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Household energy use: a study investigating viewpoints towards energy efficiency technologies and behaviour

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Abstract Improving the energy efficiency of our homes presents an excellent opportunity to reduce greenhouse gas emissions and increase thermal comfort. However, a shortfall exists between the full potential and realised adoption of energy efficiency measures, a phenomenon termed the 'Energy Efficiency Gap'. To better understand the energy efficiency gap, this research identified household viewpoints towards energy and stated preferences towards energy efficiency technologies and behaviour. The research was carried out through interviews and a Q study in the cities of Manchester and Cardiff, alongside a questionnaire. The results revealed a range of nuanced viewpoints, which mapped onto three principal household themes: energy use in terms of the environment, energy in relation to money and apathy towards energy. A key finding was the small number strong correlations between distinct energy viewpoints and specific energy efficiency technologies or behaviours. This result implies that being environmentally aware and actively concerned about energy efficiency does not in itself lead to a stated desire, or even, intention to install energy-efficient technologies. The wider implication is that households that hold proactive energy efficiency viewpoints based on environmental concern may still require specifically targeted incentives to encourage the uptake of energy efficiency measures, i.e. their proactive and environmental beliefs are not alone enough to motivate them to improve the energy efficiency of their home.

Keywords Subjectivity · Q methodology · Energy efficiency gap · Retrofit · Behaviour change

Introduction

The existing building stock in European countries accounts for over 40% of final energy consumption, of which residential use represents 63% of total energy consumption in the buildings sector (Balarasa et al. 2007). In the UK, the built environment accounts for about 45% of its anthropogenic CO_2 emissions (Kelly M. J. 2009; Lior 2010) and 50% of the total UK energy demand (Lior 2010). For homes, space and water heating account for the bulk of energy use, at approximately 72%. (Department of Environment, Food and Rural Affairs 2007; Department of Energy and Climate Change 2012; Kelly M. J. 2009). As such, installing energy efficiency measures in residential dwellings presents an excellent opportunity to cut CO_2 emissions, reduce national energy demand and improve building performance (Kelly M. J. 2009; Stafford, Gorse and Shao 2012).

Yet, despite these benefits, there exists a shortfall between the potential and realised adoption of energy efficiency measures, a phenomenon termed the 'Energy Efficiency Gap' (Jaffe and Stavins 1994; Pelenur M.

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2013). 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 underemphasised in public policy (Pelenur M. 2013).

A number of studies investigated viewpoints towards residential energy use, but they often focused on individual issues such as wind or solar power (Eltham et al., 2008; Jones and Eiser 2009; Krohn and Damborg 1999). Alternatively, other research used environmental viewpoints as a proxy towards energy use (Zhang et al., 2012; Mansouri et al., 1996), while engineering-based research often tried to capture behaviour as a variable within a model (Druckman and Jackson 2008; Swan and Ugursal, 2009). The result is that researchers may have overlooked other important factors that relate to energy use. Therefore, to address this gap, this study investigated broad household viewpoints towards energy use and linked them to technical retrofit preferences and energy efficiency behaviours in a UK context. The research was carried out through the use of interviews, a Q study and a questionnaire. Q methodology was developed in 1952 by William Stephenson (psychologist and physicist) as a research method used to study the 'subjectivity' or viewpoints of specific topics. Since then, it has been adopted by a range of disciplines.

The intended outcome of this research is to better understand how we may overcome the energy efficiency gap and help increase the adoption of residential retrofit programmes to improve the energy performance of the built environment. This research is relevant to policy makers, professionals and academics working to promote energy efficiency in the built environment.

The remainder of the paper is split into five sections: first, a background describing the relevant scholarship; second, an outline of the adopted research method; third, a presentation of the results; fourth, a discussion of the research with implications for policy and fifth, a conclusion.

