked if there is anything they would like to change about their household energy use (including motivations/barriers), C33 wrote, "cut down on electricity usage. [motivation] to save money, [barrier] teenage son." This focus on saving money manifested itself in Cardiff Factor 2, but not directly in Factor 1. As such, for participant C33 the winter reflected a shift from primarily environmentally themes to a balance between money and environment, similar to Manchester Factor 1.

Interestingly, there was no change between the summer and winter responses to the questions: "How frequently do you think about your household energy use?", and "thinking about your home in the winter, how easy or difficult is it to keep your home warm when the heating is on?" The responses in both surveys were "frequently", and "very easy" respectively. This result indicated that the change in seasons and the increase in heating use shifted participant C33's viewpoint from environmental to monetary, even though there was no change in home heating effort perception or energy use awareness.

Participant C26

Participant C26 loaded onto Cardiff Factor 1 with a significant loading score of 0.4940, but also loaded on Factor 2 (I want to be more energy efficient to save money, but I don't really know how) with a score of 0.3657. Therefore, participant C26 already represented a mix of Factors, and this was also reflected in the winter survey results. When asked to sum of their thoughts about energy use in the home, C26 responded by writing, "It is very expensive, we use too much of it. We need to be greener in our approach as individuals and as a nation.". When asked if there is anything they would like to change about their household energy use (including motivations/barriers), C26 wrote, "use less. [motivation] money, and well-being, do not want to be cold. [barriers] need hot water and cosmetics (house aesthetics)." This conflation between environment and money was captured by Manchester Factor 1.

Nevertheless, even though the overall themes and sentiments for participant C26 did not change substantially between winter and summer, their agree/disagree statement selection did. Specifically, C26 winter agree statements that were not repeats from the summer statements were: 2 (*"The energy and utility tariffs are complicated to understand"*), 7 (*"Old home should be improved to modern building standards"*), 9 (*"Parents should ensure that their kids are taught how to be energy efficient at home"*), and 25 (*"we're not using sunlight or wind effectively as a nation"*). Although these statement selections were different, other statements selected by participant C26 did overlap with the summer results. As such, more telling than the winter statement selections, that were not captured in a controlled Q-study, were the written responses that did align with the summer survey.

Participant C4

Participant C4 also significantly loaded on Cardiff Factor 1 with a score of 0.4626. However, even though the statement selections varied between winter and summer, the new winter statements now more closely aligned to Cardiff Factor 1. For example, the non-repeat environmental statements for participant 4 were: 16 (*"we are too dependant on fossil fuels"*); 25 (*"we're not using sunlight or wind effectivfely as a nation"*); and 42 (*"I [don't] believe in climate change"*).

The written responses were short, but when asked to generally sum up their thoughts about energy use in their home, participant C4 wrote, "I try to use as little as possible. Keeping heating down when not in the room." No motivation or barriers were listed, except when asked to explain the reasons for the winter statement selection, C4 wrote, "I try to conserve energy for the rising costs [that] can not be met by pensioners like me." The winter statement selections further support this participant loading on Cardiff Factor 1, while the written response also indicates concern about the rising cost of energy use.

Participant C10

Participant C10 significantly loaded on Cardiff Factor 2 with a score of 0.4632 and also had a score of 0.3038 on Factor 1. The repeated statements between summer and winter supported C10's association with money focused Factor 2, such as statement 23 (*"I try and reduce my energy use to save money"*), and 50 (*"I'm [not] happy with my energy costs"*); however the new winter statements also highlighted inter-occupant conflict. For example statements 11 (*"woman use most of the energy at home"*), and 36 (*"I try and conserve energy, but sometimes it's difficult to get other people to do the same"*).

The new statement selections were also supported by the written answers. Specifically when asked to sum up general thoughts about energy use in their home, participant C10 wrote, “it is too high due to my wife’s demands for warmth, which are greater than mine, and she needs light throughout the house.” There was no change to the Likert Item responses for “how frequently do you think about your household energy use?” (response: frequently), and “thinking about your home in the winter, how easy or difficult is it to keep your home warm when the heating is on?” (fairly difficult).

The result for participant C10 highlighted how the winter and a difference in thermal comfort may have exasperated inter-occupant relationships with respect to household energy use. During the summer such tensions may not have been present, resulting in participant C10 mostly selecting money focused statements. However in the winter, even though the focus for conserving energy is still to save money, there was now a sub-theme about the challenge of getting other people in the household to do the same.

Participant M37

Participant M37 had a conflated Q-sort that significantly loaded on both Manchester Factor 1 and 2 with the scores of 0.4453 and 0.5388 respectively. As such, M37’s Q-sort was not used in the construction of the Factors, as it represented about an equal mix between the two. For question 1, “in general, can you sum up your thoughts about energy use in your home?” participant M37 wrote, “It’s a big home and its victorian, so harder and more expensive to heat than some. I feel better about the efficiency of the heating system following an annual service, but also recently found out our chimney on the gas fireplace is the wrong type, so we’re getting a down draught in chimney, and losing heat that way.” This written response highlighted how a technical factor, such as the physical property itself can act as a barrier to energy efficiency.

From a statement selection perspective, participant M37 wrote that his statement selection for the winter survey felt too arbitrary to be reliable. Based on that admission, it was not surprising that there were only two statement repeats from the winter and summer surveys. They were statements 25 (*“we’re not using sunlight or wind effectively as a nation”*) and statement 28 (*“I [do] really think about my household energy use”*).

4.4.1 Winter summary

The winter survey results demonstrated that participants changed statement selections between seasons, most likely due to the change in temperature and heating usage. However, despite the difference, the overall new selected statements still qualitatively fell within the scope of the identified viewpoints from the Q-study, even though the participants themselves may have changed viewpoints. As such, even though the energy focus may shift for households depending on season, the overall viewpoints identified in the summer are still intact during the winter.

Interestingly, even though the participants generally changed statement selection between summer and winter, there was no significant change in energy awareness or household heating effort, as measured by question 3 “how frequently do you think about your household energy use? [5 point Likert Item]” and question 4 “thinking about your home in the winter, how easy or difficult is it to keep your home warm when the heating is on? [4 point response scale].” A Wilcoxon signed rank test for ordinal repeated measures was used to test the Null Hypothesis that there was no significant change to participant responses between seasons. Using a two-tail significance level of $\alpha = 0.01$, the Alternative Hypothesis was rejected for question 3 ($V = 86, p = 0.3339$) and question 4 ($V = 67.5, p = 0.3014$), i.e. there was no significant difference between summer and winter scores.

4.5 Summary

In summary, this chapter presented the results from both phases of research. The barriers and motivations to retrofitting in the context of large UK cities were identified; as well as expanded on by examining their associations with each other and demographics. The results revealed a broad range of socio-technical barriers and motivations that underscored a need for more holistic retrofit policies and intervention designs.

The Q-study revealed households’ attitudes towards energy in Cardiff and Manchester, specifically the viewpoints were broadly mapped onto three axes: saving the environment; saving money; and apathy. As well as those axial themes, sub-perspectives were also identified, specifically a split in energy efficiency responsibility between the household and the government. Finally, the relationships between the viewpoints and retrofit technology/energy efficiency behaviour preferences were identified. Such associations help with the interpretation of the Q factors and provide further context to the viewpoints.

5 | Discussion

Based on the research results, this chapter synthesises the main findings and discusses their application to help address the Energy Efficiency Gap. The policy implications of the results are also discussed, as well as limitations and suggestions for future research.

5.1 Discussion of retrofit barriers, motivations, and demographics

The barriers and motivations to adopting energy efficiency measures, and their specific association to demographics are summarised in Table 5.1.

It is interesting to note from Table 5.1 that occupant age, household income, and the number of bedrooms in the household were not significantly associated with any specific barrier; while on the other hand, household income, marital status, and type of dwelling were the only variables associated with motivations. In comparison, other studies also found varied association between demographics and retrofit barriers/motivations. In his renovation choice model, Jakob [2007] found that technical building characteristics had a much stronger impact on renovation choices rather than socio-economic variables, such as income, age, and professional occupation. As such, this research loosely supported those conclusions, specifically by identifying that sex, age and education were not significantly associated with any individual motivation, while the technical variable 'type of dwelling' was significant. Conversely, this study found that the socio-economic variable of household income *was* significantly associated with motivations, but that the technical variable 'number of bedrooms' in the home was not.

Table 5.1: Summary demographic variables versus barriers and motivations

Barriers	***Motivations***	**Demographic variables**							
		Sex	Income	Marital	Education	Dwellings	Occupants	Residence	Location
Beliefs		Woman				Semi/detached			Manchester
	Save money		$> £40k$	*Married*		*Semi/detached*			
Cost									Manchester
Family		Woman					3 +		
	Resource efficiency		$< £40k$	*Single*		*Flats/terraces*			
Institutional		Men							Manchester
	Other		$> £40k$	*Single*					
Landlord-tenant		Men		Single	Degree +	Flats/terraces		Tenants	
Behaviour					Degree +				Manchester
Property itself				Married	Degree +			Owner	Cardiff

Using mosaic plots, it is possible to visualise the strength of these associations using the odds-ratio (Φ). In these plots, the vertical height of each row represents the barrier/motivation frequency proportion and the horizontal width of each column represents the demographic variable frequency proportion [Friendly, 1994].

In the following sub-sections, the relationship between each of the demographic variables and barriers/motivations are discussed in detail.

5.1.1 [D1] Sex

The demographic variable of interviewee sex was not significantly associated with any motivations; however it was strongly associated with barriers. Specifically, the mosaic plot in Figure 5.1 shows that women were strongly associated (odds ratio greater than 2) with the barriers [B1] and [B3] (Beliefs/information and Family/partner/housemate), while men were more strongly associated with [B4] and [B5] (Institutional and Landlord-tenant/housing associations). Women were also weakly associated with barrier [B8] (Property itself) [Pelenur & Cruickshank, 2012a].

As such, the combined results from both studies indicate that while sex can be used to better understand the barriers preventing the adoption of energy efficiency measures, sex may not provide any meaningful guidance on how to design interventions which target specific motivations. This result supports other studies which found that sex was not associated with any particular motivation to be energy efficient [Caird *et al.*, 2008; Nair *et al.*, 2010; Sardianou, 2007]. Although, a meta-review by Zelezny *et al.* [2000] showed that woman reported stronger environmental attitudes and behaviours than men [Zelezny *et al.*, 2000], because woman had higher levels of socialisation and were more socially responsible [Zelezny *et al.*, 2000]. Burgess & Nye [2008] also found unexpected gender differences when measuring the impact of energy monitoring equipment in the home.

5.1.2 [D2] Age

Age was not significantly associated with specific motivations or barriers. This result indicates that national or regional campaigns to promote energy efficiency may

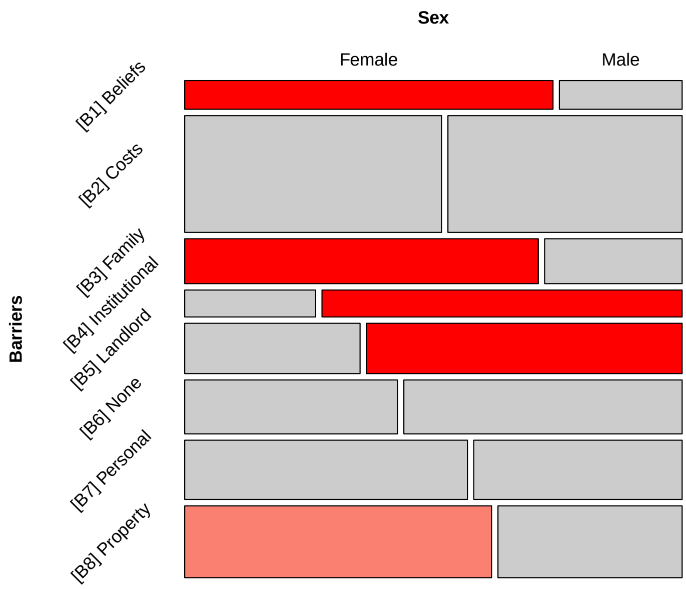

Figure 5.1: Mosaic plot for Sex versus barriers
With the left-hand side shading for 'females' (total number of responses 135 from 88 participants) and the right-hand side shading for 'males' (total number of responses 117 from 85 participants) representing the strength of the odds-ratio. Heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2

benefit from broadening to include all age groups, rather than simply targeting the young or elderly. This study contrasts other research which found that age influenced the stated likelihood to adopt certain energy efficiency measures [Carlsson-Kanyama *et al.*, 2005; Mahapatra & Gustavsson, 2008; Nair *et al.*, 2010]. It is difficult to make direct comparisons with other studies because of the contextual differences. For example the above cited studies were set in Sweden with their own specific energy efficiency measures. However, such differences highlight the need for multi-national research, that investigates and compares the Energy Efficiency Gap across countries.

5.1.3 [D3] Household income

While household income was not associated with any barriers [Pelenur & Cruickshank, 2012a], it was strongly associated with some motivations. The mosaic plot in Figure 5.2 shows that the motivation of [M1] (save money) was strongly associated with incomes of greater than £40k, the motivation of [M3] (resource efficiency) was strongly associated with household incomes less than £40k, and the other motivations [M4-8] were strongly associated with households who declined to provide income information.

This counter-intuitive result indicates that households who earned greater than £40k a year were motivated to adopt energy efficiency measures because of their cost saving potential, while households on lesser incomes were motivated by saving energy and reducing waste. Anecdotally, the reverse was expected, i.e. that homes earning less income would be motivated to install energy efficiency measures to save money. This result should be further investigated, since it can help guide policies and design incentives which directly appeal to associated demographics. For example, this research indicates that the UK government's Green Deal programme may appeal more to households earning less than £40k a year, since it is cost and savings-neutral to the home owner.

Across other studies, the influence of income on the adoption of energy efficiency measures varied [Nair *et al.*, 2010]. Some studies showed that household income influences investment behaviour [Black *et al.*, 1985; Caird *et al.*, 2007;

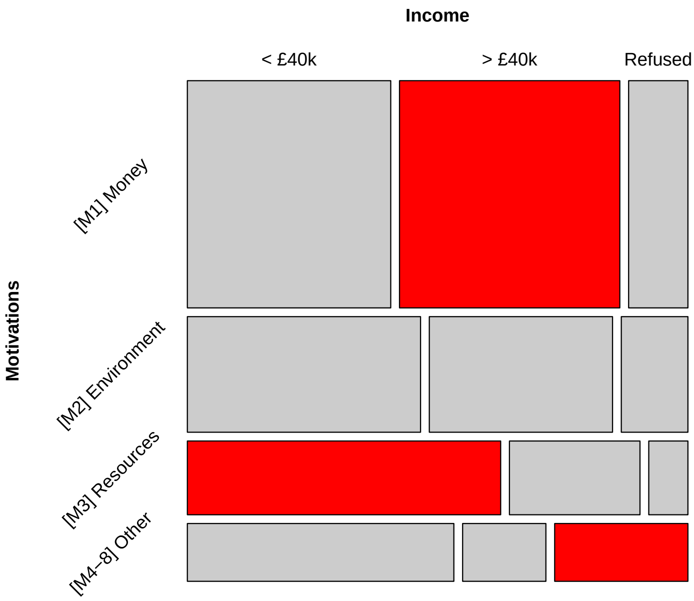

Figure 5.2: Mosaic plot for Income versus motivations

With the left-hand side shading for '£40k and less' (total number of responses 116 from 71 participants), the middle shading for 'Greater than £40k' (total number of responses 89 from 57 participants), and the right-hand side shading for 'Refused' (total number of responses 33 from 21 participants) representing the strength of the odds-ratio. Heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2

Dillman *et al.*, 1983]; while other studies indicated an absence or low correlation between income and investment behaviour [Barr *et al.*, 2005; Ürge Vorsatz & Hauff, 2001].

It is interesting to note the strong association between individuals who refused to provide their income information with the 'other' non-physical motivations (warmth & comfort, aesthetics & space, health & safety, and time & convenience). While this relationship is interesting, the coarseness of the data does not allow for a meaningful interpretation.

Surprisingly, household income was not correlated with any barrier, remarkably not even Cost. This lack of association indicates that the upfront cost of energy efficiency measures may not be as important as often expected for low income families, or re-phrased, that other barriers are as equally important as cost. From a demand perspective, this result was in line with other studies reviewed by Guerin *et al.* [2000] that found no consensus linking income and energy consumption. As such, this result implies that price incentives or subsidies that address the cost of energy efficiency measures may be equally effective for high income families as for low income families.

5.1.4 [D4] Marital status

Figure 5.3 and Figure 5.4 shows that marital status was strongly associated with barriers [B5] and [B8] (Landlord-tenant/housing associations, and Property itself) and with motivations [M1], [M3], and [M4-8] (save money, resource efficiency, and other). Marital status was also weakly associated with [B1] and [B3] (Beliefs/information and Family/partner/housemate). Specifically, married/common-law interviewees were strongly associated with the Property barrier and with the motivation to Save Money, while currently single interviewees were strongly associated with the Landlord/tenant/housing associations barrier, and strongly associated with the motivations of Resource Efficiency and Other.

These results were consistent with motivations associated with income since secondary analysis revealed that married/common-law interviewees in the sample were correlated with incomes greater than £40k ($\chi^2 = 18.40$, df $= 2$, $p < 0.001$) and that single interviewees were correlated with household incomes of less than

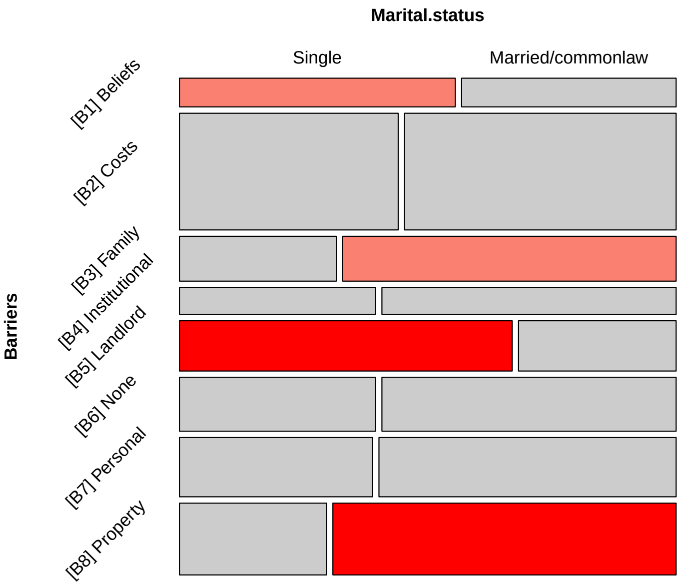

Figure 5.3: Mosaic plot for Marital status versus barriers
With the left-hand side shading for 'single' (total number of responses 108 from 77 participants) and the right-hand side shading for 'married/common-law'(total number of responses 144 from 96 participants) representing the strength of the odds-ratio. Heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2

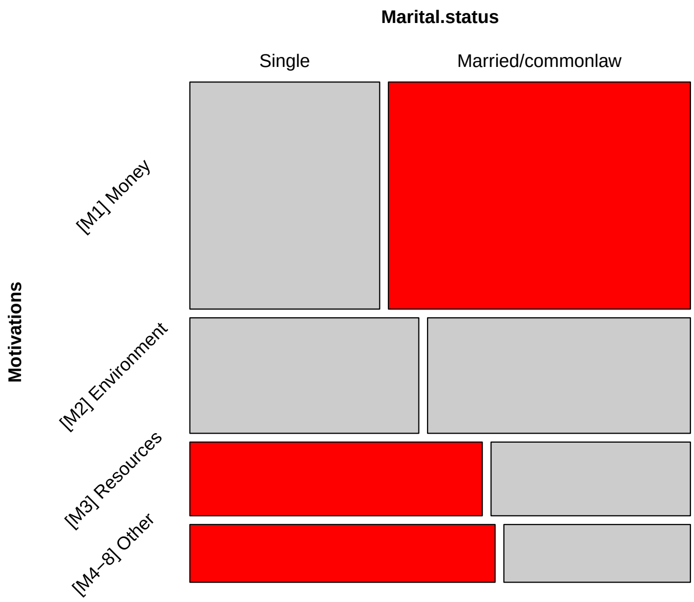

Figure 5.4: Mosaic plot for Marital status versus motivations
With the left-hand side shading for 'single' (total number of responses 111 from 67 participants) and the right-hand side shading for 'married/common-law' (total number of responses 127 from 82 participants) representing the strength of the odds-ratio. Heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2

£40k. Similarly, married/common-law interviewees in the sample were also correlated to property ownership, and correspondingly single interviewees with tenancy ($\chi^2 = 16.69$, df $= 1$, $p < 0.001$). The importance of this result is that interventions which specifically target the Landlord-tenant/housing associations and Property barriers should be designed to consider marital status as an important factor.

5.1.5 [D5] Education level

With respect to education level, Figure 5.5 shows that interviewees with a single university degree level qualification or more were strongly associated with barriers [B5], [B7], and [B8] (Landlord/tenant/housing associations, Personal behaviour, and Property itself), and interviewees with up-to a high school or trade qualification were only weakly associated with barriers [B3], [B4], and [B6] (Family/partner/housemate, Institutional, and None) [Pelenur & Cruickshank, 2012a]. The level of education was not significantly associated with any motivations. As such, while education level can be used to inform policies that target specific barriers, it should not be used to guide the design of incentives. This result contrasts other studies which found that education influenced the acceptance of energy efficiency measures or strategies [Nair *et al.*, 2010; Olsen, 1983; Ürge Vorsatz & Hauff, 2001].

It was also interesting to compare the results between education and income, which highlighted how education correlated with barriers but income did not. This result indicates that using education level as a factor to address energy efficiency barriers may be more effective than targeting income.

5.1.6 [D6] Dwelling

Figure 5.6 and 5.7 show that residents living in apartments or flats were strongly associated with barrier [B5] (Landlord-tenant/housing associations) and were strongly associated with motivation [M3] (Resource efficiency). Similarly, semi/detached households were strongly associated with motivation [M1] (Save money), but were not strongly associated with barrier [B8] (Property), instead they were associated with [B1] (Beliefs).

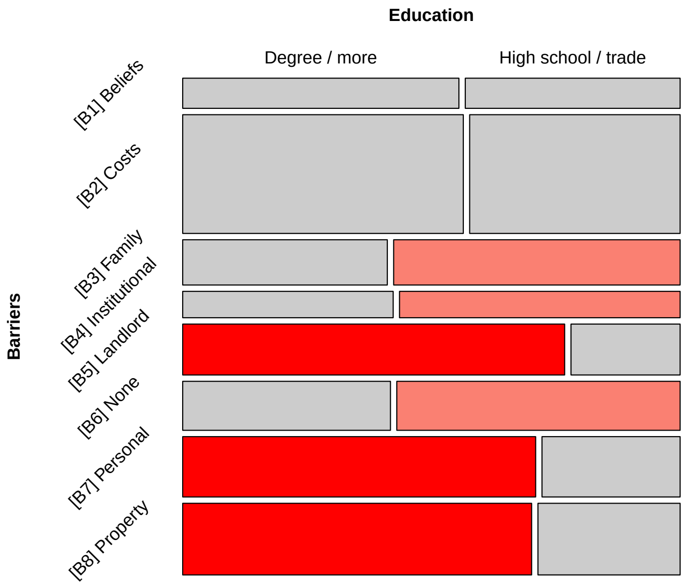

Figure 5.5: Mosaic plot for Education level versus barriers
With the left-hand side shading for 'degree/more' (total number of responses 143 from 91 participants) and the right-hand side shading for 'high school / trade' (total number of responses 97 from 71 participants) representing the strength of the odds-ratio. Heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2

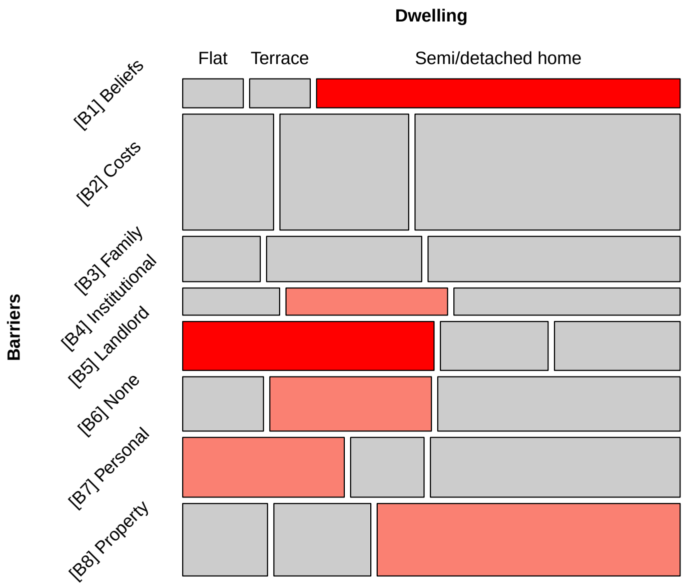

Figure 5.6: Mosaic plot for Dwelling versus barriers
With the left-hand side shading for 'flat' (total number of responses 58 from 41 participants), the middle shading for 'terrace' (total number of responses 61 from 44 participants), and the right-hand side shading for 'semi/detached home' (total number of responses 131 from 87 participants) representing the strength of the odds-ratio. Heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2

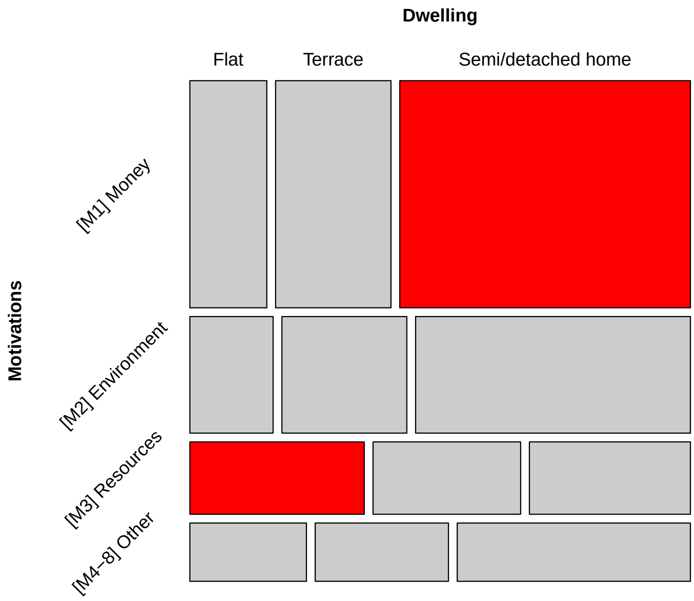

Figure 5.7: Mosaic plot for Dwelling versus motivations
With the left-hand side shading for 'flat' (total number of responses 48 from 30 participants), the middle shading for 'terrace' (total number of responses 61 from 37 participants), and the right-hand side shading for 'semi/detached home' (total number of responses 127 from 81 participants) representing the strength of the odds-ratio. Heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2

These associations were consistent with previous results for income and marital status, since apartment and flat residents in the sample were correlated with being single ($\chi^2 = 19.78$, df = 2, $p < 0.001$), with incomes of less than £40k ($\chi^2 = 18.32$, df = 4, $p < 0.002$), and with being tenants ($\chi^2 = 28.79$, df = 2, $p < 0.001$).

5.1.7 [D7] Number of bedrooms in household

The number of bedrooms was not a statistically significant variable with either motivations or barriers. As such, even though house size is an established predictor of household energy consumption [Abrahamse & Steg, 2009; Guerin *et al.*, 2000], it may not be a reliable variable to use to overcome retrofit barriers or target incentives in the UK context.

5.1.8 [D8] Number of occupants

Not surprisingly, Figure 5.8 shows a strong association between households with 3 or more occupants and barrier [B3] (Family/partner/housemate).

This result is of interest because it highlighted the importance of inter-family/occupant relationships. Often the household is treated as a single unit by economic models; however, this result showed that the inter-occupant relationships are the most significant barrier for homes with more than 3 occupants. This was consistent with other studies which found that inter-occupant relationships were an important factor affecting the adoption of energy efficiency measures [Darby, 2010; Hargreaves *et al.*, 2010; Shove *et al.*, 1998]. This result indicates that interventions to promote energy efficiency in homes with 3 or more occupants should be designed to specifically address problems that may arise due to inter-occupant relationships.

While the number of occupants in a household was strongly associated with the barrier [B3] (family/partner/housemate), it was not associated with any specific motivation to adopt energy efficiency measures. This result implies that knowing the number of occupants in a household may not help the the design of targeted incentives. As such, while it is important to identify that occupants in large multi-resident homes list their family/partner/housemates as a barrier towards the adoption of energy efficiency measures, there is no association with any specific motivation in such large households.

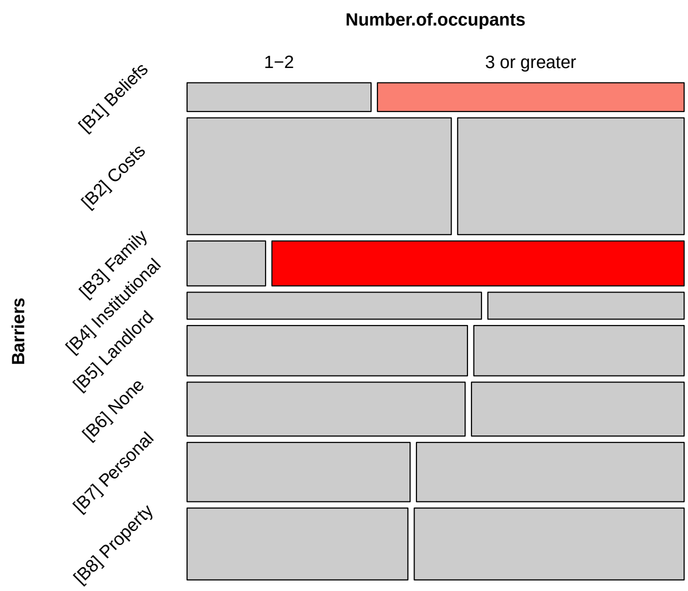

Figure 5.8: Mosaic plot for Number of occupants versus barriers with the left-hand side shading for '1 - 2' (total number of responses 120 from 90 participants) and the right-hand side shading for '3 or greater' (total number of responses 132 from 83 participants) representing the strength of the odds-ratio. Heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2

5.1.9 [D9] Residence

Residency type was not associated with any specific motivation, although as shown in Figure 5.9 tenants were correlated with barrier [B5] (Landlord-tenant/housing associations) and home owners were strongly associated with barrier [B8] (Property itself) [Pelenur & Cruickshank, 2012a].

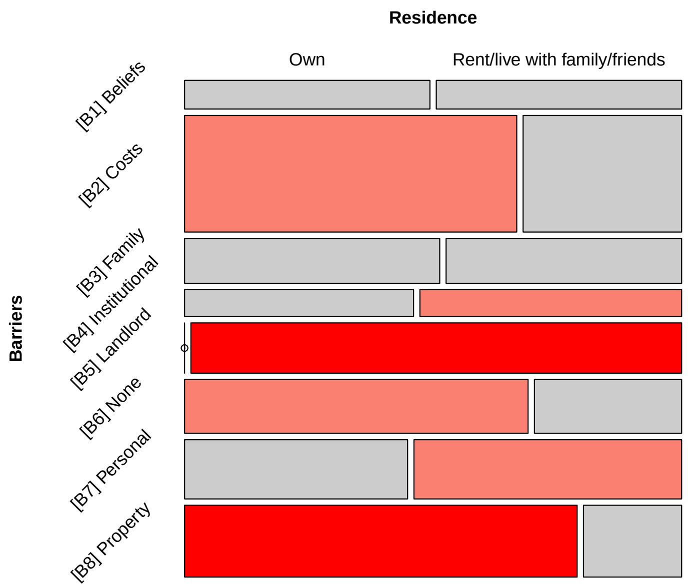

Figure 5.9: Mosaic plot for Residence versus barriers
With the left-hand side shading for 'own' (total number of responses 140 from 100 participants) and the right-hand side shading for 'rent/live with family/friends' (total number of responses 112 from 73 participants) representing the strength of the odds-ratio. Heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2

This was an interesting result given that the type of residency and dwelling type were associated with each other ($\chi^2 = 28.79$, df $= 2$, $p < 0.001$). Therefore, it was unexpected to find that type of dwelling was associated with specific motivations, but residency was not. This implies that the technical variable of dwelling type was a better predictor of motivation than the socio-economic variable of residency, a result supported by Jakob [Jakob, 2007].

Owner occupied homes were also weakly associated with barriers [B2] and [B6] (Cost and None/no barriers), and tenanted properties were weakly associated with [B4] and [B7] (Institutional and Personal behaviour).

5.1.10 [D10] Location

The location demographic variable is of particular interest, because it highlighted city level barrier correlations, although location was not significantly associated with any motivations. Specifically, Figure 5.10 showed that Manchester was strongly associated with [B1], [B2], [B4], and [B7] (Beliefs/information, Cost, Institutional, and Personal behaviour) and weakly associated with [B3] (Family/partner/housemate); while Cardiff was only strongly associated with [B6] and [B8] (None/no barriers, and Property itself). This difference should be of interest for the local governments in each city, since the results allow for comparison between local council policies.

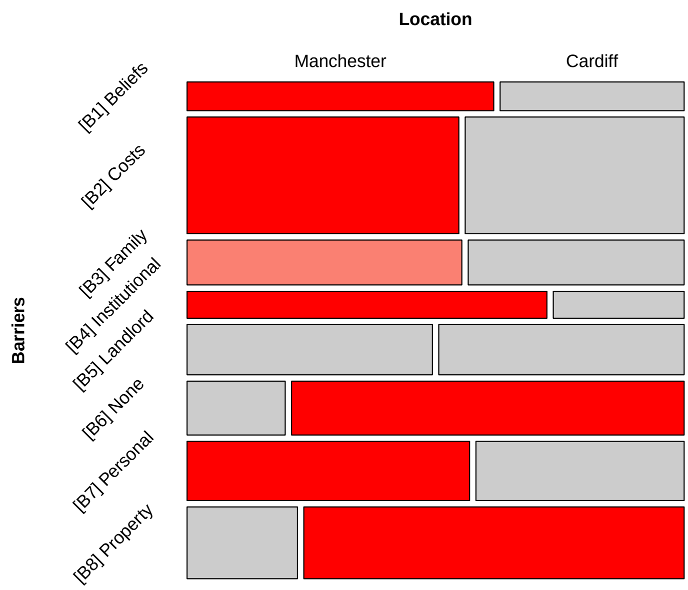

Figure 5.10: Mosaic plot for Location versus barriers
With the left-hand side shading for 'Manchester' (total number of responses 119 from 75 participants) and the right-hand side shading for 'Cardiff' (total number of responses 133 from 98 participants) representing the strength of the odds-ratio. Heavily shaded tiles represent an odds ratio of greater than 2, while lightly shaded tiles represents an odds ratio between 1.5 and 2

This result indicates that while barriers may be regionally dependent, the motivations that drive households to adopt/install energy efficiency measures may be nationally common. If true, then centrally coordinated efforts to incentivise the UK to adopt/install energy efficiency measures may be just as effective as regional targeting; however, further multi-region research is required to confirm this hypothesis.

5.1.11 Summary of barriers, motivations, and demographics

Taken together, these results suggest two consistent profiles that policy makers, local councils, and members of the construction/retrofit industry can use to improve the effectiveness of energy efficiency programmes.

Profile 1 - single/earning less than £40k/living in a flat

The results indicated that currently single individuals earning less than £40k a year and living in apartments/flats were motivated to save resources and be more efficient out of general principle, but cited that the landlord-tenant/housing association was the main barrier preventing their adoption of energy efficiency measures.

This result is also supported by the strong association shown in Figure 4.3 between the resource/efficiency motivation and the landlord-tenant/housing association barrier. Taken together, this result suggests that households that match the first profile may be ideal candidates for the government Green Deal programme, since the policy specifically addresses the landlord-tenant split incentive. In this case, the messaging should be targeted to inform households that by adopting the Green Deal, they are reducing waste and increasing efficiency.

As a balance, an implication of flats in this profile is that the household built form itself may limit the scope of possible retrofits, and thereby the extent of energy performance gains. Nevertheless, if these households are motivated to save resources and be more efficient from general principle, then it may be effective to also promote personal energy efficiency behaviours that are not limited by the landlord-tenant barrier.

Profile 2 - married/earning greater than £40k/living in a house

The second profile indicated that married/common-law individuals with incomes greater than £40k a year and living in semi/detached homes were motivated to save money, but reported that their physical property (either due to planning permission, age of home, space constraints, heritage, etc ....) was the significant barrier preventing their adoption of energy efficiency measures.

Similar to the first profile, this result is supported by the strong association between the primary profile barrier and motivation, names the relationship between the motivation to save money and the barrier of property itself. As a whole, this profile suggests that a cost savings message should accompany any new planning law or home energy efficiency standard reform that addresses the physical property barrier. Such initiatives or policies should target households that match the second profile to potentially increase their effectiveness.

On the other hand, if the physical property itself is a barrier significantly associated with this profile, then that may indicate that matching households are not good candidates for the Green Deal. Since the barrier to adoption isn't cost related, rather built form related. As such, in order to overcome this barrier, planning permission and conservation reform may be needed alongside the Green Deal.

5.1.12 Limitations to the barrier and motivation research

The thematic analysis and statistical tests of associations highlighted barriers, motivations, and corresponding associations with demographics. However, as with all complex surveys, the initial design played an important role in the outcome. The underlying limitation of this analysis was the possibility of sample bias, since the street interviews were only conducted over 3 days in each city. However, previous research [Pelenur & Cruickshank, 2012b] attempted to reduce any possible bias by varying interview locations, and choosing to conduct the interviews over an entire bank holiday weekend, when the majority of people were off work (i.e. able to participate). Nevertheless, caution should be taken before generalising the results across all UK cities.

Similarly, this research aimed to be exploratory as opposed to explanatory;

hence the emphasis was on identifying empirical barriers and motivations to installing retrofit measures, as opposed to researching their prevalence. Future research can use a representative sample to investigate the proportion of households that identify with each barrier or motivation.

A second limitation with this type of study is the temporal nature of opinions. Fundamentally, the interviews transcribed subjective motivations and barriers, i.e., perceived motivations and barriers that were expressed as modifiable opinions from the interviewees rather than stable observed truths. As such, those opinions are liable to change with the passing of time. However, while the recorded barriers and motivations may shift, the measured demographic variables are stable and unlikely to change significantly. The consequence is that future research could easily use the same demographic variables to repeat this study, and measure any change in the resulting association with identified barriers and motivations.

Finally, only individual demographic variables were used in the analysis; however, it is possible for future research to also investigate the association of two or more demographic variables with each motivation. The results of any future multi-demographic analysis can be improved by increasing the total number of participants.

5.2 Discussion of household viewpoints towards energy consumption

The factors that emerged from Cardiff and Manchester exemplified general viewpoints about household energy use. These viewpoints and themes emerged inductively from the general public and participants themselves, instead of *a priori* theory. As a result, the viewpoints were free from theoretical constraints which may have biased their narratives. By further linking the Q Study results with significant energy efficient technology/behaviour preferences and demographics, it was also possible to extend and broaden the interpretation of the factors.

The subjective viewpoints mapped onto three axes grouped by theme: saving the environment; saving money; and apathy. Within the environmental axis, two bi-polar specificity viewpoints were also identified: taking an active approach to energy efficiency because that's the right thing to do; and taking a passive approach to being energy efficient but hoping that others will make the energy supply more efficient. The interpretation of these viewpoints was further supported by the results of the questionnaire, specifically by considering which technologies and behaviours were correlated to each of the factors.

5.2.1 Cardiff viewpoints and demographics

For Cardiff Factor 1 (I think about being energy efficient for the environment and greater good), the only energy efficiency behaviour significantly correlated was using washing machines at a lower temperature. From a technology perspective, the intent to install combined heat and power generators (CHP) was negatively correlated with Factor 1. Comments from the questionnaires stated that CHPs were: unfamiliar; "not appropriate" because of rental property or area; too much of a "financial outlay"; and that some participants "needed more information about the cost and benefit." This indicates that even though this factor exemplified conserving energy for the environment and greater good, this alone may not be enough to encourage the uptake of less-known retrofit technologies such as CHPs. Based on this insight, if the government intends to promote new unfamiliar technologies, it may benefit by running early adopter trials, providing comprehensive information about the benefits and costs of the technology, and financial incentives (currently already in place with the Renewable Heat Incentive policy). The results from this study suggest that being environmentally aware and actively concerned about energy efficiency does not necessarily lead to the desire or intention to install energy efficient technologies.

For Cardiff Factor 2 (I want to be more energy efficient to save money, but I don't really know how), it was not surprising to find none of the energy efficient technologies or behaviours correlated with the viewpoint. The only questionnaire item significantly correlated was the question relating to energy awareness ("how frequently do you think about your household energy?"). The positive correlation implies that households that very frequently think about their energy use, are also strongly associated with this viewpoint. This result is encouraging for retrofit policies, since it suggests that a segment of households want to be energy efficient and think about it often, but just don't know how to go about it. Hence, these households may benefit the most with information and awareness campaigns that promote saving energy to save money with specific practical examples.

Cardiff Factors 3 (I'm consciously and actively energy efficient because it's plain common sense) and 4 (I don't really think about energy efficient behaviours, but I want my energy supply to be renewable and greener) represented a bi-polar viewpoint that was a specificity of Factor 1. Being a specificity implies general agreement with the main factor, but from different perspectives. Since Factor 3 and 4 also represented two poles from an original bi-polar factor, any correlations identified for Factor 3 would be reversed for Factor 4. No behaviours or demographics were associated with either factor, but both the installation of wall insulation and radiator thermostats were positively associated with Factor 3, and thereby negatively associated with Factor 4. These results reinforce the interpretation of the viewpoints, with Factor 3 representing a pro-active approach to energy efficiency, and Factor 4 a passive approach. It was interesting to find that even though Factor 3 represented a pro-active specificity of Factor 1 (environmental), that only the simplest and most cost effective retrofit measures were associated with it. This implies that even households that hold pro-active energy efficiency viewpoints based on environmental concern may still require tailored incentives to encourage the uptake of energy efficiency measures, i.e. even their stated pro-active and environmental beliefs may not be enough to motivate them to install retrofit measures. This research is in line with a meta-review that highlighted how pro-environmental behaviour can be predicted by multiple factors, and as such should not be simplified into a single diagram or framework [Kollmuss & Agyeman, 2002].

5.2.2 Manchester viewpoints and demographics

In Manchester, Factor 1 (I think about being energy efficient and the environment is important to me, but I reduce energy to save money) was a conflated version of Cardiff's Factor 1 and 2. Unlike Cardiff, it was not possible to cleanly separate the two axis (save the environment and save money) but they are both still present in Manchester as one Factor. No retrofit technologies were associated with the factor; however two full behaviours (desire, intention, and adoption) were correlated with the viewpoint: turning off appliances completely as opposed to leaving them on stand-by, and consciously using less energy. These behavioural associations were consistent with the factor's pro-active narrative towards energy efficiency.

Similarly consistent, the only behaviour associated with Manchester's Factor 2 (I don't really know how much energy I use, nor do I really care. I'm too lazy to change my lifestyle) was a negative correlation with turning off appliances completely. This factor highlighted households who may be deliberately wasting energy, instead of taking considered steps towards energy efficiency. Understanding how to target these households to encourage them to be energy efficient should be a vital component of any retrofit policy. This viewpoint exemplified households that were not motived to save money through energy efficiency, nor to conserve energy for environmental reasons. As such, targeting this viewpoint with traditional incentives (financial or social causes) may not be productive. Instead, the narrative suggests that these households may need to be reached at a more personal level, one that relates to their personal lifestyle and comfort. For this group, retrofit initiatives shouldn't be promoted as financial savings, rather as improvements to their convenience, comfort and lifestyle.

5.2.3 Comparisons between Manchester and Cardiff

Qualitatively, the two viewpoints within Manchester and Cardiff overlapped considerably, with the exception of Manchester Factor 2 (apathy). As such, this result may indicate that typical households in large UK cities share the common themes of viewing their energy consumption in the context of the environment and saving money. The differences between the two cities is that the apathetic viewpoint towards energy use was clearly identified in Manchester, while mostly missing from the Q Study in Cardiff. Conversely, in Cardiff the responsibility of delivering energy efficiency retrofits was split between individual households and the government. This distinction was conflated within Manchester Factor 1.

Since both Q Studies used the same statements, it was also possible to quantitatively examine the relationship between the Manchester and Cardiff results. This was accomplished by using each identified viewpoint (factor array) from Manchester and Cardiff as Q Sorts in a new Q Study. This technique, known as second-order factor analysis, yielded a secondary set of *super factors* that captured any relevant family associations or differences between the original viewpoints [Watts & Stenner, 2012]. Table 5.2 is the correlation matrix from the second-order factor analysis.

Table 5.2: Correlation matrix between Manchester and Cardiff viewpoints

Correlation matrix between Manchester and Cardiff viewpoints						
	Manchester 1	Manchester 2	Cardiff 1	Cardiff 2	Cardiff 3	Cardiff 4
Manchester 1	1.00	0.18	0.85	0.59	0.73	0.70
Manchester 2	0.18	1.00	0.36	0.09	0.01	0.45
Cardiff 1	0.85	0.36	1.00	0.45	0.68	0.84
Cardiff 2	0.59	0.09	0.45	1.00	0.44	0.52
Cardiff 3	0.73	0.01	0.68	0.44	1.00	0.48
Cardiff 4	0.70	0.45	0.84	0.52	0.48	1.00

The correlation matrix in Table 5.2 supports the interpretation of overlapping themes from Manchester and Cardiff. For example, the table demonstrated that Manchester Factor 1 was associated to some degree with all the Cardiff Factors. These associations reinforced the interpretation that Manchester Factor 1 was a conflation of the separate themes identified in Cardiff.

Conversely, Manchester Factor 2 was nearly independent apart from some association with Cardiff Factor 1 and 4. Those relationships were consistent with certain attributes identified in the Cardiff viewpoints. Specifically, even through Manchester Factor 2 represented a disinterested and apathetic approach towards household energy use, the viewpoint still exemplified a certain degree of environmental awareness, which was also strongly revealed in Cardiff Factor 1. However, unlike Cardiff Factor 1, that environmental awareness did not drive Manchester Factor 2 households towards appreciating energy efficiency. Similarly, Cardiff Factor 4 represented a passive approach to energy efficiency, with a minimal level of responsibility placed on the household. That passive approach and lack of responsibility were traits also shared with Manchester Factor 2. From the opposite pole, Manchester Factor 2 was strongly not associated with Cardiff Factors 2 and 3. Since Cardiff Factors 2 and 3 represented a pro-active desire to be energy efficient, the strong lack of correlation further reinforces the interpretation of the factors.

Analysing the resulting second-order factor matrix also supports these findings. Table 5.3 is the unrotated and varimax rotated second-order factor matrix. The factor extraction was done using centroid analysis.

Table 5.3: Second-order factor matrix between Manchester and Cardiff viewpoints

	Unrotated factors		Rotated factors	
	1	2	1	2
Manchester 1	0.9111	-0.3040	0.9495	0.1447
Manchester 2	0.2731	0.5226	0.0049	0.5896
Cardiff 1	0.9627	0.0952	0.8135	0.5234
Cardiff 2	0.5677	-0.1894	0.5917	0.0902
Cardiff 3	0.6484	-0.3172	0.7217	0.0132
Cardiff 4	0.8900	0.2662	0.6708	0.6425
Eigenvalues	3.3662	0.5819		
% expl.Var.	56	10	48	18

The loading values in Table 5.3 show that Manchester Factor 2 loads extensively on its own second-order factor, while all the remaining factors share a certain degree of each other's perspective, as shown in second-order Factor 1. This comparison identified that nearly all the viewpoints in each Q Study share a common thread. Indicating overall that the Q Study results in Manchester and Cardiff were similar.

5.2.4 Household shared viewpoints

For the Q-study, each participant was analysed independently, meaning that there was one Q-sort per person. However, the study did include multiple participants living in the same household, for example husband and wife, or mother and daughter. As such, the results for multi-participant households were examined to identify if they shared a common viewpoint, or held differing attitudes about energy use. In Cardiff, there were 6 multi-participant households, while in Manchester, there were 5. The participant relationships and factor association are shown in Table 5.4

Initial inspection revealed that 5 out of the 11 multi-participant households did not share a common viewpoint. Although, it is fair to consider Cardiff Factor 4 as a subset of Factor 1, since it was its specificity. Similarly, having no factor association does not necessarily imply a disagreement, but rather that the participant's Q-sort

Table 5.4: Multi-participant household relationships and factor associations

Location	Participant	Factor association	Relationship
Cardiff 1	C8	2	Mother (senior)
	C9	1	Daughter (late 30's)
Cardiff 2	C14	4	Wife
	C15	4	Husband
Cardiff 3	C17	1	Husband
	C18	1	Wife
Cardiff 4	C22	1	Husband
	C23	4	Wife
Cardiff 5	C25	none	Husband
	C26	1	Wife
Cardiff 6	C38	4	Daughter (late 20's)
	C39	1	Father (late 40's)
Manchester 1	M6	1	Wife
	M7	1	Husband
Manchester 2	M18	none	Daughter (late 20's)
	M19	none	Father (late 50's)
Manchester 3	M23	1	Wife
	M24	1	Husband
Manchester 4	M34	1	Wife
	M35	1	Husband
Manchester 5	M42	none	Husband
	M43	1	Wife

was conflated, i.e. loaded on multiple factors and was not used. Based on this interpretation, a second inspection of the data revealed that only one household had participants with substantially different viewpoints, Cardiff 1.

For household Cardiff 1, the elderly mother (C8) loaded significantly on Cardiff Factor 2 (I want to be more energy efficient to save money, but I don't really know how), while the adult daughter (C9) loaded on Cardiff Factor 1 (I think about being energy efficient for the environment and greater good). Looking more closely at the demographics revealed that the home was owned by occupant C8; therefore, perhaps the act of owning a home and its maintenance influenced participant C8's viewpoint towards conserving energy to save money. Although, interestingly the other two parent-child households did not show this pattern.

Overall, these results suggest that occupants in committed relationships within households may share a common viewpoint towards energy use. This insight is relevant for policy makers aiming to change household behaviour towards energy, as it indicates that a unified approach per household is justified; however, this result should be validated with a wider sample. Nevertheless, it was interesting to see that all wife/husband pairs shared very similar attitudes towards energy use.

5.2.5 Summary of household viewpoints toward energy consumption

In summary, this research identified the following three principal viewpoints that households have towards energy: energy in relation to the environment; energy in relation to money; and apathy. Naturally, these viewpoints are not mutually exclusive nor indivisible; they are summaries that contain subtle nuances that overlap.

Theoretically, the viewpoints and major sub-perspectives are shown in Figure 5.11. The overlaps underscore insights from the second-order factor analysis.

The results were not counter intuitive, households think about energy in terms of money, the environment, or don't care; yet the benefit of this research was that it was able to provide robust evidence to support such anecdotal experience. Similarly, this research was able to distil the 'noisy' subjective discourse about household energy into succinct and useful summaries. As such, these Q-studies provided

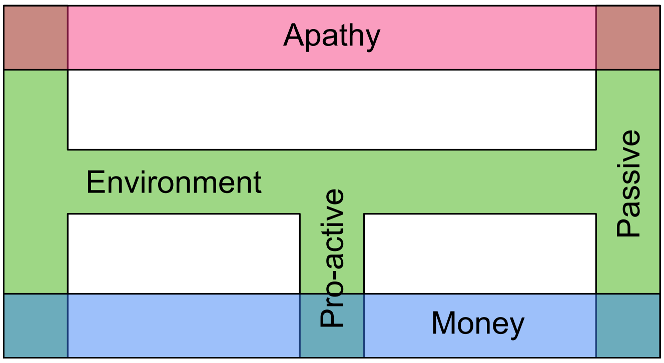

Figure 5.11: Cardiff and Manchester representation of viewpoints

rigorous and empirical results that policy makers and retrofit professionals can apply to improve the energy performance of the built environment. Specific guidance for each viewpoint is discussed below.

The environment

Even though the narratives of Cardiff Factor 1 and Manchester Factor 1 included a strong sense of environmental responsibility, they also revealed that an environmental conscious alone was not enough to consistently spur energy efficient behaviours or the adoption of energy efficiency measures. For example, in Manchester Factor 1 saving money was identified as the primary motivation despite a strong sense of environmental obligation. As such, it is recommended that public information campaigns that highlight environmental or green issues also promote secondary motivations to encourage the adoption energy efficient technologies/behaviours. This research tentatively indicated that simply promoting a public environmental conscious may not be enough to change home retrofit choices.

Saving money

Saving energy to reduce costs is an expected and standard motivation to be energy efficient. However, the desire to save money does not necessarily imply that households know which actions to take, as per Cardiff Factor 2 (I want to be more energy efficient to save money, but I don't really know how). As such, more targeted information/awareness campaigns to promote energy efficient retrofits and behaviours are needed alongside the simple cost savings message. For example, the narrative of Cardiff Factor 2 revealed that even though households with this viewpoint want to conserve energy to save money, they prefer to still heat the whole home instead of just occupied rooms. Therefore, it is recommended that as well as promoting the monetary savings of specific energy efficiency measures/behaviours, information campaigns also include the costs of inefficient behaviours or poor performing technology. Highlighting costs as opposed to savings takes advantage of behavioural economic evidence that losses or disadvantages have greater impact on preferences than gains or advantages [Tversky & Kahneman, 1991].

Apathy

Most of the identified viewpoints expressed a clear opinion about energy use in the home, but Manchester Factor 2 (I don't really know how much energy I use, nor do I really care. I'm too lazy to change my lifestyle) highlighted that some households are naturally apathetic towards energy issues. Encouraging households that hold this viewpoint to adopt energy efficient retrofits or behaviours may be a significant challenge, considering they may not be directly motivated by traditional incentives. Instead, two approaches are recommended. The first is to promote energy efficiency retrofits as an improvement in convenience or lifestyle, opposed to cost savings or environmental reasons. For example, offering a loft clearance service alongside loft insulation to make it more convenient may help its adoption, even if the clearance service is offered at retail price. The second approach is to not target these households directly, but instead focus on improving the efficiency of the overall energy supply system, such as de-carbonising the grid. Systematic changes to the overall system may not change the energy demand of these households, but it will at least reduce their impact.

5.2.6 Limitations of the Q Study

The Q Studies in Manchester and Cardiff investigated temporal and contextual dependent data, i.e. subjective viewpoints toward energy consumption. As such, the results were limited to the *here and now*, and may not necessarily be applicable in different circumstances, similar to the thematic analysis for motivations and barriers. For example, there may be substantial differences between how households in the UK or the USA view their own energy use. Even within the UK, viewpoints may vary between rural and urban communities. However, Q Methodology does not aim for generalisability in a quantitative sense, rather it excels at investigating a subjective topic within a specific context. In this case, the scope of the study was limited to typical households in Manchester and Cardiff. The overlapping results between Manchester and Cardiff suggest that the identified viewpoints may also be applicable to other large UK cities, but further research is necessary to confirm this hypothesis.

Paralleling the thematic analysis, the Q Studies also did not investigate the prevalence or representativeness of the viewpoints. Instead, the aim was to encapsulate the subjective viewpoints of households into functional narratives to be further explored by researchers, policy makers, and retrofit professionals. In order to investigate the prevalence of each viewpoint, a secondary study employing a traditional questionnaire can be used with a larger sample size [Danielson, 2009].

Another important consideration is how to scale up these household results to the neighbourhood or city-level. Meeting the challenge of improving the energy performance of the UK built environment requires a coordinated city level approach, as opposed to piecemeal retrofits [Dixon & Eames, 2013; Kelly, 2009, 2010]. Therefore, while this research focused on identifying household viewpoints towards energy consumption, further research can extend these results by investigating how these viewpoints intersect in a neighbourhood or larger community.