Background

Retrofitting the UK residential built environment to improve its energy performance is a complex challenge, exasperated by many factors including the diversity of the UK building stock and range of occupant behaviour (Stafford, Gorse and Shao 2012). With respect to homes, the UK has some of the oldest and most energy-inefficient stock in Europe (Meijer et al., 2009). Adding to the complexity is the estimate that between 70 and 80% of the existing poorly performing buildings will still be in use in 2050 (Kelly 2009, 2010; Institution of Mechanical Engineers 2009; Stafford et al. 2012; Dixon and Eames 2013). In response to this challenge, the UK government introduced a range of programmes over time, such as the following: the Carbon Emissions Reduction Target (CERT); Community Energy Saving Programme (CESP); Decent Homes; Warm Front and the Green Deal. However, many of these programmes focus only on financial incentives and do not address other factors that may be barriers or motivations to the uptake of energy efficiency measures, such as social norms or viewpoints towards energy (Pelenur and Cruickshank 2012; Pelenur and Cruickshank 2014). In order to better understand energy consumption in the home across a broad range of factors, Lutzenhiser (1992) introduced an energy culture framework that took into account social norms and culture alongside the more traditional econometrics. The energy culture framework was extended by Stephenson et al. (2010) to apply 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). This framework can be applied to individuals and households, as well as neighbourhoods and communities.

This research was guided by the energy culture framework to better understand the relationship between residential occupant viewpoints and energy efficiency retrofits. An aspect of household cognitive norms was explored through the use of a Q study that identified subjective viewpoints, while the household material culture and energy practices were captured through interviews and a questionnaire. For this research, the definition of 'viewpoint' was taken from Q methodology, which defines it as simply the sum of behavioural activity that constitutes a person's point of view (Watts and Stenner, 2012). This definition is related to, but different, to other existing definitions for 'attitudes' or 'perspectives'. To avoid confusion, this article only refers to viewpoints as defined by Q methodology.

To support the Q study, a questionnaire was administered to measure household demographics,

as well as the stated desire and intention to install various energy efficiency technologies. The design of the questionnaire was influenced by the theory of reasoned action (TRA) and theory of planned behaviour (TPB) that both suggest that the level of 'intentions' shown by an individual is the best predictor of their behaviour (Jackson 2004Kaiser et al., 1999; Kalafatis et al., 1999). Both theories have been used to model behaviour over a wide range of topics, particularly pro-environmental behaviour (Jackson 2004). However, there is also often a sizeable discrepancy between peoples' self-reported knowledge, values and intentions and their described behaviour; well-known examples include the 'knowledge-action gap' and 'value-action gap' (Frederiks et al., 2015).

As such, this study did not infer that the stated answers on the questionnaire necessarily led to behaviour change. Instead, the purpose of the questionnaire was to reveal potentially interesting relationships between the Q study factors (viewpoints) and various energy efficiency technologies/behaviours. Such relationships help with the possible interpretation of the Q factors.

After the oil shock of the 1970s, there was a marked increase of research towards environmental beliefs and viewpoints towards energy use. For example, research in the USA found that over three quarters of individuals felt personally responsible for solving the energy crisis and held strong environmental beliefs (Olsen 1981). The results from another study, which investigated the impact that fear had on attitudes towards energy use, found 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 intentions to reduce energy consumption (Hass et al., 1975). In terms of technological attitudes, another American study found no link between general viewpoints towards technology and conservation behaviour (Anderson and Lipsey 1978). The 1970s oil crisis showcased how large global events can influence viewpoints towards energy use, with the Fukushima Daiichi nuclear disaster as a more recent example that resulted in stronger anti-nuclear sentiments (Visschers and Siegrist, 2013. This highlights how research investigating subjectivity is a product of its time and may need to be revisited in light of substantial external stimuli.

Alongside environmental stimuli, local context is also an important factor to consider alongside viewpoints towards energy (Lutzenhiser 1992; Owens and Driffill 2008; Shove et al., 1998). For example, a Canadian study examined the relationship between residential winter energy use and viewpoints and found that thermal comfort was the most important determinant of household energy use (Becker et al., 1981). Alternatively, other studies found a wide range of sociodemographic variables more significant in determining household energy use (Abrahamse and Steg 2009; Guefin et al., 2000; Ritche et al., 1981). Although it is interesting to note that thermal comfort was also strongly associated with viewpoints towards energy use in a Texas study (Samuelson and Biek 1991). Even though the Canadian and Texas study conclusions were broadly similar, the interpretation of the results were quite different given that thermal comfort in Canada is largely defined by heating, whereas air conditioning determines thermal comfort in Texas. Such detailed differences highlight the need to understand and present local context before attempting to interpret social research.

In the UK, the Department of Food and Rural Affairs (Defra) conducted a range of research to better understand pro-environmental behaviour and attitudes and investigate how those attitudes can be used to encourage sustainable energy consumption at home (Department of Environment, Food and Rural Affairs 2007; Department of Environment, Food and Rural Affairs 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 (Department of Environment, Food and Rural Affairs 2007). The studies were detailed; however, they focused mostly on environmental viewpoints and may have missed other relevant factors that impact household energy use (Pelenur, 2013). Very few studies have sought to specifically identify broad viewpoints towards residential energy use and investigate how those viewpoints may be associated with different retrofit technologies. To address this research gap, this study identified broad household viewpoints towards energy use and linked them to technical retrofit preferences and energy efficiency behaviours in a UK context. The purpose of this research was to better understand how we may overcome the energy efficiency gap and help improve the adoption of residential retrofits.

Research method

This section first outlines the rationale for selecting Manchester and Cardiff as case studies and then describes how the Q study, questionnaire and interviews were designed and administered in each city.

This research was part of the research project 'Re-Engineering the City 2020-2050 Urban Foresight and Transition Management (RETROFIT 2050)' and adopted a case study approach to better understand the complex challenge associated with retrofitting the residential built environment (Pelenur, 2013). A case study designs allows researchers to investigate a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident and in which multiple sources of evidence are used (Yin, 2009).

The cities of Cardiff and Manchester were selected as case studies because both have long strong roots with the industrial revolution, yet both have suffered a decline in recent decades and are now seeking to regenerate themselves into thriving cities (RETROFIT 2050 2012). Manchester and Cardiff also present large and substantial opportunities to improve the UK's residential energy performance. Specifically, within Greater Manchester, 25% of the housing stock is of solid wall construction and there are still 500 thousand 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). Both cities are also similar in size, with approximately 145 thousand dwellings in the unitary authority of Cardiff and 200 thousand dwellings in the metropolitan district of Manchester (Office for National Statistics 2013).

Q study design

The viewpoints towards energy use in the home were collected through a Q study with 91 participants and the stated intent and desire to install various energy efficiency technologies/behaviours were measured through an accompanying questionnaire. Q methodology (Q) was selected because of its parsimonious strength to explore subjective topics and identify complex viewpoints, while a questionnaire was used to simplify the measurement of technology/behaviour preference. The questionnaire also included questions about important physical household characteristics and demographics. Q

methodology approaches the study of subjectivity by examining it through the analysis of individual choices and actions, as opposed to interviews which often take stated responses at face value. For example, with a relatively small Q-set of only 33 statements, the cognitive ranking task still presents participants with roughly 11,000 times as many [sorting] options as there are people in the world (Watts and Stenner, 2012).

To evaluate the results of Q, the methodology uses a by-person factor analysis to identify groups of participants who rank and make sense of statements in a comparable way (Watts and Stenner 2012). This is different to other quantitative methods, such as regression analysis, which identifies and combines sets of dependant variables to statistically correlate relationships between similar things. Participant interviews supplement the factor analysis and enable the results to be interpreted through a qualitative lens, thereby establishing patterns within and across individuals rather than patterns across individual traits, such as gender, age or class (Barry and Proops 1999). As an exploratory methodology, Q cannot prove hypotheses; however, it can help bring a sense of coherence to complex research questions with socially contested answers (Smith et al., 1995).

Q methodology has been applied to a range of topics with inherit subjectivity, such as investigating viewpoints towards nuclear energy and teen pregnancy.

Sample selection

The participants (P-set) for this study were drawn from four areas in Cardiff and four areas in Manchester. The areas were selected to closely match each cities' average demographic and census profile, through a statistical standardisation method. As such, these areas represented 'typical' neighbourhoods in Manchester and Cardiff, insofar as being associated with census averages, such as the following: home type, tenure, number of bedrooms and population. This was deliberate sampling in order to investigate viewpoints from 'typical' neighbourhoods in each city. This 'typical' setting was selected as the context for this study so that the results may be more representative of an average UK city and therefore applied to other areas. However, it may be interesting for future research to investigate and contrast viewpoints from fringe communities.