5.3 Policy implication of results

5.3.1 National policy

Nationally, there are a range of policies designed to encourage domestic retrofitting and the uptake of energy efficiency measures. The three most significant for ordinary households is the Green Deal, the solar energy Feed-In Tariff, and the Renewable Heat Incentive. Among these, the Green Deal is the flagship policy designed to encourage household retrofits and improve energy efficiency. However, despite 38,259 Green Deal assessments within approximately the first quarter of the policy's introduction, only 245 households signed up to the scheme [Department of Energy and Climate Change, 2013b]. Conversely for low-income households, provisional figures show that there were 81,798 measures installed under the Energy Company Obligation (ECO) scheme. This discrepancy may be due partly because households are not yet comfortable with the home loan finance structure introduced by the Green Deal, or a lack of accredited installers; as opposed to ECO, that is a standard subsidy from energy suppliers given directly to customers for their purchase of energy efficiency measures.

Supporting the Green Deal and ECO are the solar Feed-In Tariff and the Renewable Heat Incentive, that specifically offer subsidies to install renewable or low-carbon domestic energy generation (excluded in the Green Deal). Considered together, these policies provide a comprehensive financial incentive for UK households to retrofit their homes. However, as demonstrated in the first quarter uptake figures, there is a large opportunity to increase or accelerate the adoption rate of the Green Deal, the UK's flagship retrofit policy. Therefore, based on the results of this research, specific recommendations are presented to improve the uptake of the Green Deal and thereby the energy efficiency of the domestic built environment.

5.3.2 Manchester city policy

Although national policies apply to all regions in the UK, some local councils are also in the process of tailoring their own area's strategy to the initiatives. In Manchester, the local council formed a working group in 2013 to develop a neighbourhood-level housing retrofit plan that maximises ECO and Green Deal opportunities, with the aim of publishing a final plan in 2014 [Manchester City Council, 2013a]. Supporting the working group, is a set of partnerships the council established with third sector organisations, private landlords, registered Green Deal providers, and universities. These partnerships were developed to coordinate communication about the Green Deal and develop a citywide training plan for contractors, supply chain, and retrofit professionals [Manchester City Council, 2013a]. For example, the ‘Get Me Toasty’ campaign based on ECO provides funding for home energy efficiency improvements to vulnerable and low-income households [Manchester City Council, 2013b]. The scheme is a partnership between the Greater Manchester local authorities and delivery partners Dyson Energy Services, Carillion Energy Services and Forrest [Manchester City Council, 2013b].

The emergent viewpoints from the Manchester Q-study indicated that households think about energy in terms of saving money, or are generally apathetic. While it is not possible to fully generalise the results to all of Manchester, the Q-study viewpoints provided an insight into prevailing attitudes in Manchester for average neighbourhoods. As such, the Manchester City Council should align their promotion of retrofitting with saving money and specifically address household apathy in their neighbourhood-level housing retrofit plan. Household apathy is particularly important to overcome in order for national policies such as the Green Deal to be effective.

Compounding the challenge is the result that no specific motivation was associated with Manchester. Therefore, based on the Q-study viewpoints, retrofits should be promoted as a way to save money and enhance lifestyle or comfort. The latter message may help with apathetic households. On the other hand, multiple retrofit barriers were associated with Manchester over Cardiff, they were: beliefs, cost, institutional, and personal behaviour. The diverse range of barriers highlights the complexity of retrofitting in Manchester, but are in line with some of the Q-study results. For example, promoting retrofitting as a lifestyle enhancement may not only target apathetic households, but also homes that see their personal behaviour as a barrier. Likewise, the Greater Manchester local authorities should investigate further why typical households in their areas were associated with institutional barriers, such as planning regulation, versus households in Cardiff. These results illuminate possible policy initiatives that the Greater Manchester local authorities should investigate further.

5.3.3 Cardiff city policy

In Cardiff, the retrofit strategies are mostly driven by Wales wide initiatives instead of local council teams. For example, Arbed (meaning ‘to save’ in Welsh) is a strategic energy performance investment programme introduced by the Welsh Government to improve the energy efficiency of social housing and deprived areas of Wales [Welsh Government, 2013]. Phase two started in May 2012 and is partly funded by ECO and the European Regional Development Fund (ERDF) [Welsh Government, 2013]. Similarly, Warm Wales is a community interest company working in partnership with Npower and local authorities to use government grants to also deliver affordable warmth projects to vulnerable communities in Wales [Warm Wales, 2013].

Within Cardiff itself, the local council adopted a Cardiff Housing Strategy and Affordable Warmth Strategy for 2012-2017, which set out the strategic direction for housing provision and services [Department of Energy and Climate Change, 2013b]. However, while the strategies broadly outline Cardiff's commitment to reduce fuel poverty and improve the energy efficiency of the built environment, they do not outline any specific city-wide retrofit initiatives. As such, an opportunity exists for Cardiff Council to use the results from this research to help tailor a more targeted retrofit strategy.

The results from the Q study indicated that while Cardiff households may have varied motivations to conserve energy, all the emergent viewpoints contained an element of environmental awareness. If further research confirms a heightened environmental conscious in Cardiff, then future retrofit strategies may benefit by including an element of environmental protection. One possible explanation for this common thread among viewpoints may be because the long standing controversy surrounding the proposed Severn Barrage tidal power scheme. The scheme refers to a range of ideas for building a barrage to capture tidal power in the Severn tidal estuary. Such a barrage would contribute to the UK's energy and climate objectives; however the latest proposal failed to demonstrate economic, environmental and public acceptability [Energy and Climate Change Committee, 2013]. This hypothesis is supported by interview transcripts in Cardiff that highlight multiple instances of the term 'water/tidal energy'.

One approach to combine retrofitting with environmentalism for Cardiff may be to use their 'One Planet City' vision as a platform to promote domestic retrofitting [Cardiff Council, 2012a]. However, since no specific motivations were associated with Cardiff, it is important to design multi-faceted incentives, that promote retrofitting to save money, save the environment, and save resources/energy.

From a barrier perspective, the one consistent barrier associated with Cardiff over Manchester was the property itself. This barrier encompassed the sub-barriers of the physical property, and conservation & heritage, i.e. limitations that the property itself imposes on occupants (example loft space), and planning issues associated with listed buildings conservation areas. To help overcome this barrier, Cardiff Council should examine its conservation & heritage planning policies, and review the extent that building stock characteristics are hindering retrofit efforts. The aim should be to ensure that retrofit initiatives are not being unnecessarily impeded by onerous policy.

5.4 Addressing the Energy Efficiency Gap

The Energy Efficiency Gap is a complex phenomenon resulting in a shortfall between the full potential and realised adoption of energy efficiency measures in the UK. As such, addressing this gap is an important step towards improving the energy performance of the UK's built environment. Since this gap is conflated by multiple themes, an inter-disciplinary research approach was adopted that examined the interaction between social and technical factors likely contributing to the gap. This research first defined the phenomenon using a theoretical model (Figure 3.4) and followed by illuminating multiple areas within the model; specifically the barriers and motivations to retrofitting, as well as the viewpoints towards energy use and energy efficient behaviours. The results were presented individually and extended by examining cross-correlations and associations with demographics.

Based on the conducted research, Figure 5.12 highlights how the results apply to each of the model areas, specifically: cognitive norms (e.g. beliefs, understandings); material culture (e.g. technologies, building form); energy practices (e.g. activities, processes); motivations; and barriers.

The theoretical model presented in Figure 5.12 and the results underpinning

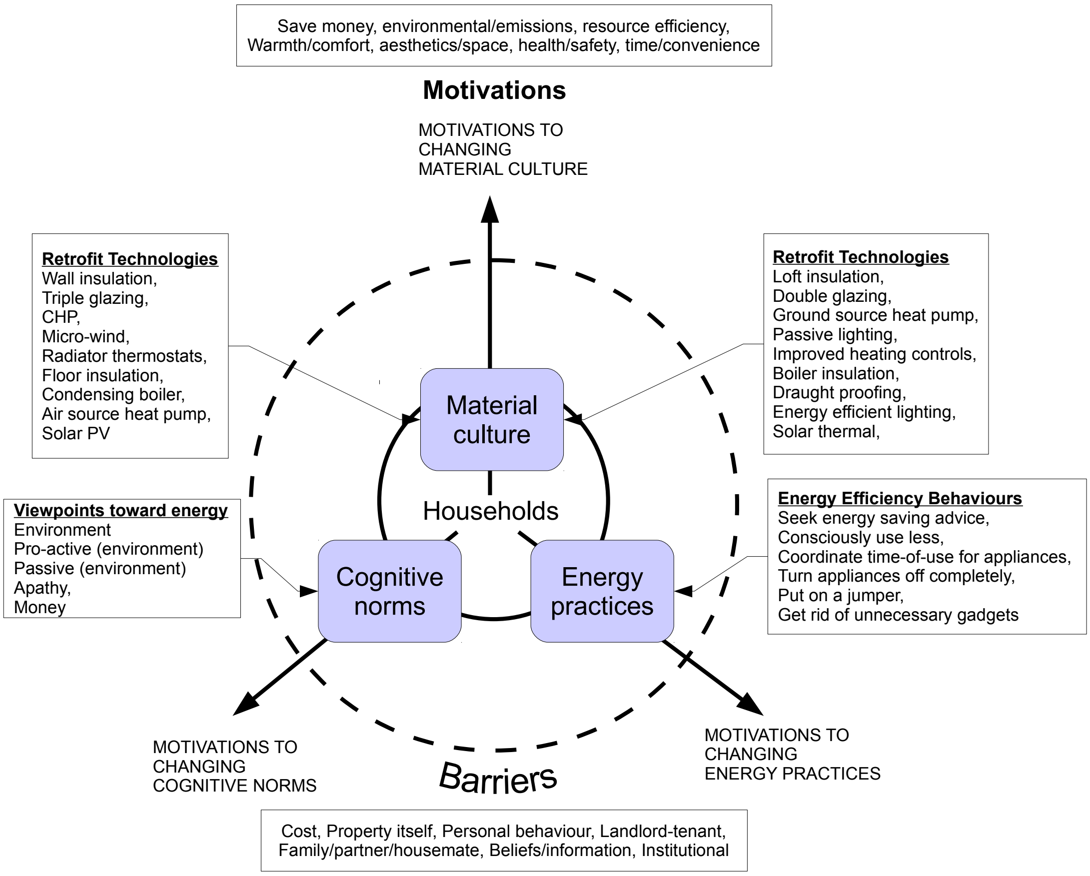

Figure 5.12: Results within theoretical research

it provide a useful roadmap to help policy makers and retrofit practitioners address the Energy Efficiency Gap. Naturally, the results were not meant to be fully exhaustive; rather they represented the outcomes of specific research methods. Future research using different methods and perspectives may illuminate further facets of the model.

Since the results of this research were exploratory, it was not possible to quantitatively measure the prevalence of the identified motivations, barriers, or viewpoints. As such it was also difficult to gauge the relative importance of each dimension within the model. Nevertheless, this research was able to empirically identify the substantial dimensions, in order to create a practical framework that policy makers and retrofit professionals can use to improve the energy performance of the built environment. Similarly, the model and results provide the foundations and guidelines for future quantitative studies to build on. Finally, such a framework also facilitates the discussion of practical solutions to the Energy Efficiency Gap, which by itself is a complex and opaque phenomenon.

6 | Conclusion

This chapter summaries the overall research project, starting with the rationale and original research questions, followed by the results and discussion. The implications of the results and recommendations for policy makers and retrofit professionals are also presented; as well as future research guidance and final concluding remarks.

As part of the EPSRC and SUE research programme, *"Re-Engineering the City 2020-2050 Urban Foresight and Transition Management (RETROFIT 2050)"*, the primary aim of this thesis was to identify UK household perspectives towards energy efficient technologies and behaviour. This was achieved by investigating the motivations and barriers to adopting energy efficient technologies, as well as identifying household viewpoints towards energy and linking them to retrofit technology and energy efficiency behaviour preferences. The overarching rationale was to better understand and recommend ways to address the Energy Efficiency Gap, in order to improve the adoption of domestic retrofit measures. In OECD countries, the energy loss due to the Energy Efficiency Gap is estimated at 30% of the total potential energy savings of the measures. This is particularly important in the UK, given the heating and moving of air and water, and the use of appliances in existing homes accounts for 27% of all the anthropogenic carbon emissions, and an estimated 72% of household energy is used for space and water heating. Therefore addressing the Energy Efficiency Gap and retrofitting the UK domestic built environment presents an outstanding opportunity to cut CO_2 emissions, reduce national energy demand, and improve building performance.

In order to improve our understanding of the Energy Efficiency Gap, this research adopted a mixed-method research methodology that employed qualitative and quantitative techniques. Specifically by using a socio-technical two phase approach that considered retrofit social and technical factors together. The first phase of research applied thematic analysis and a modified chi-square test of association to investigate the barriers and motivations of retrofitting; while the second phase applied Q Methodology and a questionnaire to investigate household viewpoints towards energy use, and retrofit technology and energy efficiency behaviour preferences. All the research was conducted in typical neighbourhoods of Manchester and Cardiff, which are cities of interest because both are seeking to overcome recent industrial decline by regenerating and retrofitting their built environment.

In total, 8 barriers to retrofitting were identified, as well as 8 distinct motivations. The barriers and motivations included traditional monetary factors, but also many social factors, such as inter-occupant relationships and beliefs. The results highlighted the importance of applying an inter-disciplinary approach to improve the adoptions of retrofit measures. As such, a holistic analysis of the barriers, motivations and demographics revealed two consistent household profiles for interventions. The first profile was defined by currently single individuals earning less than £40k a year and living in apartments/flats, who were motivated to save resources and be more efficient out of general principle, but cited that the landlord-tenant/housing association was the main barrier preventing their adoption of energy efficiency measures. The second profile was defined by married/common-law individuals with incomes greater than £40k a year and living in semi/detached homes, who were motivated to save money, but reported that their physical property (either due to planning permission, age of home, space constraints, heritage, etc.) was the significant barrier preventing their adoption of energy efficiency measures.

Complementing this research, the Q study explored subjective viewpoints towards household energy consumption. The identified viewpoints were grouped along three broad themes: saving the environment; saving money; and apathy. Within the environmental axis, two bi-polar specificity viewpoints were also identified: taking an active approach to energy efficiency because that's the right thing to do; and taking a passive approach to being energy efficient but hoping that others will make the energy supply more efficient.

These viewpoints were anecdotally intuitive, but this research helped provide further empirical evidence required for policy making. The results between Manchester and Cardiff were compared, and while they were distinct perspectives, the substantial overlaps implied a common set of viewpoints for both cities. Similarly, multi-participant households tended to share the same viewpoint within this study, particularly husband and wife partnerships. Such agreement may seem counter-intuitive; however, perhaps underneath expected superficial disagreements, this result highlighted a shared set of core values within long term partnerships. This result should be further explored in a wider explanatory study.

These results were placed within a theoretical model that provided a framework to improve our understanding and address the Energy Efficiency Gap. The overall aim was to demonstrate a socio-technical approach to improve the uptake of future retrofit programmes, in order to help reduce domestic energy demand in the context of large UK cities. Based on the research results, the next section synthesises the guidance and recommendations for policy makers, and retrofit professionals.

6.1 Recommendations

The following guidance and recommendations are presented based on the results of the barrier/motivation research, viewpoints towards household energy use, and their associations with specific demographics. Fundamentally, since this research was exploratory in nature, the proposed guidance should first act as signposts for future research, and then be tested against a national representative sample. Nevertheless, within the context of typical neighbourhoods in Cardiff and Manchester, the following recommendations apply.

6.1.1 Awareness/information campaigns

The results suggest that awareness/information campaigns to promote energy efficiency measures may be more effective by targeting woman and residents living in semi/detached dwellings. Using this insight, it is possible to specifically investigate what missing information women and semi/detached households would find most beneficial; thereby, improving the relevancy of overall awareness campaigns. This result highlights how energy efficiency awareness/information campaigns should be tailored and personalised for the appropriate segments.

6.1.2 Upfront cost and saving money

While standard economic models typically focus on the upfront cost of energy efficiency measures, this research found that this was not a significantly associated with any demographics, apart from Manchester instead of Cardiff. That is not to say the initial purchase price of retrofit measures is not a substantial barrier, just that it may apply equally between all household demographics. In order to better understand why the upfront cost was associated with only Manchester and not Cardiff, local policy makers should compare the general prices of retrofit measures between the two regions for potential insights.

Equally on the other side of the coin, saving money was identified as a motivation to install retrofit measures, as well as a viewpoint that households hold towards their energy consumption. This research suggests that simply promoting retrofits as the 'right thing' to do for environmental or social reasons may not be enough to change home retrofit choices. Instead, retrofit programmes should also promote energy efficiency measures as a way to save money.

Specific demographics associated with saving money were households with a total income of greater than £40k, married/common-law individuals, and semi/detached homes. However, even though households in general want to save money through energy efficiency retrofits, that is not always reflected in their energy practices, for example heating the whole home instead of just occupied rooms. Therefore, it is recommended to also include the costs of inefficient behaviours alongside promoting the monetary benefits of retrofit measures; since behaviour is likely to be affected more by loss aversion than potential gains.

6.1.3 Inter-occupant relationships

This research highlighted how inter-occupant relationships are an important social factor affecting the adoption of energy efficiency measures, and as such should not be ignored by technical professionals. Promoting retrofit measures to the primary individual responsible for household finances may not be enough; other individuals, especially partners in committed relationships and multi-tenanted homes with 3 or more residents, should also be engaged. As such, retrofit programmes should be designed from the onset to include a household stakeholder engagement component. Involving multiple residents may improve the adoption of such programmes.

Similarly, this result may also extend to neighbourhoods and larger communities. If the aim of government is to retrofit the built environment at a city scale, then larger stakeholder engagement groups within neighbourhoods and communities may help improve the effectiveness of the programme.

6.1.4 Landlord-tenant split incentive and institutional change

The UK Green Deal programme attempts to address the landlord-tenant split incentive with a novel financial scheme, where the cost of the retrofit measure is recouped through a charge of instalments on the household energy bill regardless of tenancy. Currently, all households are targeted; however this research suggests that the adoption of the Green Deal may be improved by specifically targeting single tenants; individuals with a degree or more of educations; and flats and terraced households. However, as well as providing a monetary incentive, policy makers should also address other important institutional barriers that may affect the adoption of the Green Deal, and retrofit measures in general. For example, mistrust in government, energy companies, and contractors.

Overcoming household mistrust towards energy/government institutions is not trivial; nevertheless it may be assuaged by using an established accreditation scheme or set of standards. This research also revealed that this type of mistrust is strongly associated with Manchester, but not Cardiff. Therefore, local policy makers and utilities within Manchester may benefit by comparing their institutions with those in Cardiff. Such city comparisons may lead to the identification of policy differences and/or practices which may help Manchester overcome established household mistrust and improve the uptake of energy efficiency measures.

6.1.5 Personal behaviour, values, attitude and thermal comfort

This research identified a wide range of motivations, barriers, and viewpoints relating to personal behaviour that may sometimes come in conflict with energy efficiency. For example: apathy; increased expectation of thermal comfort; convenience; and laziness.

Changing household attitudes and values towards energy was beyond the scope of this research; however, such a change may be required to produce the needed step-change in retrofitting. Fundamentally, households that don't care about energy use, or admit to being too lazy to change, may not be easily motived to adopt retrofit measures with traditional incentives. Instead, two possible approaches are recommended. The first is to promote retrofits as an improvement in convenience or lifestyle, instead of cost savings or environmental reasons; and the second recommendation is to improve the overall efficiency of the energy supply system. Systematic changes to the overall system, such as de-carbonising the grid, may not change the energy demand of these households, but it will at least reduce their impact.

6.1.6 Physical property and aesthetics

Many of the recommendations to overcome the Energy Efficiency Gap deal specifically with household occupants; however our material culture is also a substantial factor, i.e. our physical homes. The results imply that interventions that focus on the physical property and/or planning issues should specifically target individuals who are married/common-law, individuals with a degree or more of higher education, and owner-occupied homes. Systematically, it is possible to mandate an upgrade of the built environment by legislating stricter energy efficiency standards. Although, this approach may be too onerous for households, and take too long. Instead, a simpler recommendation is to tie the house Council Tax or Stamp Duty to its energy performance. This can be accomplished by using the existing Energy Performance Certificates (EPC). For example, homes that are rated B or above can be given a Council Tax discount, while homes rated D and below can be fined.

In 2011, only approximately 15% of homes were rated C or above [Department for Communities and Local Government, 2013b]. While this solution is practically simple to implement, it may not be politically feasible given the contentious nature of Council Taxes.

The result also showed that certain households were motivated to adopt energy efficiency measures or prevented because of the aesthetics of the home. As such, visible energy efficiency measures, such as double glazing or micro-generation, should be developed to meet households' aesthetic requirements, alongside traditional monetary expectations. To this effect, engineers and architects should work closely to develop retrofit measures that not only meet practical requirements, but also subjective demands.

In summary, these recommendations are aimed at policy makers, academics, and retrofit industry professionals who are working to improve the effectiveness of future retrofit interventions, and reduce the Energy Efficiency Gap.

6.2 Further research

With respect to further research, two possible areas to address are outlined below. The first suggests ways that further research can overcome the limitations of this work, while the second area highlights ways to build on the research and extend the results to different contexts.

6.2.1 Overcoming limitations

The methodology used by this research emphasised identifying empirical barriers, motivations, and viewpoints to installing retrofit measures, as opposed to quantifying their prevalence. As a result, a limitation of this research was that the prevalence of the identified barriers, motivations, and viewpoints within the general public was unknown. In order to address this limitation and refine the recommendations presented in this research, further research should carry out a secondary prevalence study with a much larger sample size. The aim of the secondary study should be to determine the extent to which the general public identify with each barrier, motivation, or viewpoint. Measuring and quantifying this prevalence would enable policy makers and retrofit professionals to prioritise and more accurately estimate the impact of addressing each barrier, motivation, or viewpoint.

Another limitation that can be addressed by further research is to examine the generalisability of the results. Specifically, since the participant samples for the interviews and thematic analysis were only representative of Manchester and Cardiff, caution should be applied before generalising the results to other UK cities. In order to address this limitation and improve the reliability and validity of the results, further studies should replicate this research design in other UK urban centres. The results of such studies would strengthen the recommendations of this research and improve overall generalisability.

Similarly, to test the reliability of the results over time, further research should use the same demographic variables and sampling criteria to repeat the study and contrast their findings with this research. Such repeated studies would help determine the stability over time of the identified subjective motivations, barriers, and viewpoints.

Finally, many methods exist that can be used to measure attitudes or other subjective variables, each with their own strengths and weaknesses. As such, in order to improve the validity of the identified subjective factors, future studies can adopt the same overall research design, but use different methods to investigate the motivations, barriers, and viewpoints towards energy retrofits. Those results would help triangulate the findings from this research and improve the overall validity.

6.2.2 Extending the results

Retrofitting UK homes at the city scale presents an excellent opportunity to help improve the energy performance of the domestic built environment, energy security, and reduce national GHG emissions. However, the scale of the challenge also presents substantial obstacles, one of which is the Energy Efficiency Gap.

The complexity of the Energy Efficiency Gap, with inter-linked social and technical factors, naturally lends itself to inter-disciplinary study. As such, this research used social science methods in an engineering context to investigate the motivations, barriers, and viewpoints that households hold towards their energy consumption and retrofit technologies. The hope is that this research helps policy makers and retrofit professionals better address the Energy Efficiency Gap; however, a single study in isolation is insufficient. Instead, future research should extend these results to improve their applicability and encourage the effective city-wide retrofit of homes. For example, this research can be repeated in other large urban cities, such as London or Edinburgh, to compare and contrast results. Similarly, future research can also rigorously test possible interventions that either address the identified barriers or encourage the motivations. For example, by using a randomised controlled trial, it would be possible to test the effectiveness of tailored retrofit interventions that target specific demographic profiles outlined in this research. Marketing research can also further build on the identified viewpoints through focus groups, and more intensive observational studies. Such research can help better define the population segmentation with respect to views on energy use, and provide a richer interpretation of the context.

From an engineering perspective, this research can support the design of technical retrofit measures by highlighting their link to social factors, such as subjective viewpoints. Future organisational and project management studies can build on this research to investigate new pathways for city-wide retrofits. By further building on the links between technical retrofit measures and social factors, is is possible to research new operational strategies that help policy makers and retrofit professionals implement systematic retrofits.

To widen the research applicability, further research can use the same design but target atypical demographics, such as fringe neighbourhoods in Cardiff and Manchester. The findings from such studies would complement the Q Methodology results from this research and allow for similarities/differences to be identified between samples. Together, the investigation of viewpoints in typical neighbourhoods, as well as atypical communities, would allow for a more holistic interpretation of the data and improve the applicability of the recommendations.

Another area for extension is to investigate how these results for households can be scaled up to encourage city-wide retrofitting. Such systematic city-level action, as opposed to piecemeal upgrades, is required for the step-change needed to improve the built environment's energy performance. A natural extension may be to repeat the research, but use a wider unit of study such as neighbourhoods or post codes, instead of individual households.

Beyond the UK, it would also be interesting to determine what differences/similarities exist between the factors affecting the Energy Efficiency Gap in the UK with other developed OECD countries. Despite the cultural differences, extending this research to other countries may generate novel insights still applicable to the UK.

Going forward, this research created another stepping stone on the journey towards energy efficiency. One that relied on previous research, while also creating a new footing for the way forward. It is this researcher's hope that future studies will build on these results and extend the investigation into overcoming the Energy Efficiency Gap.

6.3 Final reflections

In conclusion, this research identified household perspectives towards energy use (motivations, barriers, and viewpoints), and linked them to retrofit technology and energy efficiency behaviour preferences. The academic journey taken to obtain these results, and ensuing discussions were of great personal satisfaction. As a Chartered Engineer, the emphasis of my training centred on gathering and making decisions based on rigorous objective quantitative evidence. Such good practices are essential for the reliable design of mechanical, electrical, and civil engineering systems; however, when technical designs escape the lab and interact with society, they often encounter a new set of constraints, such as political systems and social values. Anecdotally, quantitatively trained engineers are quick to dismiss designing for these subjective factors, since they are either outside the scope of the problem or considered irrational. However, I consider engineering to be an applied science, not simply in the application of design, but also in the application within society. It is my opinion that in order for engineering projects to fully succeed, they must not only consider the technical constraints, but also adopt a sustainable and holistic approach to the design.

As well as answering the research questions, my personal motivation to undertake this PhD was to learn how to conduct rigorous research, grow as a professional, and broaden my understanding of engineering applications within society. Using these lessons, I hope to continue contributing to academic scholarship, and help expand the positive impact that engineers have on society.