In total, there were 10,908 households in the 4 areas of Cardiff and 12,667 households in Manchester.

Although this total number of households was not important to the research design; rather, it was a consequence of the size of the statistical output areas used to identify the typical neighbourhoods. 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 canvassing. The goal was to recruit about ten participants from each of the areas. Nearly all of the participants were recruited through door knocking, with a total of 46 participants in Manchester and 45 in Cardiff. This type of non-probabilistic sampling is the norm in Q (Brown 1980; Wilson and Dowlatabadi, 2007), where participants are usually chosen based on an a priori theoretical design, rather than representativeness or quantity (Eden et al., 2005). Participants for this study were chosen by first identifying 'typical' neighbourhoods and then recruited. However, it is possible to for future studies to use other selection criteria that may relate to a household's cognitive norms or demographics.

The final sample between Manchester and Cardiff were broadly similar, with some expected deviations between the cities. The sample demographics are discussed in more detail in the results section.

Administering the Q study

Each of the 91 participants took part in the Q study. Prior to administering the Q study in Manchester and Cardiff, two Q study pilots were conducted with 14 participants in Cambridge and London. The participants were a mix of individuals with no Q methodology knowledge and experienced Q practitioners. The aim of the pilots was to test the research instruments, specifically the comprehensiveness of the Q-set and validity of the questionnaire. The pilot was a full simulation of the Q study conducted in Manchester and Cardiff, and as a result, changes were made to the wording in Q-set and questionnaire to improve readability and clarity.

As presented by (Barry and Proops 1999), the general steps to a Q Study are shown below. These steps are kept intentionally simple for brevity and should not be used as a guideline in isolation (instead, see Brown (1980) and Watts and Stenner, 2012 for a more detailed overview of Q).

The first step is to identify the area of subjective 'discourse' to explore, for this study, the discourse was household viewpoints relating to energy use in Cardiff and Manchester. The next step is to widely research existing ideas on the discourse through the use of interviews, focus groups or discussions with the relevant population. The main objective of this step is to create a comprehensive and representative list of opinions on the topic.

The discourse for this Q study was derived from the transcripts of general public semi-structured interviews conducted in Manchester and Cardiff, as well as from the transcript of a multi-day workshop with energy retrofit professionals. These interviews were conducted prior to the Q study. In total, 198 public interviews were collected across multiple areas of the cities. The interview questions were worded to encourage the respondent to adopt a 'household' viewpoint so that the results not only included individual behaviours, but also insights into how relationships between family members or multi-tenanted homes affect energy demand. The interviews were piloted first to ensure the wording of the questions could easily be understood by participant, yet open enough to allow for varied responses (Pelenur and Cruickshank 2011).

The Manchester and Cardiff interviews were then transcribed and analysed to generate single-idea Q statements (Q-set) used to represent the discourse. In total, approximately 200 suitable statements were identified after removing obvious duplications. This list of 'raw' statements were grouped into themes according to an inductive and structured Q-set approach as described by McKeown and Thomas (1988). In order to select only the most salient statements from each theme and ensure an approximately equal distribution, the complete list of Q statements (grouped by theme) was shown to 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 is shown in Table 7 (see Appendix).

With the full Q-set of statements, and after the pilot, each of the 91 participants in Manchester and Cardiff performed an individual Q-sort, where they received an instruction and ranked the statements onto a quasi-normal forced distribution using a scale from − 6 (most disagree) through 0 to + 6 (most agree) (Watts and Stenner 2012). The specific condition of instruction for this Q study 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.).'. Figure 1 is an illustrative example of a participant performing a Q-sort.

After performing the Q-sorts, a semi-structured interview was also conducted with each participant before administering the questionnaire. 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. Specifically, the qualitative interview data provided context for the interpretation of the quantitative Q study results.

The total set of Q-sorts (91) were then statistically analysed through a by-person factor analysis to identify significant factors and then quantitatively and qualitatively interpreted into viewpoints and compared for similarities/differences. The quantitative data was used to statistically measure the relationship between individual Q-sorts and factors, while the interview transcripts were used to provide the context as to why participants chose their final sorts. Because Q methodology uses a by-person factor analysis, it offers the advantage of needing only a small sample to explore subjective topics and identify complex viewpoints.

Administering the questionnaire

The accompanying questionnaire was completed after each Q-sort and 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 questionnaire also captured personal and household demographics. 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 stated their desire to install solar photovoltaic systems to generate electricity, but could not do so because of the cost or due to being a tenant (low 'intent'). The questionnaire also provided an open text box to note differences between intent and desire, and any motivations or barriers to adopting the technology/behaviour. If there were any technologies or behaviours unfamiliar to the participant, they were asked to skip the question. After the questionnaire was administered, 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.

In total, the questionnaire included 18 energy technologies, from the UK's Standard Assessment Procedure (SAP), and 7 energy efficiency behaviours, shown in Table 8 (see Appendix). The technologies were taken from SAP since that is the main model used by the government for policy intervention, while the behaviours were inductively identified from the 198 general population interviews conducted previously in Manchester and Cardiff (Pelenur and Cruickshank 2011).

Linking the questionnaire with the Q study

To investigate the relationship between the results of the questionnaire with each Q-sort, 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 (Thomas and Baas, 1996; Kubier 2010; Thomas et al., 1993; Thomas et al., 1982). However,

Fig. 1 Example of a participant performing a Q-sort with cards. Source: http://www. betterevaluation. org/en/evaluation- options/qmethodology

since the questionnaire variables in this study 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 (Pelenur, 2013). Table 1 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.

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_A) was the existence of any correlation between the variables. Because there were multiple hypotheses testing between variables, the resulting p value from each test was adjusted to correct for multiple comparisons. For this study, the Benjamini-Hochberg procedure was used to adjust the final p values and control the false discovery rate.

Results

Factor analysis

A total of 45 Q-sorts were completed in Cardiff and 46 in Manchester. Table 2 is 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 affected viewpoints towards energy use. The other notable difference was 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 than the average. However, the Q study sample still captured households from all the key demographics and was representative of the areas selected.

For Cardiff, the by-person factor extraction was done using centroid factor analysis (CFA) and judgement rotation, which is a common approach in Q methodology due to the flexibility it allows in relation to data exploration (Watts and Stenner, 2012). Four factors were identified in Cardiff: a dominant factor, a positive specificity, a negative specificity and a secondary factor. 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-viewpoints. The Cardiff specificity was also bipolar, which means that it was defined by both positively and negatively loading Q-sorts (Watts and Stenner, 2012). Therefore, for analysis, the single bipolar

Table 1 Tests of associations used in study

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 product-moment correlation

Table 2 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%
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				
£20 k or less	29	24		
£20 k to £40 k	20	26		
£40 k to £60 k	13	17		
Greater than £60 k	22	26		
Refused	16	7		

factor was separated into two unique factors to represent each of the poles. 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). A higher significance level of 0.4 was used for the secondary factor in order to avoid conflating Q-sorts, i.e. Q-sorts that load onto more than one factor, while a significance level of 0.25 was used for the bipolar specificity.

As well as the four common Cardiff factors identified through CFA, a single participant (C13) was also visually identified during the judgement rotations as being of interest because their Q-sort was diametrically different from the others in the sample. Q methodology is well placed 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

and 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 easier to isolate separate factors. The Manchester factor analysis was initially done using CFA/ judgement rotation as well as a principal component analysis (PCA)/varimax rotation, which is a more mathematically precise solution but offers less flexibility with data exploration (Watts and 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. The rotated factor loadings for each factor with flagged Q-sorts are shown in Table 9 (see Appendix).

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. This type of narrative design is a recognised method to present the results from a Q study (Watts and Stenner, 2012).

Cardiff factor 1 (dominant factor): I think about being energy efficient for the environment and greater good

Twenty-six participants' Q-sorts exemplified this factor, making this the dominant factor in the Cardiff study that accounted for 40% of the variance.

This factor exemplifies the household viewpoint that energy conservation can be driven by environmental issues, including climate change. The viewpoint also includes the idea of inter-generational responsibility and that energy efficiency should not be viewed as an inconvenience, rather as a standard expectation. As such, this factor includes many statements from the 'Environment and the future' theme. Mostly missing from the extreme ends of the factor array are statements regarding economics, finance and inefficient behaviours.

'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.

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

Five participants' Q-sorts strongly exemplified this factor, which accounted for 10% of the variance.