References

ABRAHAMSE, W. & STEG, L. (2009). How do socio-demographic and psychological factors relate to households' direct and indirect energy use and savings? *Journal of Economic Psychology*, **30**, 711–720. 32, 34, 39, 45, 92, 136

ABRAMOVICH, F. & BENJAMINI, Y. (1996). Adaptive thresholding of wavelet coefficients. *Computational Statistics & Data Analysis*, **22**, 351–361. 74

AGRESTI, A. & LIU, I.M. (1999). Modeling a categorical variable allowing arbitrarily many category choices. *Biometrics*, **55**, 936–943. 54

AJZEN, I. & MADDEN, T.J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of experimental social psychology*, **22**, 453–474. 60

ALLCOTT, H. & MULLAINATHAN, S. (2010). Behavior and energy policy. *Science*, **327**, 1204 –1205. 5, 31, 32, 38

ANDERSON, R.W. & LIPSEY, M.W. (1978). Energy conservation and attitudes toward technology. *Public Opinion Quarterly*, **42**, 17–30. 45

ARDENTE, F., BECCALI, M., CELLURA, M. & MISTRETTA, M. (2010). Energy and environmental benefits in public buildings as a result of retrofit actions. *Renewable and Sustainable Energy Reviews*, **In Press, Corrected Proof**. 24

BARKER, T., EKINS, P. & FOXON, T. (2007). The macro-economic rebound effect and the UK economy. *Energy Policy*, **35**, 4935–4946. 35

BARR, S., GILG, A.W. & FORD, N. (2005). The household energy gap: examining the divide between habitual- and purchase-related conservation behaviours. *Energy Policy*, **33**, 1425–1444. 129

Barry, J. & Proops, J. (1999). Seeking sustainability discourses with q methodology. *Ecological Economics*, **28**, 337–345. 56, 59

Baruch, Y. (1999). Response rate in academic studies-a comparative analysis. *Human Relations*, **52**, 421–438. 76

Baruch, Y. & Holtom, B.C. (2008). Survey response rate levels and trends in organizational research. *Human Relations*, **61**, 1139–1160. 76

BDO U-Value (2011). Understanding U-Values. http://www.builddeskonline.com/sw56126.asp. 18

Becker, L.J., Seligman, C., Fazio, R.H. & Darley, J.M. (1981). Relating attitudes to residential energy use. *Environment and Behavior*, **13**, 590–609. 45

Behavioural Insights Team (2012). Annual update 2011-2012. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/83719/Behavioural-Insights-Team-Annual-Update-2011-12_0.pdf. 83

Bell, M. & Lowe, R. (2000). Energy efficient modernisation of housing: a UK case study. *Energy and Buildings*, **32**, 267–280. 23

Bernstein, L., Bosch, P., Canziani, O., Chen, Z., Christ, R., Davidson, O., Hare, W., Huq, S., Karoly, D., Kattsov, V. *et al.* (2007). Climate change 2007: Synthesis report. an assessment of the intergovernmental panel on climate change. Tech. rep., Technical report, Intergovernmental Panel on Climate Change, 2007. 1. 25

Bilder, C.R. & Loughin, T.M. (2004). Testing for marginal independence between two categorical variables with multiple responses. *Biometrics*, **60**, 241–248. 53

Bilder, C.R., Loughin, T.M. & Nettleton, D. (2000). Multiple marginal independence testing for pick Any/C variables. *Communications in Statistics - Simulation and Computation*, **29**, 1285–1316. 54, 55

Black, I. (2006). The presentation of interpretivist research. *Qualitative Market Research: An International Journal*, **9**, 319–324. 50

Black, J.S., Stern, P.C. & Elworth, J.T. (1985). Personal and contextual influences on househould energy adaptations. *Journal of Applied Psychology*, **70**, 3–4. 127

BLACKWELL, A. (2013). Guidance on involvement of human participants in technology research. https://camtools.cam.ac.uk/access/wiki/site/e30faf26-bc0c-4533-acbc-cff4f9234e1b/research20guidance.html. 76

BLUMSTEIN, C., KRIEG, B., SCHIPPER, L. & YORK, C. (1980). Overcoming social and institutional barriers to energy conservation. *Energy*, **5**, 355–371. 42

BOARDMAN, B. (2012). Achieving zero: delivering future-friendly buildings. Tech. rep. 19

BOARDMAN, B., DARBY, S., KILLIP, G., HINNELLS, M., JARDINE, C.N., PALMER, J., SINDEN, G., LANE, K., LAYBERRY, R. & WRIGHT, A. (2005). 40% house. Tech. rep. 11, 62, 82

BOYATZIS, R.E. (1998). *Transforming Qualitative Information: Thematic Analysis and Code Development*. Sage Publications, Inc, 1st edn. 52

BRANCO, G., LACHAL, B., GALLINELLI, P. & WEBER, W. (2004). Predicted versus observed heat consumption of a low energy multifamily complex in switzerland based on long-term experimental data. *Energy and Buildings*, **36**, 543–555. 27

BRAUN, V. & CLARKE, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, **3**, 77–101. 52

BROWN, M. (2004). Illuminating patterns of perception: An overview of q methodology. 57

BROWN, S. (1980). *Political Subjectivity: Applications of Q Methodology in Political Science*. Yale University Press. 56, 57, 68, 69, 76, 97, 98

BUILDING ACT (1984). Building act 1984. http://www.legislation.gov.uk/ukpga/1984/55. 18

BURGESS, J. & NYE, M. (2008). Re-materialising energy use through transparent monitoring systems. *Energy Policy*, **36**, 4454–4459. 34, 35, 95, 125

BUSINESSGREEN (2011). CBI: green deal a lame duck without business buy-in. http://www.businessgreen.com/bg/news/2026244/cbi-green-deal-lame-duck-business. 29

CAIRD, S., HERRING, H. & ROY, R. (2007). Can consumers save energy? results from surveys of consumer adoption and use of low and zero carbon technologies. La Colle sur Loup, Côte d'Azur, France. 127

CAIRD, S., ROY, R. & HERRING, H. (2008). Improving the energy performance of UK households: Results from surveys of consumer adoption and use of low- and zero-carbon technologies. *Energy Efficiency*, **1**, 149–166. 43, 87, 91, 125

CALDERDALE COUNCIL (2010). A brief history: Building regulations. http://www.calderdale.gov.uk/housing/buildingcontrol/buildingregulations/build-history.html. 18

CARDIFF COUNCIL (2012a). One planet city strategy. www.cardiff.gov.uk/template/oneplanet/idea1/Oneplanetliving_eng.pdf. 155

CARDIFF COUNCIL (2012b). Private sector housing policy 2012-2014. http://www.cardiff.gov.uk/objview.asp?object_id=24931. 20

CARIFIO, J. & PERLA, R.J. (2007). Ten common misunderstandings, misconceptions, persistent myths and urban legends about likert scales and likert response formats and their antidotes. *Journal of Social Sciences*, **3**, 106–116. 74

CARLSSON-KANYAMA, A., LINDÉN, A.L. & ERIKSSON, B. (2005). Residential energy behaviour: does generation matter? *International Journal of Consumer Studies*, **29**, 239–253. 127

CHAPPELLS, H. & SHOVE, E. (2005). Debating the future of comfort: environmental sustainability, energy consumption and the indoor environment. *Building Research & Information*, **33**, 32–40. 43

CHOW, D.H. & LEVERMORE, G.J. (2010). The effects of future climate change on heating and cooling demands in office buildings in the UK. *Building Services Engineering Research & Technology*, **31**, 307–323. 19

CLINCH, J. & HEALY, J.D. (2000). Domestic energy efficiency in ireland: correcting market failure. *Energy Policy*, **28**, 1–8. 41

COMMITTEE ON CLIMATE CHANGE (2011a). Climate change act. http://www.theccc.org.uk/about-the-ccc/climate-change-act. 27

COMMITTEE ON CLIMATE CHANGE (2011b). Homes. http://www.theccc.org.uk/sectors/buildings-a-industry/homes. 27

CONFEDERATION OF BRITISH INDUSTRY (2007). Climage change: everyone's business - options for greenhouse gas reduction in the UK. http://www.mckinsey.com/en/Client_Service/Sustainability/Latest_thinking/Costcurves.aspx. 25

CROTTY, M. (1998). *The foundations of social research: meaning and perspective in the research process*. SAGE. 50

DANIELSON, S. (2009). Q method and surveys: Three ways to combine q and r. *Field Methods*, **21**, 219–237. 59, 152

DARBY, S. (2010). Smart metering: what potential for householder engagement? *Building Research & Information*, **38**, 442. 84, 136

DARNTON, A. (2008). GSR behaviour change knowledge review. *Practical guide: an overview of behaviour change models and their uses. Report for Government Social Research Unit. London, Centre for Sustainable Development, University of Westminster*. 32, 34, 39

DAVIDSON (BRE), P. (2009). Qualification of carbon emissions from the UK building stock. 23

DECADY, Y.J. & THOMAS, D.R. (2000). A simple test of association for contingency tables with multiple column responses. *Biometrics*, **56**, 893–896. 54

DEFRA (2007). Public understanding of sustainable energy consumption in the home. http://www.brooklyndhurst.co.uk/public-understanding-of-sustainable-energy-consumption-in-the-home-_50. 5, 13, 46

DEFRA (2008). A framework for pro-environmental behaviours. http://archive.defra.gov.uk/evidence/social/behaviour/. 5, 42, 46, 86

DENNIS, K.E. (1992). Commentary: looking at reliability and validity through q-colored glasses. *Operant Subjectivity*, **16**, 37–44. 76

Department for Communities and Local Government (2009). English house condition survey 2007 - headline report. http://www.communities.gov.uk/publications/corporate/statistics/ehcs2007headlinereport. 19

Department for Communities and Local Government (2011). Energy performance - planning, building and the environment. http://www.communities.gov.uk/planningandbuilding/sustainability/energyperformance/. 20

Department for Communities and Local Government (2013a). Approved document l - conservation of fuel and power. http://www.planningportal.gov.uk/buildingregulations/approveddocuments/partl/approved. 28

Department for Communities and Local Government (2013b). English housing survey: annual report on england's housing stock 2011. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/211324/EHS_HOMES_REPORT_2011.pdf. 165

Department of Energy and Climate Change (2011a). Feed-in tariffs. http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/feedin_tariff/feedin_tariff.aspx. 30

Department of Energy and Climate Change (2011b). Renewable heat incentive (RHI). http://www.decc.gov.uk/en/content/cms/meeting_energy/Renewable_ener/incentive/incentive.aspx. 31

Department of Energy and Climate Change (2012a). Feed-in tariffs scheme: government response to consultation on comprehensive review phase 2a. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/43085/5386-government-response-to-consultation-on-comprehensi.pdf. 30

Department of Energy and Climate Change (2012b). Housing energy fact file. https://www.gov.uk/government/publications/housing-energy-fact-file-2012-energy-use-in-homes. 5, 11, 12, 13, 14

Department of Energy and Climate Change (2012c). Standard assessment procedure (SAP). http://www.decc.gov.uk/en/content/cms/emissions/sap/sap.aspx. 72

DEPARTMENT OF ENERGY AND CLIMATE CHANGE (2013a). Energy consumption in the UK. https://www.gov.uk/government/publications/energy-consumption-in-the-uk. 14

DEPARTMENT OF ENERGY AND CLIMATE CHANGE (2013b). Green deal and energy company obligation (ECO): monthly statistics. https://www.gov.uk/government/organisations/department-of-energy-climate-change/series/green-deal-and-energy-company-obligation-eco-statistics. 153, 155

DEPARTMENT OF ENERGY AND CLIMATE CHANGE (2013c). An investigation of the effect of epc ratings on house prices. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/207196/20130613_-_Hedonic_Pricing_study_-_DECC_template__2_.pdf. 20

DIAZ-RAINEY, I. & ASHTON, J.K. (2008). Stuck between a ROC and a hard place? barriers to the take up of green energy in the UK. *Energy Policy*, **36**, 3053–3061. 41

DILLMAN, D.A., ROSA, E.A. & DILLMAN, J.J. (1983). Lifestyle and home energy conservation in the united states: the poor accept lifestyle cutbacks while the wealthy invest in conservation. *Journal of Economic Psychology*, **3**, 299–315. 129

DIXON, T. & EAMES, M. (2013). Scaling up: the challenges of urban retrofit. *Building Research & Information*, **41**, 499–503. 2, 5, 13, 152

DOWSON, M., POOLE, A., HARRISON, D. & SUSMAN, G. (2012). Domestic UK retrofit challenge: Barriers, incentives and current performance leading into the green deal. *Energy Policy*, **50**, 294–305. 86

DRUCKMAN, A. & JACKSON, T. (2008). Household energy consumption in the UK: a highly geographically and socio-economically disaggregated model. *Energy Policy*, **36**, 3177–3192. 46

DURNING, D.W. & BROWN, S.R. (2007). Q methodology and decision making. *Public administration and public policy*, **123**, 537–550. 67, 68

EDEN, S., DONALDSON, A. & WALKER, G. (2005). Structuring subjectivities? using q methodology in human geography. *Area*, **37**, 413–422. 69

EES (1998). International update on the status of energy labelling and MEPS. http://www.energyrating.gov.au/library/details1998-internatlabelreview.html. 35

ELTHAM, D.C., HARRISON, G.P. & ALLEN, S.J. (2008). Change in public attitudes towards a cornish wind farm: Implications for planning. *Energy Policy*, **36**, 23–33. 46

ENERGY AND CLIMATE CHANGE COMMITTEE (2013). A severn barrage? Tech. rep., House of Commons. 155

ENERGY SAVING TRUST (2009). Hard to treat homes. http://www.energysavingtrust.org.uk/business/Business/Housing-professionals/Interactive-tools/Hard-to-treat-homes. 13, 19

ENERGY SAVING TRUST (2013). Homes energy efficiency database. http://www.energysavingtrust.org.uk/Organisations/Government-and-local-programmes/Free-resources-for-local-authorities/Homes-Energy-Efficiency-Database. 24

ENGLISH HERITAGE (2007). Energy performance certificates for historic and traditional homes. http://www.english-heritage.org.uk/publications/energy-performance-certificates-historic-and-traditional-homes. 21

EURACTIV (2008). Deal secured on ambitious EU renewables law. http://www.euractiv.com/en/energy/deal-secured-ambitious-eu-renewables-law/article-177897. 28

FAIERS, A. & NEAME, C. (2006). Consumer attitudes towards domestic solar power systems. *Energy Policy*, **34**, 1797–1806. 46

FAIERS, A., COOK, M. & NEAME, C. (2007). Towards a contemporary approach for understanding consumer behaviour in the context of domestic energy use. *Energy Policy*, **35**, 4381–4390. 34

FEREDAY, J. & MUIR-COCHRANE, E. (2008). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods*, **5**, 80–92. 52

FISCHER, C. (2004). Who uses innovative energy technologies, when, and why? the case of fuel cell MicroCHP. http://www.tips-project.org/download/fischer_paris2004.pdf. 44

FITZMAURICE, J. (2005). Incorporating consumers' motivations into the theory of reasoned action. *Psychology and Marketing*, **22**, 911–929. 60

FRIEDMAN, K. & COOKE, A. (2012). Is UK planning a barrier to energy efficient heritage retrofit: a comparative analysis of a selection of london boroughs. In *Proceedings of Retrofit 2012*, Salford, UK. 82

FRIENDLY, M. (1994). Mosaic displays for multi-way contingency tables. *Journal of the American Statistical Association*, **89**, 190–200. 93, 125

FUERST, F. & MCALLISTER, P. (2011). The impact of energy performance certificates on the rental and capital values of commercial property assets. *Energy Policy*, **39**, 6608–6614. 20, 21

GOV.UK (2013a). Buying or selling your home. https://www.gov.uk/buy-sell-your-home/energy-performance-certificates. 20

GOV.UK (2013b). Feed-in tariffs scheme - increasing the use of low-carbon technologies - policies. https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/feed-in-tariffs-scheme. 30

GOV.UK (2013c). FIT generation statistics - statistical data sets. https://www.gov.uk/government/statistical-data-sets/feed-in-tariff-generation-statistics. 30

GOV.UK (2013d). Green deal: energy saving for your home or business. https://www.gov.uk/green-deal-energy-saving-measures/how-the-green-deal-works. 28, 29, 30

GOV.UK (2013e). Renewable heat incentive (RHI) - increasing the use of low-carbon technologies - policies. https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/renewable-heat-incentive-rhi. 31

GOV.UK (2013f). Standard assessment procedure - detailed guidance. https://www.gov.uk/standard-assessment-procedure. 18, 19

GROMET, D.M., KUNREUTHER, H. & LARRICK, R.P. (2013). Political ideology affects energy-efficiency attitudes and choices. *Proceedings of the National Academy of Sciences*, **110**, 9314–9319. 45

GUERIN, D.A., YUST, B.L. & COOPET, J.G. (2000). Occupant predictors of household energy behavior and consumption change as found in energy studies since 1975. *Family and Consumer Sciences Research Journal*, **29**, 48–80. 45, 92, 129, 136

GUERRA-SANTIN, O., TWEED, C., JENKINS, H. & JIANG, S. (2013). Monitoring the performance of low energy dwellings: Two UK case studies. *Energy and Buildings*, **64**, 32–40. 27

HAAS, R., AUER, H. & BIERMAYR, P. (1998). The impact of consumer behavior on residential energy demand for space heating. *Energy and Buildings*, **27**, 195–205. 27, 34

HAMILTON, I.G., STEADMAN, P.J., BRUHNS, H., SUMMERFIELD, A.J. & LOWE, R. (2013). Energy efficiency in the british housing stock: Energy demand and the homes energy efficiency database. *Energy Policy*, **60**, 462–480. 24

HARGREAVES, T., NYE, M. & BURGESS, J. (2010). Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors. *Energy Policy*, **38**, 6111–6119. 37, 50, 62, 84, 136

HASS, J.W., BAGLEY, G.S. & ROGERS, R.W. (1975). Coping with the energy crisis: Effects of fear appeals upon attitudes toward energy consumption. *Journal of Applied Psychology*, **60**, 754–756. 45

HOUSING ENERGY ADVISOR (2011). Feed in tariff - the effect on green energy production. http://www.housingenergyadvisor.com/blog/feed-in-tariff-green-energy-electricity/. 30

HOWDEN-CHAPMAN, P., MATHESON, A., CRANE, J., VIGGERS, H., CUNNINGHAM, M., BLAKELY, T., CUNNINGHAM, C., WOODWARD, A., SAVILLE-SMITH, K., O'DEA, D., KENNEDY, M., BAKER, M., WAIPARA, N., CHAPMAN, R. & DAVIE, G. (2007). Effect of insulating existing houses on health inequality: cluster randomised study in the community. *BMJ*, **334**, 460–469. 20

HOWDEN-CHAPMAN, P., PIERSE, N., NICHOLLS, S., GILLESPIE-BENNETT, J., VIGGERS, H., CUNNINGHAM, M., PHIPPS, R., BOULIC, M., FJALLSTROM, P., FREE, S., CHAPMAN, R., LLOYD, B., WICKENS, K., SHIELDS, D., BAKER, M., CUNNINGHAM, C., WOODWARD, A., BULLEN, C. & CRANE, J. (2008). Effects of improved home heating on asthma in community dwelling children: randomised controlled trial. *BMJ*, **337**, 1411–1420. 20

HUEBNER, G., COOPER, J. & JONES, K. (2013). Domestic energy consumption - what role do comfort, habit, and knowledge about the heating system play? *Energy and Buildings*, **66**, 626–636. 43

HUGHES, E. (2011). UK vs. german feed-in tariff: where are we going wrong? - solar power portal. http://www.solarpowerportal.co.uk/blogs/uk_vs._german_feed-in_tariff_where_are_we_going_wrong5478/. 30

INSTITUTION OF MECHANICAL ENGINEERS (2009). UK 2050 energy plan making our commitment a reality. http://www.imeche.org/knowledge/themes/environment/climate-change/copenhagen-conference/uk-2050-energy-plan. 2, 5, 14

JACKSON, T. (2004). Motivating sustainable consumption a review of evidence on consumer behaviour and behavioural change. a report to the sustainable development research network. Tech. rep., Sustainable Development Research Network. 60, 61

JAFFE, A.B. & STAVINS, R.N. (1994). The energy-efficiency gap what does it mean? *Energy Policy*, **22**, 804–810. 5, 31, 32, 33, 41

JAKOB, M. (2007). The drivers of and barriers to energy efficiency renovation decisions of single-family home-owners. http://www.cepe.ethz.ch/publications/workingPapers/CEPE_WP56.pdf. 123, 138

JAMIESON, S. (2004). Likert scales: how to (ab)use them. *Medical education*, **38**, 1217–1218. 74

JANDA, K.B. (2011). Buildings don't use energy: people do. *Architectural Science Review*, **54**, 15–22. 7, 31, 50

JOHN NICHOLAS (2011). Reliability in q methodology: A case study. Sarasota, FL. 76

JONES, C.R. & EISER, J.R. (2009). Identifying predictors of attitudes towards local onshore wind development with reference to an english case study. *Energy Policy*, **37**, 4604–4614. 46

KAISER, F.G., WÖLFING, S. & FUHRER, U. (1999). Environmental attitude and ecological behaviour. *Journal of Environmental Psychology*, **19**, 1–19. 60

KALAFATIS, S.P., POLLARD, M., EAST, R. & TSOGAS, M.H. (1999). Green marketing and ajzen's theory of planned behaviour: a cross-market examination. *Journal of Consumer Marketing*, **16**, 441–460. 60

KARIM, K. (2001). Q methodology-advantages and the disadvantages of this research method. *Journal of Community Nursing*, **15**, 8–12. 68

KARVONEN, A. (2013). Towards systemic domestic retrofit: A social practices approach. *Building Research and Information*, **41**, 563–574. 5, 13, 31, 35

KELLY, M.J. (2009). Retrofitting the existing UK - building stock. *Building Research & Information*, **37**, 196–200. 2, 4, 5, 13, 14, 152

KELLY, M.J. (2010). Energy efficiency, resilience to future climates and long-term sustainability: the role of the built environment. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **368**, 1083–1089. 2, 5, 13, 14, 152

KOLLMUSS, A. & AGYEMAN, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, **8**, 239–260. 144

KROHN, S. & DAMBORG, S. (1999). On public attitudes towards wind power. *Renewable Energy*, **16**, 954–960. 46

KUBIER, P. (2010). *Varieties of Religious Perception: A Q-Methodological Approach to the Study of Religious Beliefs*. Master, University of Central Oklahoma, Oklahoma. 73

LENZEN, M., WIER, M., COHEN, C., HAYAMI, H., PACHAURI, S. & SCHAEFFER, R. (2006). A comparative multivariate analysis of household energy requirements in australia, brazil, denmark, india and japan. *Energy*, **31**, 181–207. 92

LIOR, N. (2010). Sustainable energy development: The present (2009) situation and possible paths to the future. *Energy*, **35**, 3976–3994. 2, 5, 13

LOUGHIN, T.M. & SCHERER, P.N. (1998). Testing for association in contingency tables with multiple column responses. *Biometrics*, **54**, 630–637. 54

LOW CARBON HOUSING RETROFIT (2012). Transforming homes from g to a. 2, 15, 61

LOW ENERGY BUILDINGS (2013). About the LEB. http://www.retrofitforthefuture.org/leb/about-the-leb-database/. 24

LOWE, R. & ORESZCZYN, T. (2008). Regulatory standards and barriers to improved performance for housing. *Energy Policy*, **36**, 4475–4481. 41

LOWERY, D.M., WAGGOTT, A., THEOBALD, K. & WALKER, S.L. (2012). Barriers to retrofit of domestic housing stock with low and zero carbon dioxide technologies. *Proceedings of the ICE - Engineering Sustainability*, **165**, 191–199. 86

LUTZENHISER, L. (1992). A cultural model of household energy consumption. *Energy*, **17**, 47–60. 5, 32, 33, 36, 37, 39, 45, 62, 82, 85

LUTZENHISER, L. (1993). Social and behavioral aspects of energy use. *Annual Review of Energy and the Environment*, **18**, 247–289. 32, 42

MADLENER, R. & ALCOTT, B. (2009). Energy rebound and economic growth: A review of the main issues and research needs. *Energy*, **34**, 370–376. 35, 89

MAHAPATRA, K. & GUSTAVSSON, L. (2008). An adopter-centric approach to analyze the diffusion patterns of innovative residential heating systems in sweden. *Energy Policy*, **36**, 577–590. 127

MANCHESTER CITY COUNCIL (2013a). Annex - what we are going to do now; action plan 2013-15 - full action plan. http://www.manchester.gov.uk/download/meetings/id/14626/annex_to_item_12-manchester-a_certain_future_refresh_action_plan. 153

MANCHESTER CITY COUNCIL (2013b). Toasty manchester. http://getmetoasty.com/news. 154

MANSOURI, I., NEWBOROUGH, M. & PROBERT, D. (1996). Energy consumption in UK households: Impact of domestic electrical appliances. *Applied Energy*, **54**, 211–285. 46

MARKS, D. & YARDLEY, L. (2004). *Research methods for clinical and health psychology*. SAGE. 52

MCKEOWN, B.F. & THOMAS, D.D. (1988). *Q Methodology*. SAGE Publications, Inc. 67, 98

MEIJER, F., ITARD, L. & SUNIKKA-BLANK, M. (2009). Comparing european residential building stocks: performance, renovation and policy opportunities. *Building Research & Information*, **37**, 533–551. 13

MILLS, E. & ROSENFELD, A. (1996). Consumer non-energy benefits as a motivation for making energy-efficiency improvements. *Energy*, **21**, 707–720. 43, 89, 91

NAIR, G., GUSTAVSSON, L. & MAHAPATRA, K. (2010). Factors influencing energy efficiency investments in existing swedish residential buildings. *Energy Policy*, **38**, 2956–2963. 125, 127, 132

NATIONAL REFURBISHMENT CENTRE (2012). Refurbishing the nation: Gathering the evidence. http://www.rethinkingrefurbishment.com/filelibrary/nrc_pdf/NRC_reportSEP2012web.pdf. 2, 3, 15, 19, 20, 61

NICHOLS, W. (2011). Greg barker clashes with building industry over coalition's green deal plans. http://www.businessgreen.com/bg/news/2029771/greg-barker-clashes-industry-coalitions-green-deal-plans. 29

OECD (2013). Greening household behaviour: Overview from the 2011 survey. In *OECD Studies on Environmental Policy and Household Behaviour*, OECD Publishing. 42

Office for National Statistics (2011a). Census: Digitised boundary data (england and wales) [computer file]. http://edina.ac.uk/ukborders. 15, 19, 96

Office for National Statistics (2011b). Super output areas (SOAs). http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/super-output-areas--soas-/index.html. 68

OFGEM (2009). Can energy charges encourage energy efficiency? 26

Olsen, M.E. (1981). Consumers' attitudes toward energy conservation. *Journal of Social Issues*, **37**, 108–131. 44

Olsen, M.E. (1983). Public acceptance of consumer energy conservation strategies. *Journal of Economic Psychology*, **4**, 183–196. 132

Oreszczyn, T. & Lowe, R. (2005). Evidence to the house of lords select committee on science and technology: energy efficient buildings. http://eprints.ucl.ac.uk/2446/. 35

Owen, A., Mitchell, G. & Unsworth, R. (2013). Reducing carbon, tackling fuel poverty: adoption and performance of air-source heat pumps in east yorkshire, UK. *Local Environment*, **18**, 817–833. 42

Owens, S. & Driffill, L. (2008). How to change attitudes and behaviours in the context of energy. *Energy Policy*, **36**, 4412–4418. 45

Oxera (2006). Policies for energy efficiency in the UK household sector. http://www.oxera.com/Oxera/media/Oxera/Policies-for-energy-efficiency-in-the-UK-household.pdf?ext=.pdf. 44, 91

PACEnow (2012). About pace. http://pacenow.org/about-pace/. 29

Pelenur, M. (2010). *A study of energy management and its effect on well-being: can we thrive by using less energy?*. MPhil, University of Cambridge, Cambridge, UK. 7, 33

PELENUR, M. & CRUICKSHANK, H. (2011a). Applying the technology acceptance model to domestic energy: will we accept passive or active energy management systems in our home? In *proceedings of the annual international conference on sustainable systems and the environment*, ISSE Conference, Sharjah, UAE. 37

PELENUR, M. & CRUICKSHANK, H. (2011b). The subjective view of energy in the urban built environment: what are the social factors that affect our interaction with energy? In *proceedings of the 6th UNESCO Dubrovnik conference on sustainable development of energy, water, and environment systems*, University of Dubrovnik, Dubrovnik, Croatia. 13, 31, 38, 64, 72

PELENUR, M. & CRUICKSHANK, H. (2012a). Closing the energy efficiency gap: A study linking demographics with barriers to adopting energy efficiency measures in the home. *Energy*, **47**, 348–357. 3, 41, 81, 125, 127, 132, 138

PELENUR, M. & CRUICKSHANK, H. (2012b). The social barriers towards adopting energy efficiency measures and behaviours in the home: a manchester and cardiff case study. In *proceedings of the RETROFIT 2012 conference*, RETROFIT 2012 Conference, Salford, UK. 52, 53, 65, 81, 141

PELENUR, M. & CRUICKSHANK, H. (2013a). Continuing to close the energy efficiency gap: a study linking demographics with motivations for adopting energy efficiency measures in the home, under review with Energy Policy. 3, 43, 87

PELENUR, M. & CRUICKSHANK, H. (2013b). Investigating the link between well-being and energy use; an explorative case study between passive and active domestic energy management systems. *Building and Environment*, **65**, 26–34. 7, 33

PELENUR, M. & CRUICKSHANK, H. (2013c). Retrofitting the domestic built environment: a socio-technical approach to reduce energy demand by linking social perspectives with energy efficiency technologies and behaviour, under review with Building Research & Information. 3, 31, 97, 98