This factor points to financial reasons as the main motivation to conserve energy, without specifically touching on other themes. This viewpoint also highlights how even though financial savings may have been the main driver, households did not necessarily understand their energy use or how they could affect their consumption. As such, 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 (Pelenur, 2013).

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 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 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.

Cardiff factor 3 (specificity of factor 1): I'm consciously and actively energy efficient because it is plain common sense.

Three participants' Q-sorts exemplified this factor, which was the positive bipolar specificity of factor 1 accounting for 4% of the variance.

This specificity goes deeper into the environmental motivation of factor 1 and highlights how energy efficiency is not only about the environment but also about reducing waste as an overarching principal. This factor also exemplifies the viewpoint that energy efficiency is a part of personal responsibility and lists specific examples instead of using broad statements.

'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?

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

Five participants' Q-sorts exemplified this factor, which was also the negative bipolar specificity of factor 1 accounting for 4% of the variance.

This factor was the bipolar viewpoint of factor 3; as such, this viewpoint focused on the responsibility of energy generation companies to promote energy efficiency instead of personal responsibility. Although environmental concerns were important to this viewpoint, the desire to be energy efficient did not always translate to action at home.

'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 sun light 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.

Cardiff single case Q-sort (C13)

Even though this Q-Sort did not load on any single factor, it was sufficiently different from the other responses that it warranted a more detailed analysis. This single case exemplified a unique viewpoint from the study, one which revealed a detached approach to energy use without a clear motivation to conserve energy.

A reason for this view may be that participant C13 did not pay any of the bills, instead his wife managed all the household finances. In the post-sort interview, the participant 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 viewpoint. As a unique single case, this viewpoint is worth including in the discussion but was unable to be quantitatively compared to the other factors.

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.

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

Twent-five participants' Q-sorts exemplified this factor accounting for 33% of the variance.

This factor presents a balanced viewpoint that considers both environmental and financial motivations to conserve energy, and as such includes a range of energy efficiency themes in a single factor. This viewpoint underscores the challenge of understanding energy use at home. This viewpoint is similar to a combination of factors 1 and 2 from Cardiff.

'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.

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.

Five participants' Q-sorts exemplified this factor accounting for 14% of the variance.

This factor is a striking viewpoint that focuses on the comfort and lifestyle effects of energy use rather than containing motivations for energy efficiency. As a result, when considering interventions to promote energy conservation, financial incentives may not be effective on these households if the result will negatively impact on the household's lifestyle.

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 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.

Questionnaire results

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 2, and their p values were adjusted to compensate for multiple comparisons using the BH step-up procedure. The results shown in Tables 3 and 4 are the variables which 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.

The results from the tests of association reveal that the only energy efficiency behaviour significantly correlated with Cardiff factor 1 was using washing machines at a lower temperature. Interestingly, the intent to install combined heat and power generators (CHP) was negatively correlated with the factor. 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 highlighted energy conservation for the environment and greater good, this alone may not be enough to encourage the uptake of less-known retrofit technologies such as combined heat and power generators.

Not surprisingly for Cardiff factor 2 (I want to be more energy efficient to save money, but I don't really

Table 3 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's rho
Behaviours			
User lower washing machine temp. (adopt)	0.032	0.510	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 is 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

know how), the viewpoint was not correlated with any energy-efficient technologies or behaviours, although there was a relationship with this viewpoint and the questionnaire question relating to energy awareness ('how frequently do you think about your household energy'?). This positive correlation supports energy efficiency interventions, as it suggests that a portion of households are motivated to be energy efficient and think about it often, but just do not know how to go about it.