PLANNING PORTAL (2011). Approved document l. http://www.planningportal.gov.uk/buildingregulations/approveddocuments/partl/approved. 18, 19

PONTEROTTO, J.G. (2005). Qualitative research in counseling psychology: A primer on research paradigms and philosophy of science. *Journal of counseling psychology*, **52**, 126–136. 49, 50

RAO, J.N.K. (1984). On chi-squared tests for multiway contingency tables with cell proportions estimated from survey data. *The Annals of Statistics*, **12**, 46–60. 54

RAO, J.N.K. & SCOTT, A.J. (1981). The analysis of categorical data from complex sample surveys: Chi-squared tests for goodness of fit and independence in two-way tables. *Journal of the American Statistical Association*, **76**, 221–230. 54

RAVETZ, J. (2008). State of the stock–What do we know about existing buildings and their future prospects? *Energy Policy*, **36**, 4462–4470. 14, 19, 32

RAYNER, S. & MALONE, E.L. (1998). *Human Choice and Climate Change*. Battelle Press,U.S. 37, 50, 62

REDDY, B. (2003). Overcoming the energy efficiency gap in india's household sector. *Energy Policy*, **31**, 1117–1127. 44

RETROFIT 2050 (2012). Re-engineering the city 2020-2050 | urban foresight and transition management. http://www.retrofit2050.org.uk/. 2, 11, 61

RH INCENTIVE (2011). What is the RHI? http://www.rhincentive.co.uk/RHI/. 31

RITCHIE, J.B., MCDOUGALL, G.H. & CLAXTON, J.D. (1981). Complexities of household energy consumption and conservation. *Journal of Consumer Research*, 233–242. 45

ROBERT WOOD JOHNSON FOUNDATION (2008). Interpretivist paradigm. http://www.qualres.org/HomeInte-3516.html. 50

ROUTLEDGE (2000). *Concise Routledge encyclopedia of philosophy*. Routledge. 50

SAMUELSON, C.D. & BIEK, M. (1991). Attitudes toward energy conservation: A confirmatory factor analysis1. *Journal of Applied Social Psychology*, **21**, 549–568. 45

SARDIANOU, E. (2007). Estimating energy conservation patterns of greek households. *Energy Policy*, **35**, 3778–3791. 125

SAUNDERS, M.N., THORNHILL, A. & LEWIS, P. (2009). *Research Methods for Business Students*. Financial Times/ Prentice Hall, 5th edn. 51

SCHERAGA, J.D. (1994). Energy and the environment something new under the sun? *Energy Policy*, **22**, 798–803. 62

SCHMOLCK, P. (2012). PQ method 2.33. http://schmolck.userweb.mwn.de/qmethod/. 97

SCHOOL OF TECHNOLOGY (2011). An ethical code for research at the school of technology university of cambridge. Tech. rep. 76

SHIPWORTH, M., FIRTH, S.K., GENTRY, M.I., WRIGHT, A.J., SHIPWORTH, D.T. & LOMAS, K.J. (2010). Central heating thermostat settings and timing: building demographics. *Building Research & Information*, **38**, 50–69. 33

SHOVE, E., LUTZENHISER, L., GUY, S., HACKETT, B. & WILHITE, H. (1998). Energy and social systems. *Human choice and climate change*, **2**, 291–325. 45, 82, 84, 136

SMITH, D.W. (2011). Phenomenology. In E.N. Zalta, ed., *The Stanford Encyclopedia of Philosophy*, fall 2011 edn. 38

SMITH, J.A., HARRÉ, R. & LANGENHOVE, L.V. (1995). *Rethinking methods in psychology*. SAGE. 59

STAFFORD, A., GORSE, C. & SHAO, L. (2012). The retrofit challenge: Delivering low carbon buildings. Tech. rep., Report. 2, 4, 5, 13, 31, 32

STEELMAN, T. & MAGUIRE, L.A. (1998). Understanding participant perspectives: Q-methodology in national forest management. *Journal of Policy Analysis and Management*, **18**, 361–388. 67

STEPHENSON, J., BARTON, B., CARRINGTON, G., GNOTH, D., LAWSON, R. & THORSNES, P. (2010). Energy cultures: A framework for understanding energy behaviours. *Energy Policy*, **38**, 6120–6129. 5, 32, 37, 38, 39, 50, 62, 64, 82, 85

STEPHENSON, W. (1952). Q-methodology and the projective techniques. *Journal of clinical psychology*, **8**, 219–229. 56

STERN, N. (2006). Stern review on the economics of climate change. Tech. rep., Stern Review on the Economics of Climate Change, UK Treasury. 33, 41, 85

STERN, P.C. (2000). New environmental theories: Toward a coherent theory of environmentally significant behavior. *Journal of Social Issues*, **56**, 407–424. 36

SUSTAINABLE DEVELOPMENT COMMISSION (2006). Stock take: delivering improvements in existing housing. http://www.sd-commission.org.uk/publications.php?id=400. 14, 29

SUTHERLAND, R.J. (1991). Market barriers to energy-efficiency investments. *The Energy Journal*, **Volume 12**, 15–34. 41

SWAN, L.G. & UGURSAL, V.I. (2009). Modeling of end-use energy consumption in the residential sector: A review of modeling techniques. *Renewable and Sustainable Energy Reviews*, **13**, 1819–1835. 46

SWAN, W., RUDDOCK, L., SMITH, L. & FITTON, R. (2013). Adoption of sustainable retrofit in UK social housing. *Structural Survey*, **31**, 181–193. 86

THE GOVERNMENT OFFICE FOR SCIENCE (2008). Powering our lives: Sustainable energy management and the built environment. final report. http://bis.ecgroup.net/Publications/Foresight/SustainableEnergyManagementBuiltEnvironment.aspx. 3, 14, 32, 37

THE POVERTY SITE (2011). UK: non-decent homes. http://www.poverty.org.uk/78/index.shtml. 19

THOMAS, D. & BAAS, L.R. (1996). The postelection campaign: Competing constructions of the clinton victory in 1992. *The Journal of Politics*, **58**, 309–331. 73

THOMAS, D., RIBICH, F. & FREIE, J. (1982). The relationship between psychological identification with instructors and student ratings of college courses. *Instructional Science*, **11**, 139–154. 73

THOMAS, D., MCCOY, C. & MCBRIDE, A. (1993). Deconstructing the political spectacle: Sex, race, and subjectivity in public response to the clarence Thomas/Anita hill "Sexual harassment" hearings. *American Journal of Political Science*, **37**, 699–720. 73

THOMAS, D.R. & DECADY, Y.J. (2000). Analyzng categorical data with multiple responses per subject. In *Statistics Society of Canada Proceedings of the Survey Methods Section*, 121–130. 54

THOMAS, D.R. & DECADY, Y.J. (2004). Testing for association using multiple response survey data: Approximate procedures based on the rao-scott approach. *International Journal of Testing*, **4**, 43–59. 54, 55, 56, 66, 93

TVERSKY, A. & KAHNEMAN, D. (1991). Loss aversion in riskless choice: A reference-dependent model. *The Quarterly Journal of Economics*, **106**, 1039–1061. 151

TWEED, C. (2013). Socio-technical issues in dwelling retrofit. *Building Research & Information*, **41**, 551–562. 13, 27, 38

TWEED, C. & SUTHERLAND, M. (2007). Built cultural heritage and sustainable urban development. *Landscape and Urban Planning*, **83**, 62–69. 3, 82

UK-GBC (2008). Low carbon existing homes. http://www.ukgbc.org/site/document/download/?document_id=370. 86

UKERC (2008). Implementation of energy performance certificates in the domestic sector. http://www.law.monash.edu/regstudies/implementation-of-energy-certificates-in-the-domestic-sector.pdf. 21

UPHAM, P., WHITMARSH, L., POORTINGA, W., PURDAM, K., DARNTON, A., MCLACHLAN, C. & DEVINE-WRIGHT, P. (2009). Public attitudes to environmental change: a selective review of theory and practice. *A research synthesis for the Living With Environmental Change Programme. London: Research Councils UK*. 32, 34, 39

ÜRGE VORSATZ, D. & HAUFF, J. (2001). Drivers of market transformation: analysis of the hungarian lighting success story. *Energy Policy*, **29**, 801–810. 129, 132

VISSCHERS, V.H.M. & SIEGRIST, M. (2013). How a nuclear power plant accident influences acceptance of nuclear power: Results of a longitudinal study before and after the fukushima disaster. *Risk Analysis*, **33**, 333–347. 45, 62

WARD, I.C. (2008). What are the energy and power consumption patterns of different types of built environment? *Energy Policy*, **36**, 4622–4629. 13, 19

WARM WALES (2013). Warm wales. http://www.warmwales.org.uk/lang/en-gb/about/. 155

WATTS, S. & STENNER, P. (2005). Doing q methodology: theory, method and interpretation. *Qualitative Research in Psychology*, **2**, 67–91. 57, 59

WATTS, S. & STENNER, P. (2012). *Doing Q Methodological Research: Theory, Method & Interpretation*. Sage Publications Ltd. 56, 57, 69, 71, 97, 98, 105, 146

WEBER, L. (1997). Some reflections on barriers to the efficient use of energy. *Energy Policy*, **25**, 833–835. 5, 32, 33, 42, 85

WELLER, J.I., SONG, J.Z., HEYEN, D.W., LEWIN, H.A. & RON, M. (1998). A new approach to the problem of multiple comparisons in the genetic dissection of complex traits. *Genetics*, **150**, 1699–1706. 74

WELSH GOVERNMENT (2013). Arbed - strategic energy performance investment programme. http://wales.gov.uk/topics/environmentcountryside/energy/efficiency/arbed/?lang=en. 155

WILLIAM TROCHIM (2006). Types of reliability. http://www.socialresearchmethods.net/kb/reltypes.php. 76

WILSON, C. & DOWLATABADI, H. (2007). Models of decision making and residential energy use. *Annual Review of Environment and Resources*, **32**, 169–203. 5, 32, 33, 36

YATES, D., MOORE, D.S. & MCCABE, G.P. (1999). *The Practice of Statistics AP: TI-83 Graphing Calculator Enhanced*. W. H. Freeman, 1st edn. 66, 91

YEKUTIELI, D. & BENJAMINI, Y. (1999). Resampling-based false discovery rate controlling multiple test procedures for correlated test statistics. *Journal of Statistical Planning and Inference*, **82**, 171–196. 74

YOHANIS, Y.G., MONDOL, J.D., WRIGHT, A. & NORTON, B. (2008). Real-life energy use in the UK: how occupancy and dwelling characteristics affect domestic electricity use. *Energy and Buildings*, **40**, 1053–1059. 38

ZELEZNY, L.C., CHUA, P.P. & ALDRICH, C. (2000). New ways of thinking about environmentalism: Elaborating on gender differences in environmentalism. *Journal of Social Issues*, **56**, 443–457. 125

ZERO CARBON HUB (2013). Closing the gap between design and as-built performance. http://www.zerocarbonhub.org/resourcefiles/ZCH_DvAB_FullReport.pdf. 13, 27

ZHANG, T., SIEBERS, P.O. & AICKELIN, U. (2012). A three-dimensional model of residential energy consumer archetypes for local energy policy design in the UK. *Energy Policy*, **47**, 102–110. 46

A | Q statements

Q Statements	Cardiff factors				Man. factors	
	1	2	3	4	1	2
1. I don't know how I would start going about changing my household's energy use	-1	-1	-2	-2	-1	3
2. The energy and utility tariffs are complicated to understand	2	4	0	4	1	2
3. I'm too lazy to always turn off the lights or TV	-3	1	-5	-1	-5	6
4. Even though there are government grants to install renewable generation, it is still too expensive	0	3	1	2	2	0
5. I use as little energy as possible	0	2	1	-2	3	-4
6. I rather use multiple blankets or put on more layers than turn up the heating	1	-2	1	0	2	-3
7. Old homes should be improved to modern building standards	0	5	0	-1	1	3
8. I don't know how much heating I use	-1	3	-2	2	-2	5
9. Parents should ensure that their kids are taught how to be energy efficient at home	3	0	3	1	3	2
10. I want to reduce my heating	0	2	0	1	2	3

Continued on next page

Table A.1 – *Continued from previous page*

Q Statements	Cardiff factors				Man. factors	
	1	2	3	4	1	2
11. Woman use most of the energy at home	-3	3	1	-2	-2	-4
12. I don't know how to control my heating efficiently	-2	1	-6	0	-2	-2
13. I'd like there to be more environmentally friendly sources of energy	5	1	2	5	4	1
14. I want my energy use to be greener	3	0	3	5	3	1
15. I want to change how my household uses energy	0	1	0	1	1	-2
16. We are too dependent on fossil fuels	4	-2	-1	2	1	6
17. The appearance of my home is more important than being energy efficient	-5	-3	-3	-5	-5	-1
18. When I buy an appliance, I check the energy ratings	1	0	2	0	0	-5
19. Trying to keep up with the neighbours is more important than being energy efficient	-6	-4	-5	-6	-6	-4
20. People should pay the same 'per unit cost' of energy regardless of how much they use	-1	0	-2	-1	0	-5
21. I'm concerned about the effect of energy use on on the atmosphere	6	-1	1	4	4	3
22. I'd like to generate my own energy	1	0	2	1	0	0
23. I try and reduce my energy use to save money	2	6	0	2	5	-1
24. The government is not doing enough about improving energy use	5	-2	2	3	0	1

Continued on next page

Table A.1 – *Continued from previous page*

Q Statements	Cardiff factors				Man. factors	
	1	2	3	4	1	2
25. We're not using sunlight or wind effectively as a nation	4	0	1	6	1	5
26. I switch energy tariffs regularly to get the best deal	-4	-4	-3	-4	-2	-1
27. Protecting the environment is important to me	6	1	4	5	6	3
28. I never really think about my household energy use	-4	-5	-4	-3	-5	-2
29. I think solar panels should be built into all new properties	4	2	6	6	4	1
30. I was raised to not waste energy	0	2	3	0	3	1
31. It's better to heat one room rather than the whole home	1	-5	4	3	2	5
32. People tell me what I should do to conserve energy, but they don't actually do it themselves	-1	-2	0	0	-1	0
33. I leave lights on for appearances	-3	-3	-3	-2	-4	2
34. The heating in my home isn't thought out properly	-1	0	-3	3	-1	-1
35. Teenagers are not serious about saving energy	-1	-1	1	-2	0	4
36. I try and conserve energy, but sometimes it's difficult to get other people to do the same	1	3	3	0	1	-2
37. It's a balance between what you pay for energy and what it costs you to improve energy efficiency	0	-3	2	-1	0	-1

Continued on next page

Table A.1 – *Continued from previous page*

Q Statements	Cardiff factors				Man. factors	
	1	2	3	4	1	2
38. I'd like more information about my household's energy use	0	1	-1	0	2	1
39. I try and conserve energy out of general principle	4	4	5	0	5	-1
40. Families waste energy because of convenience	1	5	2	3	0	2
41. Not enough communication being done within households about energy issues	1	-1	4	-1	-1	0
42. I don't believe in climate change	-6	-3	0	-5	-6	-6
43. I think other people should be more aware about their energy use	0	4	3	1	1	0
44. I would like my household energy use to be more cost effective	2	6	4	3	5	2
45. Solar panels are changing the look of cities, not in a nice way	-3	-1	-1	-3	-3	-2
46. I sometimes forget to turn the heating off	-2	0	-6	-1	-2	4
47. Being energy efficient is about saving time	-2	-1	-1	-3	-3	-3
48. I make a conscious effort to turn things off at the socket	1	3	5	-3	3	-6
49. It's our responsibility to look after the next generation's future	5	1	1	4	6	2
50. I'm happy with my energy costs	-2	-6	-1	-4	-2	-3
51. I turn off lighting when not in the room	2	4	6	1	4	-5
52. Being energy efficient is a disruption to my lifestyle	-5	-3	-4	-3	-4	-3

Continued on next page

Table A.1 – *Continued from previous page*

Q Statements	Cardiff factors				Man. factors	
	1	2	3	4	1	2
53. As a society, we should be self sufficient with our energy	3	0	0	4	1	0
54. The ever increasing number of gadgets is a problem for energy efficiency	3	1	-1	2	0	4
55. Energy efficient bulbs are not good	-4	-4	-5	-4	-4	-1
56. Being comfortable is more important than saving energy	-2	-2	-1	-2	-3	4
57. Schools should be teaching more about energy efficiency to kids	3	2	5	-1	2	1
58. I don't know if my energy use is above average or below average	-1	5	-1	2	-1	0
59. Modern technology, such as plasma screens, are more important to me than being energy efficient	-5	-5	-4	-5	-3	1
60. I can afford my energy bills, so I'm not bothered about conserving energy	-4	-6	-3	-6	-4	0
61. I don't usually think about how to be energy efficient	-2	-1	-2	-1	-3	-2
62. Better insulation for my home means I can keep the heating on for a longer time	-3	-4	-2	-4	-1	-4
63. I don't trust the energy companies when they say they will give you advice	2	-2	-2	1	-1	0
64. My house is very hard to heat	-1	2	-4	1	0	-3
65. Nuclear energy is dangerous	2	-1	0	0	-1	-1

Table A.1: Q statements and factor arrays

B | Census calculations

This Appendix shows the demographic variables and calculations used to determine the most typical MSOAs that represent Manchester and Cardiff. This was achieved by standardising the census data within each MSOA and then taking the difference between the MSOA data and the corresponding city variable. The differences for all the variables were then summed, and the four areas with the smallest total (i.e. smallest difference from city average) were selected.

- For Manchester, the most typical MSOAs were: 11, 30, 35, 42
- For Cardiff the most typical MSOAs were: 5, 10, 35, 46

B. Census calculations

Table B.1: Manchester census calculations and data

CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1 (i.e. the difference between row value and Manchester value is greater than one standard deviation)

MSOAs compared against Manchester average using standard deviation

Demographic variables			MSOA 001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	016	017	018	019
Owner occupied: Owns with a mortgage or loan	Households	Percentage	0.24	0.40	0.04	1.18	1.58	0.16	1.45	0.19	1.06	1.19	0.26	1.00	1.56	1.06	1.00	1.39	0.04	2.09	0.22
Owner occupied: Shared ownership	Households	Percentage	0.20	2.40	0.75	0.55	0.43	0.17	1.56	3.10	1.45	0.64	0.41	0.64	0.29	1.77	0.78	0.90	1.33	0.12	1.33
Rented from: Council (local authority)	Households	Percentage	0.61	0.55	1.20	0.91	0.38	0.26	1.11	1.34	1.23	0.56	0.44	1.03	2.23	0.11	0.90	0.70	0.23	2.02	0.11
Rented from: Housing Association / Registered Social Landlord	Households	Percentage	0.56	0.89	1.13	0.30	0.88	0.32	0.52	0.35	0.28	0.88	0.64	0.66	0.49	0.07	0.52	0.94	0.54	0.41	1.50
Rented from: Private landlord or letting agency	Households	Percentage	0.89	0.72	1.02	0.45	0.97	0.18	0.09	0.96	0.56	0.22	0.54	0.67	0.73	1.66	0.40	0.39	0.26	0.62	0.12
Rented from: Other	Households	Percentage	0.26	0.32	0.36	0.95	0.95	0.31	1.02	0.36	0.32	1.47	0.11	0.22	1.13	3.17	0.87	0.90	0.07	2.04	0.52
Owner occupied: Owns outright	Households	Percentage	0.30	0.22	0.08	1.73	1.49	0.49	1.56	1.25	0.96	0.61	0.22	0.65	1.48	1.57	0.77	1.52	0.30	1.60	1.43
Median age of population in the area	Persons	Years	1.81	1.13	1.81	1.58	1.36	0.91	1.13	0.23	0.68	0.45	1.13	0.68	0.68	1.13	0.68	0.91	1.13	0.68	1.81
Mean age of population in the area	Persons	Years	1.49	0.70	1.63	1.39	1.00	0.58	0.81	0.43	0.56	0.90	0.79	0.45	0.20	0.93	0.24	1.20	0.96	1.00	2.40
Dwelling Stock by Council Tax Band; Band A	Dwellings	Percentage	0.91	0.51	0.53	0.24	0.31	0.91	0.27	0.28	1.44	0.22	0.94	1.52	0.00	1.60	0.49	1.53	0.95	0.86	0.33
Dwelling Stock by Council Tax Band; Band B	Dwellings	Percentage	0.91	0.14	0.25	1.20	1.76	0.04	1.35	0.90	1.40	0.39	0.40	1.69	0.53	0.60	0.47	0.72	0.36	0.14	2.52
Dwelling Stock by Council Tax Band; Band C	Dwellings	Percentage	0.67	0.29	0.64	0.14	0.09	0.99	0.58	0.52	1.08	0.34	0.81	1.05	0.79	0.80	0.45	0.63	0.79	0.77	0.21
Dwelling Stock by Council Tax Band; Band D	Dwellings	Percentage	0.53	0.60	0.44	0.47	0.62	0.80	0.83	0.53	0.91	0.69	0.83	0.91	0.38	3.29	0.89	2.84	0.89	0.88	0.78
Dwelling Stock by Council Tax Band; Band E	Dwellings	Percentage	0.58	0.66	0.72	0.36	0.61	0.73	0.79	0.77	0.79	0.61	0.73	0.79	0.66	2.34	0.75	3.53	0.79	0.80	0.76
Dwelling Stock by Council Tax Band; Band F	Dwellings	Percentage	0.36	0.55	0.60	0.47	0.57	0.56	0.60	0.54	0.59	0.60	0.59	0.58	0.57	1.25	0.59	1.73	0.59	0.60	0.60
Dwelling Stock by Council Tax Band; Band G	Dwellings	Percentage	0.34	0.28	0.38	0.14	0.40	0.40	0.40	0.27	0.35	0.36	0.26	0.31	0.38	0.53	0.40	0.65	0.38	0.31	0.35
Dwelling Stock by Council Tax Band; Band H	Dwellings	Percentage	0.00	0.81	0.81	0.32	0.81	0.16	0.32	0.48	0.81	0.48	0.48	0.81	0.81	1.78	0.81	2.26	0.81	0.48	0.81
One person: Pensioner	Households	Percentage	1.64	0.14	2.05	1.45	0.09	0.67	0.15	0.18	1.05	0.50	0.58	0.86	0.70	0.97	0.42	1.60	1.23	0.60	2.28
One person: Other	Households	Percentage	0.68	0.36	0.49	0.46	1.15	0.09	0.48	0.12	0.61	0.54	0.28	0.40	0.59	3.68	0.23	3.89	0.12	1.41	1.91
One family and no others: All pensioners	Households	Percentage	1.11	0.68	0.83	1.48	1.21	0.32	1.22	0.03	0.60	1.02	0.46	0.16	1.01	1.44	0.55	1.87	0.53	1.26	1.83
One family and no others: Married couple households: No children	Households	Percentage	0.75	0.37	0.70	1.31	2.23	0.54	0.90	0.41	0.53	0.87	0.99	0.22	0.79	1.23	0.36	1.51	0.07	1.50	1.92
One family and no others: Married couple households: With dependent children	Households	Percentage	0.19	0.12	0.31	1.07	1.61	0.20	0.61	2.21	1.18	0.36	0.04	0.72	1.41	2.61	0.89	2.16	0.30	0.45	1.91
One family and no others: Married couple households: All children non-dependent	Households	Percentage	0.53	1.13	1.00	1.07	2.13	0.26	1.77	0.04	0.40	0.59	0.52	0.17	0.72	2.15	0.31	2.14	0.51	1.30	2.03
One family and no others: Cohabiting couple households: No children	Households	Percentage	0.73	0.56	0.65	0.50	0.73	0.65	0.54	0.91	0.66	0.48	0.75	0.92	0.54	1.72	0.80	0.48	0.82	0.34	1.44
One family and no others: Cohabiting couple households: With dependent children	Households	Percentage	0.50	0.63	0.82	0.29	1.65	0.20	1.45	1.25	0.01	1.10	0.84	0.80	0.14	1.99	0.17	1.50	0.79	1.24	0.59
One family and no others: Cohabiting couple households: All children non-dependent	Households	Percentage	0.83	0.83	0.35	0.76	0.90	0.35	1.46	0.42	0.63	0.21	0.70	1.39	0.35	1.18	0.21	1.39	0.83	0.28	1.18
One family and no others: Lone parent households: With dependent children	Households	Percentage	0.23	0.49	0.12	0.80	0.14	0.40	0.20	0.48	0.91	1.05	0.54	1.52	1.39	1.55	1.14	1.06	0.46	0.37	0.06

Continued on next page

Table B.1 – *Continued from previous page*

MANCHESTER
CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1 (i.e. the difference between row value and Manchester value is greater than one standard deviation)

MSOAs compared against Manchester average using standard deviation

Demographic variables			**MSOA** 001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	016	017	018
Other households: With dependent children	Households	Percentage	0.62	0.22	1.06	0.74	0.37	0.21	0.57	2.18	0.10	0.93	0.72	0.07	0.21	2.25	0.23	1.26	0.77	0.86
Other households: All student	Households	Percentage	0.44	0.43	0.43	0.41	0.43	0.35	0.41	0.35	0.43	0.38	0.39	0.41	0.44	0.01	0.36	0.10	0.38	0.07
Other households: All pensioner	Households	Percentage	1.45	0.00	1.67	0.29	0.07	0.65	0.94	1.52	0.65	0.43	0.72	2.25	1.45	2.10	0.65	1.30	1.45	0.51
Other households: Other	Households	Percentage	0.93	0.72	1.06	0.92	1.02	0.70	0.73	0.33	0.68	0.26	0.88	0.92	0.59	0.16	0.64	0.23	0.71	0.36
Accommodation type: Whole house or bungalow: Detached	Household Spaces	Percentage	1.22	0.69	0.21	0.01	1.33	0.84	0.58	0.25	0.52	0.25	0.06	0.66	0.17	1.29	0.99	0.98	0.93	0.03
Accommodation type: Whole house or bungalow: Semi-detached	Household Spaces	Percentage	0.35	1.13	0.93	1.05	1.32	0.65	0.09	0.16	0.87	0.82	0.24	0.64	0.88	1.80	0.81	1.71	0.92	1.01
Accommodation type: Whole house or bungalow: Terraced (including end terrace)	Household Spaces	Percentage	0.02	0.66	1.04	0.85	0.30	1.25	1.30	0.03	1.02	0.58	0.90	0.00	0.76	1.59	1.53	1.27	1.59	0.27
Accommodation type: Flat; maisonette or apartment: Purpose Built block of flats or tenement	Household Spaces	Percentage	0.28	0.31	0.76	0.15	1.15	0.62	1.19	0.50	0.32	0.47	0.59	0.37	0.50	3.95	0.49	3.86	0.51	1.34
Accommodation type: Flat; maisonette or apartment: Part of a converted or shared house (including bed-sits)	Household Spaces	Percentage	0.66	0.60	0.67	0.45	0.73	0.21	0.73	1.26	0.70	0.36	0.56	0.55	0.60	1.55	0.58	0.56	0.56	0.46
Accommodation type: Flat; maisonette or apartment: In commercial building	Household Spaces	Percentage	0.85	0.75	0.65	1.02	0.84	0.72	0.24	0.26	0.64	0.33	0.62	0.74	0.44	3.14	0.69	3.73	0.05	0.14
Accommodation type: Caravan or other mobile or temporary structure	Household Spaces	Percentage	0.04	0.41	0.41	0.41	0.41	1.33	0.41	0.12	0.12	6.63	0.08	0.41	0.04	0.08	0.41	0.08	0.12	0.08
Average Consumption of Domestic Gas	Kilowatt Hours	Count	0.41	0.17	0.18	0.95	0.39	0.40	0.12	0.79	1.04	0.05	0.22	0.75	1.69	0.40	1.23	1.96	0.41	1.56
Average Consumption of Economy 7 Domestic Electricity	Kilowatt Hours	Count	0.82	0.13	1.80	0.33	0.70	0.88	0.33	0.17	0.24	0.02	0.51	0.60	2.61	1.00	1.16	1.10	0.43	0.92
Average Consumption of Ordinary Domestic Electricity	Kilowatt Hours	Count	0.39	0.15	0.11	0.11	0.24	0.90	0.33	0.82	1.18	0.40	0.74	0.34	0.56	4.52	0.86	3.37	1.03	1.46
Average household size	Persons	Rate	0.34	0.09	0.56	0.17	0.82	0.43	0.22	1.47	1.03	0.34	0.26	0.13	0.86	3.40	0.56	3.10	0.47	0.90
Average number of rooms per household	Rooms	Rate	0.19	0.53	0.08	0.13	0.96	0.13	0.61	0.03	0.58	0.61	0.05	0.16	0.77	3.96	0.40	3.06	0.27	1.78
Occupancy rating of -1 or less	Households	Percentage	0.78	0.93	0.90	0.55	0.95	0.54	0.67	0.78	0.43	0.27	0.50	0.50	0.15	3.94	0.46	1.82	0.65	1.55
With central heating and sole use of bath / shower and toilet	Households	Percentage	0.74	0.98	0.62	0.34	0.69	1.03	1.65	1.09	0.30	0.78	0.24	0.61	1.32	1.36	0.17	0.12	1.54	1.05
Without central heating or sole use of bath / shower and toilet	Households	Percentage	0.71	0.44	0.38	0.44	0.71	0.12	0.44	0.53	0.38	0.26	0.71	0.71	0.71	4.08	0.44	2.09	0.29	0.71
Without central heating; with sole use of bath / shower and toilet	Households	Percentage	0.61	0.86	0.49	0.21	0.54	1.19	1.89	1.08	0.20	0.79	0.10	0.49	1.28	0.01	0.02	1.03	1.72	1.21
With central heating; without sole use of bath / shower and toilet	Households	Percentage	0.39	0.51	0.56	0.42	0.58	0.59	0.63	0.01	0.35	0.05	0.40	0.40	0.19	5.05	0.51	3.51	0.48	0.86
Lowest floor level; Basement or semi-basement	Households	Percentage	0.65	0.24	0.83	0.33	0.63	0.24	0.50	0.83	0.71	0.52	0.39	0.69	0.79	1.27	0.81	0.31	0.11	0.36
Lowest floor level; Ground level (street level)	Households	Percentage	0.54	0.51	0.04	0.17	1.08	0.42	1.04	0.29	0.22	0.12	0.67	0.55	0.29	3.90	0.71	3.35	0.40	0.63
Lowest floor level; 1st / 2nd / 3rd or 4th floor	Households	Percentage	0.44	0.51	0.53	0.11	1.20	0.57	1.13	0.21	0.09	0.27	0.69	0.61	0.37	3.79	0.54	3.32	0.55	0.73
Lowest floor level; 5th floor or higher	Households	Percentage	0.26	0.41	2.77	0.03	0.34	0.41	0.53	0.39	0.20	0.35	0.37	0.28	0.80	4.04	0.47	4.23	0.25	1.00
		Total	32.99	30.05	38.99	32.93	43.94	27.57	41.06	34.21	34.34	34.01	27.57	36.25	39.90	103.30	32.69	90.11	32.74	44.32

Continued on next page

Table B.1 – *Continued from previous page*

MANCHESTER
CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1
(i.e. the difference between row value and Manchester value is greater than one standard deviation)

MSOAs compared against Manchester average using standard deviation

Demographic variables			**MSOA** 019	020	021	022	023	024	025	026	027	028	029	030	031	032	033	034	035	036	037
Owner occupied: Owns with a mortgage or loan	Households	Percentage	0.22	0.85	1.20	1.31	1.07	1.77	0.91	0.58	0.31	0.21	1.09	0.30	0.45	0.74	1.22	1.43	0.63	0.49	1.77
Owner occupied: Shared ownership	Households	Percentage	1.33	0.12	0.03	0.87	1.24	0.43	0.58	1.30	0.75	1.56	0.84	0.20	1.36	0.58	0.12	0.64	0.64	0.29	1.07
Rented from: Council (local authority)	Households	Percentage	0.11	1.26	1.10	0.71	0.57	0.62	0.60	0.07	0.94	1.28	1.46	0.61	1.35	0.94	1.30	1.20	0.82	0.92	0.97
Rented from: Housing Association / Registered Social Landlord	Households	Percentage	1.50	0.08	0.23	0.64	1.17	2.21	1.16	0.41	0.28	1.23	0.08	0.53	0.09	0.82	0.66	0.11	0.58	0.33	0.45
Rented from: Private landlord or letting agency	Households	Percentage	0.12	0.52	0.04	2.00	0.30	0.37	0.90	0.96	0.63	1.28	0.92	0.03	1.23	2.61	0.86	0.20	0.00	1.91	0.14
Rented from: Other	Households	Percentage	0.52	0.59	1.03	0.21	0.20	0.16	1.40	1.37	0.50	1.00	1.46	0.02	0.15	1.54	2.02	1.45	0.09	1.13	1.28
Owner occupied: Owns outright	Households	Percentage	1.43	0.94	1.27	0.57	0.82	1.01	0.33	0.70	0.40	0.17	0.58	0.47	0.49	0.30	1.01	1.53	0.43	0.20	0.75
Median age of population in the area	Persons	Years	1.81	0.23	0.91	1.58	0.45	0.23	1.13	1.81	0.45	0.00	0.23	0.23	0.23	2.26	0.45	0.68	0.68	1.81	0.68
Mean age of population in the area	Persons	Years	2.40	0.05	0.37	1.59	0.01	0.81	1.36	1.88	1.06	0.24	0.14	0.08	0.66	2.83	0.14	0.42	0.37	1.27	0.50
Dwelling Stock by Council Tax Band; Band A	Dwellings	Percentage	0.33	1.02	0.82	0.21	1.17	1.27	1.30	0.17	1.02	0.04	1.28	0.41	0.77	1.40	1.20	1.36	0.08	1.26	1.34
Dwelling Stock by Council Tax Band; Band B	Dwellings	Percentage	2.52	0.46	0.34	1.46	0.77	1.02	1.26	0.47	0.40	0.34	0.99	0.78	0.24	1.89	0.17	0.65	0.38	1.80	2.40
Dwelling Stock by Council Tax Band; Band C	Dwellings	Percentage	0.21	0.87	0.60	0.58	0.93	0.97	0.93	0.10	0.89	0.08	1.90	0.47	0.59	1.39	0.91	2.59	0.50	1.47	0.63
Dwelling Stock by Council Tax Band; Band D	Dwellings	Percentage	0.78	0.87	0.84	0.82	0.91	0.90	0.88	0.05	0.91	0.07	0.09	0.56	0.78	0.29	2.03	0.40	0.51	0.29	0.17
Dwelling Stock by Council Tax Band; Band E	Dwellings	Percentage	0.76	0.80	0.69	0.77	0.82	0.82	0.75	0.41	0.77	0.40	0.29	0.36	0.73	0.01	0.38	0.40	0.09	0.21	2.35
Dwelling Stock by Council Tax Band; Band F	Dwellings	Percentage	0.60	0.58	0.58	0.49	0.60	0.60	0.55	0.53	0.59	0.51	0.37	0.42	0.56	0.46	0.24	0.50	0.58	0.37	0.00
Dwelling Stock by Council Tax Band; Band G	Dwellings	Percentage	0.35	0.34	0.36	0.23	0.40	0.40	0.38	0.31	0.40	0.19	0.26	0.23	0.40	0.36	0.04	0.36	0.36	0.33	0.27
Dwelling Stock by Council Tax Band; Band H	Dwellings	Percentage	0.81	0.32	0.81	0.48	0.81	0.81	0.81	3.07	0.48	0.32	0.81	0.65	0.81	2.59	0.32	0.81	0.32	0.81	0.81
One person: Pensioner	Households	Percentage	2.28	0.15	0.10	1.82	0.86	0.45	0.85	0.88	1.15	1.43	0.42	0.10	0.98	1.75	0.75	0.15	0.22	0.57	0.29
One person: Other	Households	Percentage	1.91	0.28	0.24	0.35	0.29	0.59	0.04	0.29	0.10	1.84	0.12	0.16	0.47	0.69	0.13	0.98	0.82	0.31	0.36
One family and no others: All pensioners	Households	Percentage	1.83	0.51	0.39	1.31	0.13	1.06	1.13	0.99	0.60	1.28	0.34	0.29	0.98	1.04	0.28	0.88	0.05	0.67	0.17
One family and no others: Married couple households: No children	Households	Percentage	1.92	0.21	1.15	1.36	0.44	1.78	0.97	1.10	0.05	1.36	0.51	0.46	0.34	1.22	0.47	0.67	0.84	0.76	1.57
One family and no others: Married couple households: With dependent children	Households	Percentage	1.91	0.13	0.82	0.13	0.89	1.09	0.43	0.12	1.44	0.16	0.62	0.32	0.18	0.71	0.76	1.73	0.36	0.99	0.55
One family and no others: Married couple households: All children non-dependent	Households	Percentage	2.03	0.47	0.79	1.22	0.05	1.46	1.12	1.10	0.09	1.16	0.36	0.01	0.39	0.75	0.14	1.89	0.13	0.69	0.19
One family and no others: Cohabiting couple households: No children	Households	Percentage	1.44	0.61	0.42	0.23	0.88	0.88	0.30	0.29	0.40	0.53	1.26	0.30	0.07	0.01	1.79	0.39	0.54	0.84	1.59
One family and no others: Cohabiting couple households: With dependent children	Households	Percentage	0.59	0.26	1.18	2.02	0.60	1.19	0.86	1.13	0.63	0.51	0.41	0.59	0.24	1.83	0.59	0.13	0.04	1.42	0.46
One family and no others: Cohabiting couple households: All children non-dependent	Households	Percentage	1.18	0.14	0.49	2.09	1.04	1.32	0.76	0.97	1.53	1.39	0.21	0.21	0.14	0.97	0.49	0.90	0.14	1.39	1.04
One family and no others: Lone parent households: With dependent children	Households	Percentage	0.06	1.07	0.03	0.88	1.66	1.63	0.16	0.93	0.29	1.03	1.45	0.02	0.04	1.38	1.33	0.87	0.74	1.17	1.12
One family and no others: Lone parent households: All children non-dependent	Households	Percentage	1.24	0.07	0.01	0.45	0.86	0.34	0.07	1.09	0.43	1.46	1.24	1.29	0.94	1.39	0.92	0.26	1.18	0.86	0.38

Continued on next page

Table B.1 – *Continued from previous page*

MANCHESTER CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1 (i.e. the difference between row value and Manchester value is greater than one standard deviation) **Demographic variables**			**MSOAs compared against Manchester average using standard deviation** **MSOA** 019	020	021	022	023	024	025	026	027	028	029	030	031	032	033	034	035	036	037
Other households: With dependent children	Households	Percentage	0.03	1.04	0.58	1.93	0.73	2.29	1.10	2.26	1.73	0.29	0.06	1.39	0.95	0.40	0.40	0.71	0.29	0.42	0.82
Other households: All student	Households	Percentage	0.74	0.34	0.41	2.11	0.39	0.24	1.47	1.17	0.27	0.16	0.20	0.18	0.12	5.25	0.27	0.14	0.87	3.08	0.38
Other households: All pensioner	Households	Percentage	1.16	1.23	0.58	2.03	0.22	0.51	1.38	0.07	0.51	1.52	0.36	1.09	1.23	0.43	0.80	0.65	0.00	1.38	0.22
Other households: Other	Households	Percentage	0.95	0.56	1.00	1.66	0.87	0.10	1.06	1.16	0.38	0.77	1.70	0.33	0.63	2.05	1.38	0.14	0.66	1.40	1.06
Accommodation type: Whole house or bungalow: Detached	Household Spaces	Percentage	0.07	0.69	1.07	0.61	0.59	0.02	0.86	0.26	0.90	0.73	0.64	0.70	1.07	0.50	0.02	0.07	0.71	0.80	0.49
Accommodation type: Whole house or bungalow: Semi-detached	Household Spaces	Percentage	0.92	0.32	0.57	1.13	0.08	1.47	1.67	0.24	1.29	0.57	0.46	0.73	1.06	0.18	0.82	1.78	1.21	0.28	0.32
Accommodation type: Whole house or bungalow: Terraced (including end terrace)	Household Spaces	Percentage	0.12	0.50	1.61	0.51	0.30	1.64	2.35	1.32	2.22	1.11	0.93	0.83	1.33	0.03	1.10	0.88	0.59	0.50	0.13
Accommodation type: Flat; maisonette or apartment: Purpose Built block of flats or tenement	Household Spaces	Percentage	1.94	0.08	1.05	0.10	0.02	0.02	0.65	1.37	1.02	0.74	0.02	0.23	0.71	0.39	0.51	0.90	0.57	0.00	0.53
Accommodation type: Flat; maisonette or apartment: Part of a converted or shared house (including bed-sits)	Household Spaces	Percentage	0.63	0.46	0.49	1.68	0.59	0.57	0.41	0.45	0.45	2.96	1.21	0.48	0.45	0.02	1.45	0.46	0.14	0.76	0.10
Accommodation type: Flat; maisonette or apartment: In commercial building	Household Spaces	Percentage	0.95	0.79	0.17	0.24	0.25	0.09	0.59	0.49	0.01	0.45	1.48	0.20	2.36	0.18	0.96	0.07	0.24	0.23	0.89
Accommodation type: Caravan or other mobile or temporary structure	Household Spaces	Percentage	0.41	0.41	0.41	0.33	0.41	0.50	0.25	0.41	0.21	0.29	0.08	0.41	0.41	0.41	0.41	0.08	0.41	0.04	0.41
Average Consumption of Domestic Gas	Kilowatt Hours	Count	1.43	1.61	0.07	0.61	0.31	1.54	0.19	1.17	0.28	0.64	2.01	0.24	0.54	0.34	2.43	1.55	0.08	0.23	1.04
Average Consumption of Economy 7 Domestic Electricity	Kilowatt Hours	Count	0.19	1.06	0.81	0.70	1.20	1.12	0.31	0.49	1.42	0.03	0.07	0.24	1.23	0.05	0.14	0.02	0.35	0.20	0.79
Average Consumption of Ordinary Domestic Electricity	Kilowatt Hours	Count	1.59	0.95	0.41	0.92	0.74	1.36	0.78	0.16	0.75	0.91	0.12	0.15	0.28	0.04	0.43	0.19	0.24	0.42	0.42
Average household size	Persons	Rate	1.29	0.00	0.04	1.68	0.04	0.26	0.30	1.25	1.12	0.69	0.39	0.69	0.17	2.59	0.56	1.25	0.90	1.42	0.26
Average number of rooms per household	Rooms	Rate	1.20	0.93	0.19	0.27	0.24	0.43	0.48	0.40	0.13	0.74	0.45	0.29	0.13	0.88	1.20	1.33	0.48	0.27	0.69
Occupancy rating of -1 or less	Households	Percentage	0.78	0.70	0.88	2.10	0.25	0.73	0.89	1.55	0.44	1.22	0.58	0.39	0.08	1.28	0.06	0.58	0.12	1.03	0.60
With central heating and sole use of bath / shower and toilet	Households	Percentage	1.23	0.24	2.64	0.62	0.09	0.10	1.64	0.45	2.99	0.98	0.58	0.63	2.69	0.37	0.26	0.59	0.79	0.26	0.13
Without central heating or sole use of bath / shower and toilet	Households	Percentage	0.18	0.15	0.26	1.03	0.41	0.03	0.03	0.32	0.32	3.29	1.09	0.26	0.76	0.12	2.00	0.47	0.15	0.62	0.06
Without central heating; with sole use of bath / shower and toilet	Households	Percentage	1.19	0.22	2.81	0.47	0.25	0.20	1.68	0.64	3.06	0.46	0.13	0.64	2.72	0.56	0.15	0.72	0.73	0.27	0.09
With central heating; without sole use of bath / shower and toilet	Households	Percentage	0.28	0.03	0.32	0.38	0.50	0.54	0.07	0.71	0.01	1.26	1.84	0.17	0.08	0.86	0.30	0.27	0.32	0.27	0.15
Lowest floor level; Basement or semi-basement	Households	Percentage	0.68	0.57	0.13	1.87	0.50	0.46	0.40	0.19	0.02	1.91	0.77	0.06	1.39	0.52	3.09	0.12	0.07	0.52	0.89
Lowest floor level; Ground level (street level)	Households	Percentage	1.08	0.42	0.79	0.91	0.46	0.34	0.54	0.85	0.56	1.57	0.78	0.12	0.18	0.44	0.99	0.72	0.38	0.36	0.06
Lowest floor level; 1st / 2nd / 3rd or 4th floor	Households	Percentage	1.36	0.22	0.99	0.65	0.45	0.21	0.50	1.17	0.78	1.62	0.97	0.03	0.14	0.57	0.36	0.83	0.43	0.49	0.30
Lowest floor level; 5th floor or higher	Households	Percentage	1.45	0.49	0.30	0.27	0.06	0.28	0.38	0.43	0.13	0.35	0.45	0.37	0.51	0.42	0.54	0.49	0.43	0.53	0.42
		Total	54.06	27.77	35.41	51.22	29.90	41.24	41.88	42.02	38.51	46.34	37.08	20.98	36.90	51.62	41.34	38.59	23.27	40.36	34.54

Continued on next page

Table B.1 – *Continued from previous page*

MANCHESTER CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1 (i.e. the difference between row value and Manchester value is greater than one standard deviation)			MSOAs compared against Manchester average using standard deviation															
Demographic variables			MSOA 038	039	040	041	042	043	044	045	046	047	048	049	050	051	052	053
Owner occupied: Owns with a mortgage or loan	Households	Percentage	0.08	0.56	0.47	0.62	0.01	1.15	0.21	1.93	1.60	1.27	0.48	0.02	1.40	0.17	0.99	0.15
Owner occupied: Shared ownership	Households	Percentage	0.98	0.75	0.43	0.78	0.90	1.24	0.20	0.64	0.38	0.55	0.67	0.75	0.06	0.46	1.85	0.20
Rented from: Council (local authority)	Households	Percentage	0.90	0.64	0.50	1.79	0.45	1.36	1.25	1.46	0.73	0.09	1.00	0.08	0.21	1.41	0.35	1.22
Rented from: Housing Association / Registered Social Landlord	Households	Percentage	0.90	0.84	0.64	1.03	0.56	0.66	1.13	1.02	0.57	0.30	0.98	2.64	3.89	0.75	0.98	0.76
Rented from: Private landlord or letting agency	Households	Percentage	2.14	2.58	0.48	0.89	0.21	0.60	1.01	0.42	0.77	0.94	1.06	0.98	1.06	0.89	1.04	1.04
Rented from: Other	Households	Percentage	1.29	0.54	0.87	0.59	0.45	0.80	0.85	1.71	0.79	0.47	0.19	0.05	0.86	0.36	0.23	0.63
Owner occupied: Owns outright	Households	Percentage	0.24	0.86	0.61	0.73	0.04	1.52	0.36	2.85	1.53	0.45	0.12	1.15	1.44	0.75	0.04	0.55
Median age of population in the area	Persons	Years	0.91	0.68	0.23	0.23	0.23	0.45	0.68	1.13	1.81	1.58	0.91	0.00	0.45	0.68	0.91	0.68
Mean age of population in the area	Persons	Years	0.65	0.72	0.02	0.09	0.57	0.81	0.67	1.01	1.84	1.61	0.68	0.25	0.01	0.59	0.52	0.61
Dwelling Stock by Council Tax Band; Band A	Dwellings	Percentage	0.93	0.82	1.00	1.23	0.42	1.90	0.11	2.22	1.45	0.59	0.31	0.38	1.38	1.06	0.11	1.14
Dwelling Stock by Council Tax Band; Band B	Dwellings	Percentage	0.22	0.13	0.34	1.67	0.20	0.44	1.18	1.03	1.16	0.94	0.53	0.05	1.37	0.54	0.13	0.86
Dwelling Stock by Council Tax Band; Band C	Dwellings	Percentage	0.20	0.80	1.53	0.50	0.18	0.86	0.39	3.64	1.53	0.01	0.01	0.45	0.97	0.96	0.07	1.02
Dwelling Stock by Council Tax Band; Band D	Dwellings	Percentage	1.24	0.30	0.04	0.90	0.27	2.81	0.08	1.48	0.35	0.35	0.26	0.38	0.90	0.86	0.09	0.69
Dwelling Stock by Council Tax Band; Band E	Dwellings	Percentage	1.36	1.34	1.19	0.77	1.02	2.29	0.33	0.50	0.77	1.12	0.26	0.00	0.80	0.62	0.33	0.75
Dwelling Stock by Council Tax Band; Band F	Dwellings	Percentage	3.08	1.40	2.06	0.60	1.80	3.69	0.02	1.66	1.19	0.38	0.06	0.53	0.60	0.55	0.48	0.47
Dwelling Stock by Council Tax Band; Band G	Dwellings	Percentage	0.58	0.21	1.19	0.40	1.98	6.36	0.15	0.94	0.25	0.55	0.40	0.36	0.40	0.36	0.40	0.13
Dwelling Stock by Council Tax Band; Band H	Dwellings	Percentage	0.32	0.48	0.32	0.32	0.81	3.23	0.81	0.16	0.81	0.81	0.81	0.00	0.81	0.00	0.81	0.16
One person: Pensioner	Households	Percentage	1.72	2.23	0.10	0.47	0.55	0.20	0.77	0.15	1.09	1.08	1.10	0.92	1.36	0.30	0.16	0.27
One person: Other	Households	Percentage	0.52	1.17	0.70	0.98	0.10	0.04	0.55	1.37	0.89	0.37	0.54	0.25	0.65	0.69	0.52	0.54
One family and no others: All pensioners	Households	Percentage	1.12	1.27	0.07	0.15	0.13	0.72	0.70	2.41	1.93	1.62	1.04	0.18	0.06	0.82	1.26	1.11
One family and no others: Married couple households: No children	Households	Percentage	0.68	1.45	0.22	0.21	0.39	1.35	0.19	1.70	1.69	1.65	0.59	0.35	0.08	0.31	0.73	0.25
One family and no others: Married couple households: With dependent children	Households	Percentage	0.56	1.36	0.60	0.05	0.25	0.41	0.02	2.95	0.83	0.26	0.08	0.22	0.47	0.10	0.36	0.22
One family and no others: Married couple households: All children non-dependent	Households	Percentage	1.00	1.55	0.07	0.48	0.31	0.39	0.91	1.68	1.00	0.64	0.69	0.23	0.27	0.21	1.46	0.27
One family and no others: Cohabiting couple households: No children	Households	Percentage	2.45	4.00	0.79	0.72	0.27	2.02	0.21	0.14	0.42	0.26	0.39	0.20	0.80	0.69	0.15	0.34
One family and no others: Cohabiting couple households: With dependent children	Households	Percentage	1.20	0.79	0.80	0.87	0.28	1.01	0.95	0.78	0.05	0.31	1.04	1.63	1.88	0.60	1.61	1.01
One family and no others: Cohabiting couple households: All children non-dependent	Households	Percentage	0.49	2.09	0.07	1.04	1.39	0.56	0.56	0.63	0.14	0.21	0.00	2.29	2.02	0.76	0.35	1.46
One family and no others: Lone parent households: With dependent children	Households	Percentage	1.48	1.26	0.81	1.55	0.11	1.67	0.52	1.47	1.25	0.70	0.35	1.44	1.52	1.26	0.25	0.81
One family and no others: Lone parent households: All children non-dependent	Households	Percentage	1.21	1.66	0.54	1.68	0.30	1.62	0.61	0.34	0.18	0.20	0.43	1.33	0.70	1.56	0.17	1.33

Continued on next page

MANCHESTER
CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1 (i.e. the difference between row value and Manchester value is greater than one standard deviation)

MSOAs compared against Manchester average using standard deviation

Demographic variables			**MSOA** 038	039	040	041	042	043	044	045	046	047	048	049	050	051	052	053
Other households: With dependent children	Households	Percentage	1.14	1.28	0.72	1.25	0.62	1.57	0.41	0.53	0.86	1.19	0.73	0.08	0.26	0.15	0.37	0.06
Other households: All student	Households	Percentage	1.04	0.30	0.64	0.39	0.29	0.26	0.39	0.34	0.41	0.41	0.36	0.39	0.39	0.30	0.44	0.41
Other households: All pensioner	Households	Percentage	0.00	1.01	0.14	1.16	0.94	0.58	1.01	0.87	0.51	0.22	0.51	0.65	0.07	0.80	1.23	0.87
Other households: Other	Households	Percentage	2.44	2.48	1.57	0.28	0.58	1.19	0.51	0.16	0.00	0.98	1.03	0.87	0.95	0.56	0.89	0.71
Accommodation type: Whole house or bungalow: Detached	Household Spaces	Percentage	0.03	1.01	0.03	0.79	0.89	1.95	1.10	1.32	3.08	3.18	1.57	0.60	0.66	0.21	1.59	0.01
Accommodation type: Whole house or bungalow: Semi-detached	Household Spaces	Percentage	0.30	1.12	1.38	1.94	0.63	0.03	0.46	2.95	0.76	0.38	0.53	1.04	0.54	0.48	0.43	0.03
Accommodation type: Whole house or bungalow: Terraced (including end terrace)	Household Spaces	Percentage	0.94	0.55	1.27	1.03	1.19	0.74	0.02	1.90	0.74	0.23	0.31	0.32	0.32	0.02	0.13	0.34
Accommodation type: Flat; maisonette or apartment: Purpose Built block of flats or tenement	Household Spaces	Percentage	0.10	0.26	0.21	0.75	0.40	0.17	0.43	1.19	0.32	0.78	0.15	0.57	0.27	0.25	0.31	0.20
Accommodation type: Flat; maisonette or apartment: Part of a converted or shared house (including bed-sits)	Household Spaces	Percentage	2.89	3.45	0.24	0.49	0.45	0.77	0.62	0.61	0.62	0.73	0.63	0.70	0.56	0.62	0.57	0.52
Accommodation type: Flat; maisonette or apartment: In commercial building	Household Spaces	Percentage	1.21	1.85	0.27	0.33	0.05	0.02	0.21	0.38	1.19	1.04	0.56	1.06	0.98	0.27	0.74	0.26
Accommodation type: Caravan or other mobile or temporary structure	Household Spaces	Percentage	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	1.29	0.08	0.04	0.41	0.41	0.41	0.04	0.04
Average Consumption of Domestic Gas	Kilowatt Hours	Count	0.99	0.17	1.22	0.31	0.03	1.92	0.62	2.03	0.99	0.33	0.20	0.75	1.12	0.76	0.31	0.73
Average Consumption of Economy 7 Domestic Electricity	Kilowatt Hours	Count	0.84	0.14	0.97	1.41	0.28	0.71	0.87	0.16	0.77	0.06	1.13	0.29	1.16	4.82	0.96	0.29
Average Consumption of Ordinary Domestic Electricity	Kilowatt Hours	Count	0.20	1.30	0.05	0.00	0.14	0.42	0.18	1.01	0.19	0.24	0.35	0.32	0.00	0.15	0.18	0.16
Average household size	Persons	Rate	0.09	0.99	0.69	0.78	0.56	0.69	0.04	1.16	0.13	0.65	0.13	0.34	0.00	0.13	0.17	0.04
Average number of rooms per household	Rooms	Rate	0.32	1.30	1.04	0.32	0.05	1.01	0.37	2.34	1.14	0.08	0.64	0.19	0.29	0.72	0.53	0.82
Occupancy rating of -1 or less	Households	Percentage	1.00	1.10	0.02	0.35	0.05	0.44	0.77	1.25	0.94	0.97	0.78	0.62	0.55	0.77	0.84	0.94
With central heating and sole use of bath / shower and toilet	Households	Percentage	0.18	0.29	0.49	0.27	0.90	0.58	0.88	0.61	0.58	0.62	1.08	0.90	0.85	0.36	0.21	0.18
Without central heating or sole use of bath / shower and toilet	Households	Percentage	1.44	0.85	0.71	0.32	0.71	0.24	0.44	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Without central heating; with sole use of bath / shower and toilet	Households	Percentage	0.54	0.35	0.37	0.16	0.92	0.54	0.76	0.51	0.45	0.45	0.98	0.77	0.74	0.21	0.37	0.38
With central heating; without sole use of bath / shower and toilet	Households	Percentage	1.10	0.13	0.42	0.44	0.24	0.36	0.44	0.32	0.42	0.64	0.35	0.44	0.36	0.54	0.50	0.63
Lowest floor level; Basement or semi-basement	Households	Percentage	2.35	2.64	0.53	0.90	0.10	1.71	0.95	0.37	0.07	0.96	0.95	0.96	0.90	0.91	0.91	1.01
Lowest floor level; Ground level (street level)	Households	Percentage	1.44	2.00	0.01	0.80	0.36	0.85	0.80	0.96	0.31	0.25	0.65	0.86	0.44	0.64	0.74	0.63
Lowest floor level; 1st / 2nd / 3rd or 4th floor	Households	Percentage	1.32	1.98	0.02	0.63	0.68	0.67	0.62	1.09	0.48	0.14	0.55	0.92	0.37	0.37	0.49	0.36
Lowest floor level; 5th floor or higher	Households	Percentage	0.53	0.46	0.52	0.50	0.38	0.41	0.46	0.46	0.01	0.33	0.00	0.19	0.29	0.56	0.62	0.46
		Total	51.31	59.95	30.67	37.38	26.04	58.41	29.19	61.04	43.96	34.98	29.90	32.08	39.64	34.03	30.62	29.49