Cardiff factors 3 (I'm consciously and actively energy efficient because it is 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) were specificities of factor 1 and represented two bipolar viewpoint. Being a specificity implies general agreement with the main factor, but from alternate perspectives. There were no associations between either factor and energy efficiency demographics or behaviours, but the installation of radiator thermostats and wall

Table 4 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's rho
Turn off appliances completely (intent)	0.017	0.488	Spearman's rho
Turn off appliances completely (adopt)	0.004	0.578	Point biserial
Consciously use less (desire)	0.017	0.488	Spearman's rho
Consciously use less (intent)	0.017	0.482	Spearman's 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	− 0.500	Point biserial

insulation were positively associated with factor 3 and thereby negatively associated with factor 4. The associations support the interpretation of the viewpoints. Factor 3 represented a proactive perspective to energy efficiency while factor 4 represented the passive perspective. An interesting result was that only the that only the simplest and most cost effective retrofit measures were associated with factor 3, even though it represented a proactive specificity of factor 1 (environmental). This suggests that households with proactive energy efficiency viewpoints based on environmental concern may still require specific targeted incentives to encourage the uptake of energy efficiency measures, i.e. their proactive and environmental beliefs may not be enough to motivate them to install retrofit measures (Pelenur M., 2013).

For the results from Manchester, it was not possible to easily identify the two axes seen in Cardiff (save the environment and save money); rather, Manchester's factor 1 was a conflation of both themes. Two energy efficiency behaviours (desire, intention and adoption) were correlated with the viewpoint: turning off appliances completely as opposed to leaving them on standby and consciously using less energy. No retrofit technology was associated with the factor. These behavioural associations were consistent with the factor's proactive approach towards energy efficiency.

For 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), the only behaviour correlated with the viewpoint was a negative association with turning off appliances completely. This factor shines a light on households that may be deliberately wasting energy. Improving our understanding of the motivations and barriers to energy efficiency for these households should be the topic of future research, as reaching households who hold this viewpoint through traditional incentives (financial or social pressure) may not be effective.

Comparison between Manchester and Cardiff

The viewpoints within Manchester and Cardiff overlapped substantially when compared qualitatively, with the exception of Manchester factor 2 (apathy). On the surface, this may indicate that typical households in large UK cities consider energy use within the themes of the environment and financial concerns. The main difference between the two studies is that the apathetic viewpoint towards energy use was clearly identified in Manchester, while mostly missing in Cardiff. Another

difference was that in Cardiff, the responsibility of delivering energy efficiency measures was split between the government and households. A possible reason for the difference in apathy between cities may be due to differing awareness campaigns by local councils, or large external projects that are highly visible to the community, such as the proposed tidal power plants in Wales.

Because the same statements were used in both cities, it was also possible to compare the results quantitatively between Cardiff and Manchester. 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 and Stenner, 2012). Table 5 is the correlation matrix from the second-order factor analysis.

The correlation matrix in Table 5 demonstrates how the themes from Manchester and Cardiff overlap. For example, Manchester factor 1 was associated to some degree with all the Cardiff factors, which supports the interpretation that Manchester factor 1 was a conflation of the separate themes identified in Cardiff.

Alternatively, Manchester factor 2 only showed a weak association with Cardiff factor 1 and 4. This result also supports the interpretation of Manchester factor 2, since even though it 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. Although unlike Cardiff factor 1, environmental awareness did not motivate households to adopt energy efficiency practices.

Cardiff factor 4 and Manchester factor 2 also shared themes of a passive approach to energy efficiency with a minimum amount of responsibility placed on the household. From the opposite pole, Manchester factor 2 was strongly not associated with Cardiff factors 2 and 3. This is in line with the interpretation of Manchester factor 2 since Cardiff factors 2 and 3 represented a proactive desire to be energy efficient.

Household-shared viewpoints

In a Q study, each participant is analysed independently using their Q-sort. However, the Q-set was created from statements that reflected a household perspective

Table 5 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

towards energy use. To investigate the similarities/ differences between the viewpoints of individuals living in the same household, this study did include multiple participants from the same dwelling, 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 viewpoints about energy use. In Cardiff, there were six multi-participant households, while in

Manchester, there were five. The participant relationships and factor association are shown in Table 6.

Table 6 revealed that 5 out of the 11 multi-participant households did not share a common viewpoint. However, Cardiff factor 4 was as a subset of factor 1, since it was its specificity, so it may be considered to share the same overarching theme. Likewise, having no factor association does not necessarily imply a disagreement, but rather that the participant's Q-sort was conflated, i.e.