Table B.2: Cardiff census calculations and data

CARDIFF CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1 (i.e. the difference between row value and Manchester value is greater than one standard deviation) Demographic variables			MSOAs compared against Cardiff average using standard deviation MSOA 001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	016	017	018	019
Owner occupied: Owns with a mortgage or loan	Households	Percentage	1.01	2.10	2.77	0.35	0.05	1.08	0.37	0.58	0.92	0.00	2.27	0.55	1.45	1.50	0.41	0.57	0.89	0.63	0.10
Owner occupied: Shared ownership	Households	Percentage	0.51	4.14	3.39	0.99	0.32	0.91	0.89	0.57	0.95	0.42	1.72	0.83	1.45	0.95	0.20	0.51	0.00	0.02	1.03
Rented from: Council (local authority)	Households	Percentage	0.90	0.81	0.92	0.92	0.61	0.66	1.55	0.88	0.83	0.31	0.29	0.78	0.84	0.60	1.10	1.56	0.91	0.78	0.92
Rented from: Housing Association / Registered Social Landlord	Households	Percentage	0.93	0.54	0.31	0.92	0.69	0.65	0.11	0.76	0.11	0.25	0.53	0.78	4.32	0.96	0.51	0.55	0.55	0.77	0.58
Rented from: Private landlord or letting agency	Households	Percentage	0.65	0.40	0.51	0.67	0.63	0.67	0.61	0.66	0.45	0.62	0.47	0.57	0.49	0.58	0.56	0.69	0.54	0.62	0.33
Rented from: Other	Households	Percentage	0.93	1.57	1.13	1.15	0.65	1.26	0.68	1.32	0.22	0.56	0.87	1.31	0.88	0.65	0.59	0.93	0.17	1.30	0.65
Owner occupied: Owns outright	Households	Percentage	1.26	0.49	1.07	2.64	0.36	0.87	0.59	1.61	1.29	0.29	1.06	1.47	1.68	0.43	0.17	0.71	0.81	1.41	1.78
Median age of population in the area	Persons	Years	1.45	0.00	0.48	2.73	0.96	0.96	0.32	1.61	0.80	0.96	0.48	1.29	1.29	0.96	0.80	0.16	0.00	0.80	1.61
Mean age of population in the area	Persons	Years	1.12	0.82	1.39	2.68	1.02	0.60	0.04	1.13	1.37	0.99	1.13	1.31	1.75	0.37	0.92	0.06	0.40	0.81	1.39
Dwelling Stock by Council Tax Band; Band A	Dwellings	Percentage	0.74	0.66	0.74	0.73	0.31	0.75	0.89	0.75	0.52	0.71	0.03	0.74	2.60	0.75	0.28	2.21	1.62	0.73	0.75
Dwelling Stock by Council Tax Band; Band B	Dwellings	Percentage	0.76	0.78	0.79	0.87	0.56	0.78	0.57	0.86	0.13	0.05	0.41	0.86	2.09	0.73	0.61	0.60	0.47	0.86	0.66
Dwelling Stock by Council Tax Band; Band C	Dwellings	Percentage	1.14	1.03	1.15	1.06	0.24	1.02	1.57	1.11	1.17	0.36	1.21	0.99	0.71	0.69	2.19	1.99	1.55	1.15	1.21
Dwelling Stock by Council Tax Band; Band D	Dwellings	Percentage	0.71	1.15	0.92	0.88	1.53	0.67	1.21	0.77	1.01	0.51	0.02	0.79	1.18	1.22	1.31	0.92	0.50	0.98	1.29
Dwelling Stock by Council Tax Band; Band E	Dwellings	Percentage	0.85	0.45	1.13	0.14	0.49	0.27	0.77	0.16	0.99	0.79	0.04	0.62	1.22	0.13	0.71	1.29	1.49	1.14	0.48
Dwelling Stock by Council Tax Band; Band F	Dwellings	Percentage	0.08	0.06	0.61	2.16	0.28	1.08	0.54	0.38	0.82	0.12	0.47	1.74	0.81	1.09	0.82	0.87	0.95	3.73	0.87
Dwelling Stock by Council Tax Band; Band G	Dwellings	Percentage	3.26	1.34	0.18	0.70	0.03	1.89	0.43	1.75	0.63	0.04	0.54	0.63	0.68	1.30	0.69	0.66	0.70	0.41	2.84
Dwelling Stock by Council Tax Band; Band H	Dwellings	Percentage	3.53	0.32	0.12	0.14	0.25	1.41	0.22	3.66	0.52	0.35	0.08	0.12	0.44	1.90	0.51	0.52	0.52	0.23	2.27
Dwelling Stock by Council Tax Band; Band I	Dwellings	Percentage	3.89	0.42	0.25	0.08	0.30	0.86	0.26	3.66	0.40	0.19	0.35	0.16	0.42	1.66	0.41	0.38	0.41	0.08	1.76
One person: Pensioner	Households	Percentage	0.54	1.65	2.41	2.04	1.67	0.46	0.07	0.38	2.02	1.34	1.98	0.79	1.09	1.30	1.20	0.31	1.01	0.88	1.26
One person: Other	Households	Percentage	0.73	0.32	0.23	1.33	0.77	1.00	0.80	1.59	0.02	0.20	0.60	1.09	0.12	0.91	0.48	0.54	0.08	1.40	1.08
One family and no others: All pensioners	Households	Percentage	1.39	0.60	1.14	3.18	0.68	0.58	0.39	1.55	1.01	0.49	0.89	1.62	0.97	0.07	1.16	0.04	0.74	1.19	1.74
One family and no others: Married couple households: No children	Households	Percentage	1.81	0.58	1.76	0.81	0.18	2.24	0.30	1.33	0.18	0.09	1.24	0.86	0.77	2.45	0.36	0.23	0.48	0.99	0.80
One family and no others: Married couple households: With dependent children	Households	Percentage	1.57	1.96	1.87	0.04	0.15	1.61	0.11	1.27	0.61	0.02	0.82	0.92	0.40	2.03	0.62	0.41	0.15	1.42	0.90
One family and no others: Married couple households: All children non-dependent	Households	Percentage	0.87	0.28	1.08	0.65	0.79	1.31	0.54	1.89	0.70	0.19	0.79	1.07	0.53	1.35	0.03	0.75	2.07	1.40	0.39
One family and no others: Cohabiting couple households: No children	Households	Percentage	0.51	0.87	2.64	1.14	0.81	0.97	0.66	1.25	0.26	0.15	1.88	0.63	0.58	0.54	0.75	1.27	0.42	0.80	0.89
One family and no others: Cohabiting couple households: With dependent children	Households	Percentage	1.22	0.46	0.96	1.34	0.25	0.35	0.51	1.10	1.77	0.36	1.35	0.52	1.99	0.69	0.55	1.19	1.07	1.00	1.38
One family and no others: Cohabiting couple households: All children non-dependent	Households	Percentage	0.85	0.85	0.00	0.78	0.93	1.86	0.39	0.47	0.23	0.39	2.25	0.47	1.17	0.00	1.17	0.54	0.31	0.08	0.93
One family and no others: Lone parent households: With dependent children	Households	Percentage	0.95	0.17	0.20	1.11	0.12	0.62	1.03	0.80	1.51	0.21	0.01	1.11	3.47	0.57	0.25	1.11	0.55	1.16	0.94

Continued on next page

Table B.2 – *Continued from previous page*

CARDIFF
CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1 (i.e. the difference between row value and Manchester value is greater than one standard deviation)

MSOAs compared against Cardiff average using standard deviation

Demographic variables			**MSOA** 001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	016	017	018	019
One family and no others: Lone parent households: All children non-dependent	Households	Percentage	1.50	0.93	1.96	0.59	0.41	1.35	1.92	0.73	0.40	0.72	0.92	0.21	0.67	0.67	1.73	2.07	0.53	0.19	1.04
Other households: With dependent children	Households	Percentage	1.16	1.25	0.66	1.49	0.40	0.93	0.66	0.22	0.69	0.65	0.62	0.99	0.65	0.41	0.14	1.56	0.68	1.37	0.84
Other households: All student	Households	Percentage	0.33	0.33	0.33	0.33	0.33	0.33	0.30	0.31	0.28	0.33	0.27	0.33	0.23	0.33	0.29	0.33	0.31	0.31	0.26
Other households: All pensioner	Households	Percentage	1.59	1.41	2.18	0.23	1.13	0.36	0.95	0.05	1.59	0.36	1.45	0.36	1.41	1.63	0.23	0.27	1.22	1.72	0.82
Other households: Other	Households	Percentage	0.92	0.67	0.64	1.01	0.73	0.91	0.54	0.64	0.29	0.78	0.56	0.77	0.62	0.83	0.60	0.55	0.48	0.57	0.75
Accommodation type: Whole house or bungalow: Detached	Household Spaces	Percentage	2.93	1.34	2.26	0.55	0.05	2.35	0.17	1.99	0.51	0.08	0.82	0.23	0.30	2.99	0.57	0.48	0.68	0.19	0.75
Accommodation type: Whole house or bungalow: Semi-detached	Household Spaces	Percentage	0.97	0.05	0.16	1.28	0.95	0.27	0.25	0.19	0.20	0.43	0.52	1.35	0.38	0.70	0.66	1.16	0.65	2.45	0.76
Accommodation type: Whole house or bungalow: Terraced (including end terrace)	Household Spaces	Percentage	0.98	0.29	0.81	1.38	0.77	1.16	0.02	1.23	0.63	0.85	0.42	0.87	0.04	1.05	0.31	0.69	0.94	1.38	1.27
Accommodation type: Flat; maisonette or apartment: Purpose Built block of flats or tenement	Household Spaces	Percentage	0.60	1.29	1.34	0.19	0.46	0.63	0.28	0.64	0.46	1.53	1.12	0.71	0.32	1.04	0.98	0.69	1.04	0.93	0.37
Accommodation type: Flat; maisonette or apartment: Part of a converted or shared house (including bed-sits)	Household Spaces	Percentage	0.61	0.71	0.70	0.70	0.61	0.56	0.62	0.65	0.63	0.57	0.69	0.65	0.65	0.68	0.61	0.70	0.65	0.68	0.36
Accommodation type: Flat; maisonette or apartment: In commercial building	Household Spaces	Percentage	0.85	1.06	1.07	0.74	0.21	0.45	0.44	0.67	0.89	0.68	1.07	0.10	1.23	0.93	0.36	0.21	1.05	0.59	0.61
Accommodation type: Caravan or other mobile or temporary structure	Household Spaces	Percentage	0.54	0.54	0.54	0.54	0.05	0.10	0.00	0.54	0.54	0.54	3.76	0.54	0.54	0.05	0.00	0.10	0.54	0.54	0.54
Average Consumption of Domestic Gas	Kilowatt Hours	Count	2.79	0.41	0.13	0.72	0.16	1.73	0.20	2.58	0.91	0.09	0.77	0.80	1.63	1.78	0.50	0.53	0.82	0.97	2.10
Average Consumption of Economy 7 Domestic Electricity	Kilowatt Hours	Count	1.92	1.02	0.30	2.33	0.59	0.05	0.42	0.35	1.74	0.70	2.38	0.24	1.58	1.48	0.61	0.47	0.35	0.71	0.15
Average Consumption of Ordinary Domestic Electricity	Kilowatt Hours	Count	2.77	0.37	0.73	0.02	0.06	1.79	0.35	1.99	0.31	0.15	0.22	0.50	1.00	2.36	0.69	0.25	0.10	0.54	1.13
Average household size	Persons	Rate	0.44	0.55	0.61	1.21	0.17	0.72	0.66	0.83	1.65	0.88	0.17	0.11	0.88	1.21	0.77	0.77	0.55	0.50	0.22
Average number of rooms per household	Rooms	Rate	2.63	0.53	0.86	0.40	0.31	1.99	0.16	1.95	0.22	0.24	0.33	0.64	1.15	2.35	0.78	0.44	0.49	1.37	1.13
Occupancy rating of -1 or less	Households	Percentage	1.23	0.94	0.99	1.46	0.45	1.36	0.13	1.34	0.11	0.20	0.14	1.38	0.44	1.24	0.06	0.00	0.15	1.37	0.65
With central heating and sole use of bath / shower and toilet	Households	Percentage	1.42	1.37	1.41	1.17	0.08	1.25	0.08	1.36	1.40	0.72	0.61	0.64	1.14	1.35	0.42	0.16	1.23	1.11	0.86
Without central heating or sole use of bath / shower and toilet	Households	Percentage	0.55	0.55	0.55	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.05
Without central heating; with sole use of bath / shower and toilet	Households	Percentage	1.45	1.36	1.43	1.15	0.03	1.26	0.01	1.39	1.44	0.68	0.56	0.61	1.16	1.37	0.52	0.20	1.24	1.10	0.93
With central heating; without sole use of bath / shower and toilet	Households	Percentage	0.53	0.96	0.56	0.96	0.33	0.53	0.46	0.53	0.36	0.60	0.56	0.96	0.40	0.56	0.36	0.07	0.60	0.50	0.13
Lowest floor level; Basement or semi-basement	Households	Percentage	0.31	0.66	0.71	0.54	0.71	0.08	0.75	0.18	0.55	0.11	0.74	0.78	0.53	0.25	0.61	0.65	0.26	0.65	0.12
Lowest floor level; Ground level (street level)	Households	Percentage	0.72	1.37	1.33	0.44	0.26	0.71	0.63	0.81	0.03	0.83	1.25	0.90	0.34	1.09	0.33	0.09	0.54	1.15	0.04
Lowest floor level; 1st / 2nd / 3rd or 4th floor	Households	Percentage	0.77	1.48	1.42	0.38	0.13	0.81	0.57	0.92	0.11	0.76	1.32	0.89	0.26	1.24	0.55	0.08	0.55	1.25	0.04
Lowest floor level; 5th floor or higher	Households	Percentage	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.20	1.94	0.38	0.22	0.38	0.38	0.13	0.38	0.42	0.13	0.08
		Total	65.04	46.59	54.22	52.44	25.95	50.01	27.96	56.85	38.11	26.95	45.99	40.94	53.85	54.89	32.70	35.02	35.92	49.58	46.81

Continued on next page

Table B.2 – *Continued from previous page*

CARDIFF CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1 (i.e. the difference between row value and Manchester value is greater than one standard deviation) **Demographic variables**			**MSOAs compared against Cardiff average using standard deviation** **MSOA** 020	021	022	023	024	025	026	027	028	029	030	031	032	033	034	035	036	037	038
Owner occupied: Owns with a mortgage or loan	Households	Percentage	0.06	0.67	0.26	0.12	0.01	0.11	0.87	0.37	1.15	0.13	0.64	0.24	2.52	1.58	0.39	0.46	0.87	0.47	0.39
Owner occupied: Shared ownership	Households	Percentage	0.61	0.85	0.26	0.10	0.99	1.23	0.14	0.16	0.08	0.51	0.32	0.34	0.38	0.28	0.10	0.34	0.32	0.02	0.04
Rented from: Council (local authority)	Households	Percentage	0.61	0.84	0.22	0.78	0.90	0.27	0.86	0.92	0.89	0.86	0.75	0.45	0.70	0.78	0.73	0.85	0.53	1.43	0.65
Rented from: Housing Association / Registered Social Landlord	Households	Percentage	0.64	0.88	0.32	0.17	0.44	0.68	0.44	0.77	0.65	0.15	0.48	0.36	0.32	0.84	0.08	0.26	2.19	0.34	2.57
Rented from: Private landlord or letting agency	Households	Percentage	0.46	0.37	0.63	0.52	0.51	0.89	0.30	0.55	2.53	0.68	2.08	0.64	3.77	2.61	1.47	0.15	0.82	0.49	0.09
Rented from: Other	Households	Percentage	0.76	0.95	0.58	0.50	1.26	0.63	0.64	0.69	0.96	0.85	0.89	0.56	2.98	0.17	0.25	0.92	0.66	0.89	0.06
Owner occupied: Owns outright	Households	Percentage	1.51	1.22	0.88	0.26	1.87	0.28	0.64	0.28	0.39	0.04	0.65	0.19	0.97	0.91	0.37	0.50	0.90	0.73	0.46
Median age of population in the area	Persons	Years	1.61	0.80	0.80	0.16	1.12	1.77	0.96	0.48	1.77	0.16	1.61	0.64	2.09	1.12	0.00	0.48	0.64	0.48	0.16
Mean age of population in the area	Persons	Years	1.48	0.82	0.73	0.09	1.13	1.54	0.65	0.46	1.35	0.20	1.40	0.67	2.06	0.57	0.24	0.47	0.74	0.75	0.37
Dwelling Stock by Council Tax Band; Band A	Dwellings	Percentage	0.75	0.45	0.02	0.36	0.72	0.58	0.70	0.83	0.45	0.45	0.42	0.07	0.43	0.81	0.69	0.72	0.08	0.84	0.22
Dwelling Stock by Council Tax Band; Band B	Dwellings	Percentage	0.76	0.80	0.26	0.25	0.79	0.58	0.68	0.20	0.40	0.39	0.53	0.40	0.34	1.13	0.36	0.64	0.72	0.44	0.52
Dwelling Stock by Council Tax Band; Band C	Dwellings	Percentage	0.64	0.98	0.03	0.78	1.10	0.33	0.98	0.68	0.54	0.66	0.42	0.05	0.31	0.01	0.41	0.57	0.40	2.18	0.83
Dwelling Stock by Council Tax Band; Band D	Dwellings	Percentage	1.04	1.00	0.41	1.70	0.98	0.07	0.47	1.68	0.67	0.48	0.39	1.99	0.53	0.13	0.30	0.45	1.59	0.24	1.59
Dwelling Stock by Council Tax Band; Band E	Dwellings	Percentage	0.93	1.70	1.55	0.45	0.18	1.60	0.32	1.11	2.77	0.84	1.38	0.39	1.15	0.48	0.20	0.87	0.94	1.16	1.16
Dwelling Stock by Council Tax Band; Band F	Dwellings	Percentage	0.96	1.50	0.32	0.77	0.81	0.42	0.97	0.77	0.27	1.73	0.24	0.81	0.35	0.30	0.54	0.13	0.84	0.73	0.95
Dwelling Stock by Council Tax Band; Band G	Dwellings	Percentage	0.66	0.28	0.58	0.68	1.92	0.67	0.81	0.68	0.65	1.01	0.18	0.66	0.28	0.46	0.64	0.46	0.64	0.70	0.70
Dwelling Stock by Council Tax Band; Band H	Dwellings	Percentage	0.59	0.46	0.46	0.52	1.07	0.51	1.46	0.51	0.52	0.27	0.08	0.48	0.07	0.40	0.25	0.26	0.51	0.52	0.52
Dwelling Stock by Council Tax Band; Band I	Dwellings	Percentage	0.05	0.42	0.38	0.41	2.57	0.42	0.69	0.39	0.39	0.35	0.39	0.41	0.18	0.36	0.16	0.39	0.35	0.42	0.39
One person: Pensioner	Households	Percentage	1.72	0.29	0.36	0.83	1.15	0.45	0.02	0.37	1.12	0.16	1.03	1.26	0.89	0.66	0.54	0.47	0.49	0.01	0.29
One person: Other	Households	Percentage	1.08	0.86	1.17	0.50	1.31	0.19	0.07	0.51	0.26	0.62	0.51	0.26	0.05	2.36	1.97	0.11	1.93	0.09	0.71
One family and no others: All pensioners	Households	Percentage	1.28	0.72	0.72	0.29	1.71	0.45	0.24	0.22	0.60	0.44	1.19	0.47	1.07	1.08	1.08	0.03	1.08	0.47	0.83
One family and no others: Married couple households: No children	Households	Percentage	0.64	0.86	0.85	0.33	1.16	0.65	0.59	0.53	1.37	0.27	1.26	0.02	1.74	1.42	0.48	0.16	1.29	0.84	0.92
One family and no others: Married couple households: With dependent children	Households	Percentage	0.67	0.71	0.59	0.07	0.56	0.65	1.16	0.62	1.47	0.21	0.88	0.35	2.22	1.74	1.02	0.01	1.46	0.33	0.64
One family and no others: Married couple households: All children non-dependent	Households	Percentage	0.85	1.27	1.46	0.35	1.18	0.56	0.33	0.03	1.25	0.04	1.06	0.19	1.67	1.81	1.34	0.18	1.39	0.52	0.92
One family and no others: Cohabiting couple households: No children	Households	Percentage	1.08	0.46	1.09	0.42	0.94	0.30	0.09	0.05	0.46	1.03	0.99	0.84	0.58	2.12	2.57	0.44	1.41	0.04	0.27
One family and no others: Cohabiting couple households: With dependent children	Households	Percentage	0.93	0.39	0.43	0.54	1.22	0.51	0.67	0.45	1.05	0.82	0.63	0.11	1.68	1.18	0.06	0.37	0.14	1.53	1.01
One family and no others: Cohabiting couple households: All children non-dependent	Households	Percentage	0.93	0.23	0.47	2.25	0.78	0.31	1.01	0.78	0.62	0.85	0.16	0.47	1.86	0.08	1.86	0.85	2.18	0.31	0.93
One family and no others: Lone parent households: With dependent children	Households	Percentage	0.92	0.73	0.17	0.56	1.01	0.46	0.69	0.39	1.05	0.76	0.94	0.29	1.24	0.86	0.69	0.47	0.34	1.43	0.76

Continued on next page

Table B.2 – *Continued from previous page*

CARDIFF
CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1 (i.e. the difference between row value and Manchester value is greater than one standard deviation)

MSOAs compared against Cardiff average using standard deviation

Demographic variables			**MSOA** 020	021	022	023	024	025	026	027	028	029	030	031	032	033	034	035	036	037	038
One family and no others: Lone parent households: All children non-dependent	Households	Percentage	0.41	0.31	0.08	1.15	0.20	0.60	0.75	1.16	0.59	0.87	1.20	0.53	1.53	1.17	1.08	0.13	0.13	0.58	0.58
Other households: With dependent children	Households	Percentage	1.59	0.56	0.24	0.76	1.05	0.27	0.94	0.15	0.47	0.24	0.91	0.20	0.93	0.64	0.72	0.84	0.13	0.10	0.87
Other households: All student	Households	Percentage	0.33	0.28	0.31	0.31	0.25	1.07	0.31	0.31	3.37	0.05	1.88	0.33	5.15	1.02	0.14	0.28	0.06	0.25	0.25
Other households: All pensioner	Households	Percentage	1.45	1.50	0.23	0.05	0.91	2.27	0.41	0.63	0.18	1.27	0.32	0.36	0.14	0.14	1.27	0.32	0.14	0.23	0.32
Other households: Other	Households	Percentage	0.63	0.33	0.45	0.24	0.55	1.84	0.61	0.59	2.98	0.47	2.70	0.57	2.33	1.95	1.23	0.38	1.18	0.06	0.49
Accommodation type: Whole house or bungalow: Detached	Household Spaces	Percentage	0.00	0.29	0.17	0.55	0.76	0.71	0.76	0.34	0.73	0.56	0.77	0.59	0.71	0.75	0.78	0.50	0.76	0.57	0.72
Accommodation type: Whole house or bungalow: Semi-detached	Household Spaces	Percentage	1.18	0.78	1.88	1.09	0.66	0.67	0.45	0.25	1.51	0.59	1.53	0.76	1.45	1.31	1.34	0.53	1.48	0.09	1.47
Accommodation type: Whole house or bungalow: Terraced (including end terrace)	Household Spaces	Percentage	0.94	0.30	1.05	0.21	1.22	1.42	0.86	0.20	2.20	0.63	1.85	0.40	1.04	0.33	0.92	0.99	1.17	0.72	2.01
Accommodation type: Flat; maisonette or apartment: Purpose Built block of flats or tenement	Household Spaces	Percentage	0.18	1.08	0.67	0.35	0.40	1.05	0.17	1.12	1.16	0.56	1.04	0.97	0.34	0.18	0.17	0.37	0.48	0.43	0.43
Accommodation type: Flat; maisonette or apartment: Part of a converted or shared house (including bed-sits)	Household Spaces	Percentage	0.48	0.48	0.61	0.55	0.30	0.36	0.12	0.67	0.44	1.72	1.38	0.66	1.70	3.85	2.70	0.16	1.45	0.48	0.06
Accommodation type: Flat; maisonette or apartment: In commercial building	Household Spaces	Percentage	0.26	0.15	0.18	0.35	0.66	1.41	0.65	0.10	1.52	0.17	1.95	0.81	2.78	1.91	1.64	0.58	1.74	0.67	0.63
Accommodation type: Caravan or other mobile or temporary structure	Household Spaces	Percentage	0.54	0.54	0.54	0.54	0.54	0.54	0.54	1.78	0.00	0.54	0.49	4.50	0.54	0.20	0.05	0.54	0.05	1.19	0.00
Average Consumption of Domestic Gas	Kilowatt Hours	Count	0.75	0.41	0.50	0.39	1.81	0.16	1.03	0.98	0.53	0.69	0.14	0.37	0.01	0.70	0.32	0.05	0.69	0.84	0.61
Average Consumption of Economy 7 Domestic Electricity	Kilowatt Hours	Count	0.15	0.57	1.21	0.14	1.20	1.42	0.66	0.01	0.99	0.02	0.10	1.35	0.12	1.34	0.70	0.57	0.91	0.95	1.20
Average Consumption of Ordinary Domestic Electricity	Kilowatt Hours	Count	0.33	0.03	0.81	0.38	0.99	0.33	0.86	0.69	0.30	0.15	0.61	0.46	1.96	1.35	0.81	0.63	1.35	0.85	1.13
Average household size	Persons	Rate	0.50	0.11	0.61	0.17	0.22	0.72	0.17	1.05	1.87	0.39	1.54	0.66	3.03	1.43	1.87	0.72	1.49	0.11	0.66
Average number of rooms per household	Rooms	Rate	0.75	0.62	0.35	0.42	1.44	0.36	1.02	0.80	0.20	0.55	0.11	0.62	0.07	1.44	0.22	0.26	1.20	0.93	0.82
Occupancy rating of -1 or less	Households	Percentage	1.02	1.07	0.80	0.30	0.93	0.31	0.75	0.31	0.54	0.39	1.18	0.01	2.41	2.62	0.73	0.25	1.13	0.46	0.39
With central heating and sole use of bath / shower and toilet	Households	Percentage	0.44	0.55	0.13	0.29	1.06	0.30	0.74	0.66	1.12	0.48	1.21	0.07	1.09	1.67	1.03	0.39	1.53	0.53	1.71
Without central heating or sole use of bath / shower and toilet	Households	Percentage	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	1.05	2.60	0.90	0.55	0.70	5.24	1.10	0.05	0.50	0.05	0.25
Without central heating; with sole use of bath / shower and toilet	Households	Percentage	0.40	0.52	0.11	0.40	1.07	0.39	0.70	0.80	1.14	0.30	1.00	0.17	1.13	1.17	1.03	0.43	1.58	0.59	1.78
With central heating; without sole use of bath / shower and toilet	Households	Percentage	0.46	0.40	0.10	0.66	0.50	0.33	0.96	0.60	0.10	0.86	2.91	0.60	0.20	3.81	0.23	0.17	0.53	0.17	0.60
Lowest floor level; Basement or semi-basement	Households	Percentage	0.77	0.86	0.60	0.68	0.58	0.65	0.12	0.78	0.25	0.98	0.58	0.67	1.65	2.20	3.50	0.10	1.57	0.71	0.08
Lowest floor level; Ground level (street level)	Households	Percentage	0.25	1.06	0.84	0.44	0.05	0.67	0.15	0.16	0.35	0.55	0.12	0.08	1.50	2.25	1.89	0.12	1.24	0.62	0.24
Lowest floor level; 1st / 2nd / 3rd or 4th floor	Households	Percentage	0.11	1.07	0.85	0.62	0.22	0.65	0.19	0.39	0.43	0.50	0.07	0.09	1.41	2.30	1.59	0.13	1.20	0.57	0.24
Lowest floor level; 5th floor or higher	Households	Percentage	0.25	0.38	0.38	1.86	0.18	0.38	0.18	0.22	0.38	0.20	0.38	0.38	0.52	0.27	0.22	0.38	0.24	0.21	0.38
		Total	38.97	36.31	30.23	28.15	47.70	36.52	32.10	30.80	50.07	31.30	48.36	30.34	66.85	67.50	46.08	21.88	49.39	31.33	36.83

Continued on next page

Table B.2 – *Continued from previous page*

CARDIFF
CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1
(i.e. the difference between row value and Manchester value is greater than one standard deviation)

MSOAs compared against Cardiff average using standard deviation

Demographic variables			MSOA 039	040	041	042	043	044	045	046	047
Owner occupied: Owns with a mortgage or loan	Households	Percentage	1.51	0.45	0.34	1.46	0.05	0.26	0.30	0.17	1.15
Owner occupied: Shared ownership	Households	Percentage	0.24	0.28	0.20	0.18	0.53	0.12	0.46	0.16	0.81
Rented from: Council (local authority)	Households	Percentage	3.66	0.50	1.53	0.07	1.27	0.53	0.85	0.08	1.10
Rented from: Housing Association / Registered Social Landlord	Households	Percentage	0.64	0.53	0.07	1.53	0.42	0.44	0.94	0.40	0.86
Rented from: Private landlord or letting agency	Households	Percentage	0.52	0.00	0.49	0.91	0.60	0.40	0.47	0.06	0.71
Rented from: Other	Households	Percentage	1.96	0.09	1.15	1.26	0.26	0.09	0.53	0.16	1.91
Owner occupied: Owns outright	Households	Percentage	1.35	0.36	0.79	0.70	0.39	0.09	0.65	0.24	1.46
Median age of population in the area	Persons	Years	0.80	0.32	0.00	0.64	0.16	0.48	0.00	0.16	0.48
Mean age of population in the area	Persons	Years	1.06	0.47	0.01	0.60	0.00	0.76	0.33	0.26	0.42
Dwelling Stock by Council Tax Band; Band A	Dwellings	Percentage	1.91	0.16	2.24	0.63	0.69	0.49	3.02	0.71	0.20
Dwelling Stock by Council Tax Band; Band B	Dwellings	Percentage	4.40	0.36	1.35	0.98	2.29	0.09	0.51	0.19	0.35
Dwelling Stock by Council Tax Band; Band C	Dwellings	Percentage	0.07	0.22	1.22	0.05	0.34	1.53	1.53	0.00	0.59
Dwelling Stock by Council Tax Band; Band D	Dwellings	Percentage	2.09	0.67	0.76	1.03	0.05	0.30	0.82	1.13	0.86
Dwelling Stock by Council Tax Band; Band E	Dwellings	Percentage	1.52	1.31	1.19	0.20	0.61	0.04	0.92	0.62	0.94
Dwelling Stock by Council Tax Band; Band F	Dwellings	Percentage	0.95	0.47	0.91	0.79	0.70	0.68	0.86	0.74	0.16
Dwelling Stock by Council Tax Band; Band G	Dwellings	Percentage	0.70	0.60	0.70	0.62	0.70	0.67	0.70	0.69	0.20
Dwelling Stock by Council Tax Band; Band H	Dwellings	Percentage	0.52	0.51	0.52	0.51	0.49	0.51	0.52	0.52	0.40
Dwelling Stock by Council Tax Band; Band I	Dwellings	Percentage	0.42	0.38	0.37	0.42	0.40	0.41	0.39	0.42	0.33
One person: Pensioner	Households	Percentage	0.04	0.31	0.76	0.08	0.36	0.52	0.10	0.07	0.38
One person: Other	Households	Percentage	0.49	0.54	0.19	2.07	0.45	0.37	0.25	0.58	2.86
One family and no others: All pensioners	Households	Percentage	0.59	0.18	0.33	1.05	0.01	0.73	0.46	0.50	1.34
One family and no others: Married couple households: No children	Households	Percentage	1.07	0.28	0.22	1.53	0.30	0.92	0.08	0.02	0.95
One family and no others: Married couple households: With dependent children	Households	Percentage	0.73	0.44	0.69	0.71	0.07	0.01	0.30	0.25	1.76
One family and no others: Married couple households: All children non-dependent	Households	Percentage	0.34	0.25	0.00	1.35	0.42	0.52	0.15	0.60	2.05
One family and no others: Cohabiting couple households: No children	Households	Percentage	1.13	0.72	0.68	0.09	0.75	0.22	0.54	0.40	1.41
One family and no others: Cohabiting couple households: With dependent children	Households	Percentage	1.96	0.08	1.67	1.10	1.27	0.03	1.11	0.22	0.91
One family and no others: Cohabiting couple households: All children non-dependent	Households	Percentage	1.40	0.39	0.54	0.23	0.62	0.16	1.01	1.86	0.31
One family and no others: Lone parent households: With dependent children	Households	Percentage	2.81	0.29	1.02	0.07	0.68	0.62	0.91	0.30	0.48

Continued on next page

Table B.2 – *Continued from previous page*

CARDIFF
CELLS ARE SHADED WHEN THEY ARE GREATER THAN 1
(i.e. the difference between row value and Manchester value is greater than one standard deviation)

MSOAs compared against Cardiff average using standard deviation

Demographic variables			**MSOA** 039	040	041	042	043	044	045	046	047
One family and no others: Lone parent households: All children non-dependent	Households	Percentage	2.18	0.50	1.60	0.39	0.92	0.15	1.02	0.66	0.20
Other households: With dependent children	Households	Percentage	1.77	0.64	0.12	2.32	0.79	3.04	0.81	1.28	0.70
Other households: All student	Households	Percentage	0.29	0.23	0.31	0.13	0.33	0.19	0.33	0.33	0.26
Other households: All pensioner	Households	Percentage	0.05	1.36	0.86	0.27	0.23	1.13	0.86	0.18	1.04
Other households: Other	Households	Percentage	0.66	0.70	0.31	0.88	0.66	0.73	0.40	0.09	0.59
Accommodation type: Whole house or bungalow: Detached	Household Spaces	Percentage	0.42	0.74	0.43	0.69	0.10	0.70	0.35	0.54	0.71
Accommodation type: Whole house or bungalow: Semi-detached	Household Spaces	Percentage	1.15	0.69	0.52	1.30	0.64	1.37	0.71	0.49	1.06
Accommodation type: Whole house or bungalow: Terraced (including end terrace)	Household Spaces	Percentage	0.38	1.50	0.05	0.63	0.39	1.91	0.48	0.85	0.32
Accommodation type: Flat; maisonette or apartment: Purpose Built block of flats or tenement	Household Spaces	Percentage	0.29	0.82	0.25	1.02	0.14	0.87	0.91	0.01	4.55
Accommodation type: Flat; maisonette or apartment: Part of a converted or shared house (including bed-sits)	Household Spaces	Percentage	0.45	0.09	0.50	1.80	0.56	0.40	0.65	0.11	0.23
Accommodation type: Flat; maisonette or apartment: In commercial building	Household Spaces	Percentage	0.88	0.32	0.13	1.24	0.40	2.08	0.45	0.67	0.31
Accommodation type: Caravan or other mobile or temporary structure	Household Spaces	Percentage	0.05	0.54	0.05	0.54	0.64	0.00	0.05	0.54	0.10
Average Consumption of Domestic Gas	Kilowatt Hours	Count	0.84	0.34	0.80	0.78	0.78	0.25	0.80	0.35	1.17
Average Consumption of Economy 7 Domestic Electricity	Kilowatt Hours	Count	1.93	0.65	1.02	0.68	1.98	0.64	0.87	0.32	1.17
Average Consumption of Ordinary Domestic Electricity	Kilowatt Hours	Count	0.46	0.86	0.31	1.68	0.10	1.33	0.18	0.95	1.13
Average household size	Persons	Rate	0.88	0.61	0.33	0.50	0.06	0.83	0.11	0.39	2.54
Average number of rooms per household	Rooms	Rate	1.08	0.02	0.89	1.28	0.66	0.04	0.67	0.49	1.93
Occupancy rating of -1 or less	Households	Percentage	1.17	0.27	0.32	2.43	0.10	0.30	0.47	0.37	1.58
With central heating and sole use of bath / shower and toilet	Households	Percentage	0.04	1.61	0.32	0.69	0.15	2.35	0.24	0.89	0.49
Without central heating or sole use of bath / shower and toilet	Households	Percentage	0.55	0.10	0.55	0.40	0.05	0.00	0.55	0.25	0.05
Without central heating; with sole use of bath / shower and toilet	Households	Percentage	0.04	1.71	0.40	0.44	0.11	2.44	0.30	0.95	0.53
With central heating; without sole use of bath / shower and toilet	Households	Percentage	0.43	0.23	0.13	3.38	0.56	1.19	0.00	0.03	0.17
Lowest floor level; Basement or semi-basement	Households	Percentage	0.54	0.34	0.48	3.37	0.71	0.17	0.70	0.62	0.03
Lowest floor level; Ground level (street level)	Households	Percentage	0.54	0.29	0.20	2.46	0.46	0.24	0.01	0.08	3.52
Lowest floor level; 1st / 2nd / 3rd or 4th floor	Households	Percentage	0.51	0.38	0.10	2.21	0.37	0.29	0.13	0.20	3.59
Lowest floor level; 5th floor or higher	Households	Percentage	0.38	0.38	0.38	0.43	0.38	0.38	0.32	0.21	5.91
		Total	52.83	27.07	31.28	52.80	27.13	35.01	31.06	23.38	59.24

B. Census calculations

C | Q study factor loadings

Cardiff Factors					Manchester Factors		
Qsort	1	2	3	4	**Qsort**	1	2
C1HTY1	0.7068X	0.2671	0.2048	−0.2048	M1HOY1	0.7019X	0.342
C1HOY2	0.7661X	0.2399	−0.1937	0.1937	M1HOO2	0.2943	0.1681
C1HOY3	0.6260X	0.3757	−0.2308	0.2308	M1HOY3	0.7937X	−0.0968
C2HOY4	0.4626X	0.2787	0.2251	−0.2251	M1HTY4	0.6904X	−0.0984
C1HOY5	0.18	0.5455X	−0.1022	0.1022	M1FTO5	0.2745	0.2602
C1HOY6	0.6971	0.1962	0.2818X	−0.2818	M1HTY6	0.6609X	0.0564
C1HOY7	0.7977X	0.083	0.236	−0.236	M1HTY7	0.6150X	0.1629
C2HOY8	0.3548	0.4679X	−0.245	0.245	M1HTY8	0.5096X	0.1729
C2HTY9	0.4028X	0.1311	−0.034	0.034	M2HOO9	0.4855	0.4702
C1HOY10	0.3038	0.4632X	0.0646	−0.0646	M3HTY10	−0.0529	0.7494X
C1HOY11	0.5695X	0.225	−0.2223	0.2223	M2HOY11	0.4713	0.4969
C2HOY12	0.7549X	0.1582	−0.0357	0.0357	M2HOY12	0.2389	0.4386X
C2HOY13	−0.1006	−0.1848	0.1657	−0.1657	M2FTY13	0.6272	0.4946
C2HTY14	0.4971	0.358	−0.288	0.2880X	M2HOY14	0.6752	0.4383
C2HTY15	0.8362	0.2152	−0.3362	0.3362X	M2HOY15	0.6266X	0.3505
C1HOY16	0.7354X	0.2686	−0.0693	0.0693	M2HOY16	0.6036X	0.2083
C1HOY17	0.8918X	−0.0388	0.1312	−0.1312	M2HOO17	0.8025X	0.0721
C1HOY18	0.8690X	0.1059	−0.1248	0.1248	M3HTY18	0.4877	0.4628

Continued on next page

Table C.1 – *Continued from previous page*

Cardiff Factors					Manchester Factors		
Qsort	1	2	3	4	**Qsort**	1	2
C2HTY19	0.3896	0.4491X	−0.1767	0.1767	M3HOY19	0.4143	0.591
C1HOY20	0.6011	0.452	−0.1813	0.1813	M3HOO20	0.4857	0.4583
C3FTY21	0.5065	0.4242	0.1956	−0.1956	M2FTO21	−0.055	0.3728X
C2HOY22	0.5849	0.2143	−0.338	0.3380X	M2HOY22	0.4398X	0.3314
C2HOY23	0.8487X	0.0944	−0.008	0.008	M2HOY23	0.6452X	0.2344
C1HTY24	0.8074X	0.1921	0.0389	−0.0389	M2HOY24	0.6323X	0.1226
C3HOY25	0.5543	0.4987	0.0474	−0.0474	M1HOY25	0.5949	0.3996
C3HOY26	0.4940X	0.3657	−0.1379	0.1379	M3HOO26	−0.3191	0.6026X
C3FOO27	0.6256X	0.345	0.1792	−0.1792	M1HTY27	0.5816X	0.1197
C3HOO28	0.6715	0.4219	0.2317	−0.2317	M2HOY28	0.5953X	0.2415
C3HOY29	0.7808X	0.2196	−0.0534	0.0534	M3HOY29	0.6439X	0.3069
C4HOY30	0.554	−0.0459	0.3009X	−0.3009	M4HOO30	0.0688	0.3714X
C4HOY31	0.6731	0.4089	0.2082	−0.2082	M3HTY31	0.5572X	0.1902
C2HOY32	0.7022X	0.1821	−0.1779	0.1779	M4FOO32	0.6262X	0.2707
C3HOO33	0.6194X	0.3176	0.137	−0.137	M3HTY33	0.4333	0.7265
C4HOY34	0.6918X	0.2246	0.1496	−0.1496	M3HOO34	0.6497X	0.1197
C3FTY35	0.8220X	0.0412	0.104	−0.104	M3HOO35	0.6966X	0.1762
C4HOY36	0.4576	0.4588	−0.2687	0.2687X	M4HOY36	0.5637X	0.237
C3HOO37	0.5397X	0.3666	0.2002	−0.2002	M4HTY37	0.4453	0.5388
C4HTY38	0.6778	0.0327	−0.3847	0.3847X	M4HOO38	0.6249X	−0.0582
C4HOY39	0.8554X	−0.0723	−0.0997	0.0997	M4HOY39	0.5967	0.5039
C4HTY40	0.6665X	0.0914	−0.1141	0.1141	M4HOY40	0.6820X	0.3135
C4HOY41	0.2948	0.4112	0.2941X	−0.2941	M3HTO41	0.6845	0.3786
C3HOY42	0.7252X	0.1467	−0.1374	0.1374	M3HTY42	0.4981	0.4245
C3HOY43	0.7860X	0.2277	−0.0282	0.0282	M3HTY43	0.7403X	0.3644

Continued on next page

Table C.1 – *Continued from previous page*

Cardiff Factors					**Manchester Factors**		
Qsort	1	2	3	4	**Qsort**	1	2
C4FOY44	0.5674X	0.3364	−0.1926	0.1926	M4HOY44	0.6401	0.4403
C4FTY45	0.0408	0.5981X	0.0128	−0.0128	M4HOO45	0.7884X	0.3142
					M4HOO46	0.6395X	0.288
%expl.Var.	40	10	4	4	%expl.Var.	33	14

Table C.1: Factor loadings

C. Q study factor loadings

D | Winter and summer survey data

This Appendix compares the returned winter survey results with the summer equivalent. The green shading highlights which statements between summer and winter were in agreement. A bright green indicates winter statements that overlap with +6 summer statements, the mid-green indicates winter overlap with +5 summer, and the dark brown-green indicates overlap with +4. The responses to the other questions in the winter survey are shown in short hand for context.

D. Winter and summer survey data

Table D.1: Manchester winter versus summer survey results

MANCHESTER RETURNED SURVEYS

ID	Question 1 (thoughts)	Question 2 (motivation & barrier)	Q 3 (freq)	Q 4 (heat)	Question 5 (reasons)	Winter Agree	Summer Agree +6	Summer Agree +5	Summer Agree +4	Winter Disagree	Summer Disagree -6	Summer Disagree -5	Summer Disagree -4
15	Make effort but do not go without just to save	Nothing to change	2	1	D – that climate change is not real, and energy costs are rea A – that gov isn't doing enough	2 13 24 38 57	2 57	9 16 29	14 23 38 39	19 42 45 50 65	42 45	19 52 65	11 33 47 55
22	To save resources	Doing best to conserve because of budget constraints	0	2	Would like to help	- - - - -				- - - - -			
40	Energy bill is high but trying to conserve	energy use reasonable, prices to place. House itself is barrier to more retrofits	1	1	A – reflect frustration with energy. Powerless D – only fools would agree	1 2 4 34 49	53 65	14 27 51	22 25 29 39	11 19 42 52 60	55 60	28 42 45	19 33 52 61
29	Try to be economical, but hard with heating	like to be better insulated but barriers money and husband resistant	2	2	Statements that reflect view. Too dep. On fossil fuels and should be more energ eff	16 18 30 39 54	30 51	16 18 27	2 39 48 49	3 11 52 59	19 47	17 52 59	3 12 35 62
1	gas central heating is efficient and easy to manage, and try overall	wants solar but cant afford if on benefits then save money cause council does free	1	1	D – appearance don't mean much, who cares A – generate own energy	12 22 25 49 51	29 44	2 4 13	1 21 23 27	3 17 19 42 60	33 56	17 42 60	18 19 55 61
34	Happy since energy isnt wasted in household	No	1	0	Brought up to not waste things, so even in good finances dont want to waste energy	6 30 31 48 57	6 50	16 48 49	9 20 41 51	17 19 42 60 62	17 19	3 33 42	12 55 59 61
16	Essential and convinient, but expensive	low energy bulbs are expensive and not as bright, want solar/wind but cost	2	1	BLANK	2 13 16 20 39	13 39	16 27 29	20 21 49 53	11 12 17 28 42	55 58	47 61 62	42 45 63 65
26	Use as little as necessary, but leave lights on and use a little too much heating	good finance, dont care about reducing	4	0	because agree or disagree naturally	3 17 30 56 60	30 59	3 33 56	17 26 31 54	5 18 20 23 48	42 48	18 51 58	5 36 62 64
11	Try to be efficient and use minimal amount	Moving house soon so no need to invest, expensive central heating and double gl	2	1	A – global warming major thread, so gov should be do. M D – Not a disruption to lfestyle	16 21 24 37 39	16 21	22 24 27	14 38 39 49	20 33 42 48 52	17 42	26 52 55	28 37 56 57
14	Try to keep it down because of environment and costs. Wear extra clothes	Maybe use microwave to cook inertia keeps me from checking	2	1	A – mainly around personal actions D – are mainly too general P.S. More effort needed for marine	6 10 39 49	49 57	24 43 53	7 16 25 27	17 19 42 56 60	33 42	8 11 17	26 46 60 64
18	Now live in housing assoc flat. Bill included in rent and big relief. Auto heating	Would like ability to set own usage	3	1	TOO MUCH ANSWER TO WRITE HERE	16 20 21 63 65	29 44	23 51 63	8 21 46 49	6 19 26 42 50	42 50	5 18 19	6 33 59 62
33	House needs too much heat, elec cooker slow, would like suppliers to go renewable	As tenant, can't change much prefer gas cooker and investigate insulation	2	2	A – human cons is a prob due to enviro but guilty of not doing enough D – problems should be tackled by consumer (no should be gov)	7 13 14 27 54	21 27	13 16 25	9 39 49 53	11 17 18 42 48	42 60	20 26 48	11 17 18 19
37	Big house and victorian so harder and exp to heat. Feel better after annual service	Replace chim and get flue lined needed for safety and save heat	1	1	Wasn't able. Felt answers were too arbitrary	9 14 16 25 39	34 44	21 25 65	13 23 38 64	7 26 28 45 52	5 42	50 55 60	19 28 37 48
39	Use as much as needed	Wall insulaion better control of heating because save energy, barrier time, cost, and effort	2	1	Save environment, don't like wasting resources, being self-sufficient	13 22 39 51 65	49 65	2 21 25	16 39 57 63	3 11 42 59 60	42 60	19 50 52	11 35 40 59

Continued on next page

Table D.1 – *Continued from previous page*

MANCHESTER RETURNED SURVEYS							+6	+5	+4		-6	-5	-4
ID	**Question 1 (thoughts)**	**Question 2 (motivation & barrier)**	**Q 3 (freq)**	**Q 4 (heat)**	**Question 5 (reasons)**	**Winter Agree**	**Summer Agree**			**Winter Disagree**	**Summer Disagree**		
44	Worry about using to much in terms of enviro resp. and cost	limited to cost and confilcting advice. Like to be self-sufficent but worried about age and outlay	0	3	Looked for those I felt nearest to 100% certain about	13 18 30 37 63	18 63	23 30 44	21 27 39 49	19 26 28 42 60	11 42	19 47 60	28 35 45 50

Table D.2: Cardiff winter versus summer survey results

ID	Question 1 (thoughts)	Question 2 (motivation & barrier)	Q 3 (freq)	Q 4 (heat)	Question 5 (reasons)	Winter Agree	Summer Agree +6	Summer Agree +5	Summer Agree +4	Winter Disagree	Summer Disagree -6	Summer Disagree -5	Summer Disagree -4
3	Use a great deal, mention of family and kids	Family and supplier/hassle, personal habit more efficient dishwash	2	0	D – appearances not relevant. A – want household to be more cost effective	2 9 35 44 63	44 63	2 24 49	9 15 46 54	11 17 19 42 55	19 59	17 26 62	18 42 52 55
7	Use least possible, keep CO2 footprint down but keep warm	change supplier to coop for environment but don't know of group	2	1	D – disagree with myths A – all about environment and energy efficiency	5 13 24 29 49	27 49	24 41 57	2 5 9 21	3 33 35 42 55	42 55	3 8 52	12 19 28 61
1	energy aware for finance but also environment. All family on board	M – improve heating system B – rented properly and age of property	1	0	D – with gov not doing good job A – makes conscious effort and considers social + tech	9 18 36 40 54	40 54	13 49 57	9 20 21 35	8 24 33 46 52	46 62	33 42 52	11 12 26 55
4	Use as little as possible, keep heating down when not in house	BLANK	1	1	Consume energy with respect to rising cost	2 16 25 49 54	40 41	43 44 57	2 61 62 64	34 42 45 59 65	12 26	20 28 33	38 52 58 59
27	Doesn't like to waste energy	Gas and elec in home, feels confident how to use them	1	1	Raised by dad not to waste, money should be spent to use resources like water for energ	9 23 25 30 48 51	13 25	7 48 57	9 23 39 51	3 28 42 55 61	3 55	28 33 61	35 52 59 64
42	Have already done a lot	Wants double glazing on front but would require to much money and aesthetic	1	0	Need regulation and strong standards to deal with global climate	2 18 24 25 65	4 24	21 22 65	2 14 27 37	26 28 42 45 47	11 26	55 59 61	1 19 33 60
18	Aware about planet and society energy, but doesn't feel in control	Power plugs not easy to reach, needs more information	1	0	Need to be considerate of finite resources. As grandparents worried about world	7 27 29 49 65	21 49	4 29 65	14 24 25 27	1 26 42 45 59	42 59	17 19 60	26 45 52 55
17	Already did a lot of retrofit for world, money is second though	Nothing really	1	0	D- irresponsible and superficial attitudes towards problem A – gov should have big lead	7 24 29 49 65	21 65	49 53 57	16 27 29 39	1 3 17 19 42	42 59	4 19 55	17 26 52 62
26	Energy too expensive and use to much. Need to be greener as home and natio	Use less; mone; well-being; cosmetics; need hot water	3	1	Chose statements because makes the most sense	2 7 9 25 51	10 23	6 36 48	21 30 39 51	42 47 52 60 62	11 42	3 19 50	28 33 52 57
32	Conscious mainly for cost reason. Hence try to turn things off	Awkward position of sockets wants to increase loft insul but super cluttered	1	1	Fossil fuel is an issue but reduce energy to save money	2 6 16 23 24	16 34	24 29 63	13 20 25 49	11 19 20 42 46	42 46	19 45 59	26 33 56 65
29	Be careful as possible with energy, do lot's of things	Wants to be greener lead to happier, solar is expensive wants to fix clothes line	1	1	A – reflect ideals, good education, believe in climate change	16 27 39 49 57	49 57	13 21 27	7 14 16 53	19 26 33 35 42	26 42	19 20 59	35 45 52 56
9	Energy is expensive	Wants a cheaper supplier	1	0	Teenagers should learn for envi and money. Cost is important for money and env	- - - - -				- - - - -			
39	Energy use is contradictory do many things to reduce energy but have lots of gadgets	Want to make better use of energy in home but cant because of costs and inertia	1	2	D – aware about energy and climate change A – heating takes up big prop...	10 14 21 22 24	21 27	16 29 65	24 25 31 49	8 11 28 42 59	11 42	17 45 60	8 12 33 62
12	Economy has become buzzward, is economical because of rising prices	Rising prices and limited income made more aware of cost. Cold is a barrie	0	1	D – young are aware and nuclear not bad option A – school, future generations	- - - - -				- - - - -			

Continued on next page

Table D.2 – *Continued from previous page*

CARDIFF RETURNED SURVEYS

ID	Question 1 (thoughts)	Question 2 (motivation & barrier)	Q 3 (freq)	Q 4 (heat)	Question 5 (reasons)	Winter Agree	Summer Agree +6	Summer Agree +5	Summer Agree +4	Winter Disagree	Summer Disagree -6	Summer Disagree -5	Summer Disagree -4
33	Think about cost to reduce heating	wants to save money but teenage son is a barrier!	1	0	Live in a new build home and aware about global warming	14 23 25 33 40	26 30	14 21 43	2 7 40 49	3 12 17 19 55	42 65	19 20 60	1 52 59 61
10	Energy use too high due to wife heat and light requirements	not really	1	2	BLANK	11 18 23 30 36	39 44	22 23 38	4 7 46 48	42 45 50 59 65	50 59	24 28 61	19 52 55 60
6	Heating and lighting, reliable control system. Installed energy management sys	Would like solar panels but too old to see payback	0	0	Interested in solar panels, trusts manufacturer rating, more info needed from gov	18 29 31 41 57	27 29	14 18 57	21 31 44 48	19 42 52 55 60	46 52	8 55 62	17 34 60 61
30	Use as the need arises	would like to reduce heat loss and energy use in lounge area without light loss	3	1	D – untrue, or misleading and wasteful A – common sense	9 20 31 51 57	31 39	22 51 65	36 44 50 57	3 33 42 55 62	19 33	3 42 46	12 26 55 64
20	Worried about rising cost of bills, no confidence in future proposals	Better information on affordable energy, solar, etc	0	1	BLANK	4 13 18 22 24	10 14	23 27 49	4 44 51 63	11 17 19 33 55	11 50	17 60 61	19 28 46 59
25	Very expensive commodity, need to treat as luxury, working on changing mindset	Stop using standby, dont leave light on, put on more clothings. Barrier – people	2	1	A – energy too expensive and getting people onboard hard D – Non-educated statements, the whatever attitude	9 13 26 35 44	26 51	29 44 54	9 14 27 57	3 19 42 50 62	50 60	19 59 64	12 17 33 52