Table 6 Multi-participant household relationships and factor associations

Location	Participant	Factor association	Relationship
Cardiff 1	C8	2	Mother (senior)
	C9	1	Daughter (late 30s)
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 20s)
	C39	1	Father (late 40s)
Manchester 1	M6	1	Wife
	M7	1	Husband
Manchester 2	M18	None	Daughter (late 20s)
	M19	None	Father (late 50s)
Manchester 3	M23	1	Wife
	M24	1	Husband
Manchester 4	M34	1	Wife
	M35	1	Husband
Manchester 5	M42	None	Husband
	M43	1	Wife

loaded on multiple factors. Based on this interpretation, the results from Table 6 show only one household (Cardiff 1) with substantially different viewpoints.

For this household, the adult daughter (C9) loaded on Cardiff factor 1 (I think about being energy efficient for the environment and greater good), while 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). Examining the demographics revealed that occupant C8 owned the home, and therefore, ownership and maintenance of a home influenced participant C8's viewpoint towards conserving energy to save money. Although, interestingly, the other two parent-child households did not show this pattern.

The overall results suggest that occupants in households with committed relationship may share an aligned 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 viewpoints towards energy use.

Discussion

The factors that emerged from Cardiff and Manchester exemplified viewpoints about household energy use from typical neighbourhoods. 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. Though it is possible that the researchers may have inadvertently introduced their own bias into the results, care was taken at all stages of the study design and research to minimise possible sources of such bias.

The viewpoints generally mapped onto three axes grouped by theme: saving the environment, saving money and apathy. Within the environmental axis, two bipolar specificity viewpoints were also identified: taking an active approach to energy efficiency because that is 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 not counter-intuitive, households think about energy in terms of money, the

environment or do not care. Yet, this research was able to describe those viewpoints in more detail and distil the 'noisy' subjective discourse about household energy into succinct and useful summaries, as well as investigate their relationship to energy efficiency technologies and behaviours. As such, these Q-studies provided rigorous and empirical results that policy makers and retrofit professionals can apply to improve the energy performance of the built environment. Each viewpoint is discussed in more detail below.

The environment

A strong theme of environmental responsibility was strongly seen in Cardiff factor 1 and Manchester factor 1. However, these factors also showed that such environmental motivations did not always lead to the adoption of energy-efficient technology or behaviours. For example, reducing costs was a strong motivation in Manchester factor 1. This insight is in line with other research which highlight the disconnect between environmental intentions and action (Lutzenhiser 1992; Jackson 2004; Allcott and Mullainathan 2010; Upham et al. 2009; Faiers et al. 2007). A consequence of this result is that public information campaigns to encourage the adoption energy-efficient technologies/behaviours should not rely solely on an environmental or green message; rather, the specific motivations from the target audience should be well researched and understood. The results from this study show that environmental awareness alone may not be enough to spur home energy efficiency improvements.

Saving money

Unsurprisingly, reducing energy costs is a common theme across energy efficiency research (Swan and Ugursal, 2009). Although, similar to the environmental theme, saving money alone does not always lead to the uptake of energy efficiency technologies or behaviours Pelenur, 2013). Households also need to know what action to take and how to take them, as exemplified in Cardiff factor 2 (I want to be more energy efficient to save money, but I don't really know how). As such, a clear call to action (the 'how') should be presented alongside the cost savings benefits of energy efficiency.

An interesting insight from Cardiff factor 2 was that even though households want to reduce their energy costs, some still indicated a preference to heat their whole home, thereby potentially wasting heat, as opposed to just heating the most used rooms. This indicates differing preferences for the utility of energy. In this case, adopting a loss frame to promote energy efficiency may be more effective than a gain frame, i.e. instead of promoting the monetary savings of specific energy efficiency measures/behaviours, information campaigns should highlight the costs of inefficient behaviours or poor performing technology. Highlighting costs as opposed to savings uses insights from behavioural economics that losses or disadvantages have greater impact on preferences than gains or advantages (Tversky and Kahneman, 1991).

Apathy

It should be recognised that not all households are interested or think about their energy use. 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 this apathy. Targeting the segment of households with this viewpoint through traditional energy efficiency interventions may not be effective. For these households, it may be more effective to frame energy efficiency interventions in terms of convenience or lifestyle improvements. For example, offering a house tidy up service alongside loft insulation. Alternatively, it may be that the most effective way to reach these households is not through direct interventions, but rather by 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 minimise their environmental impact.

Limitations of the Q study

A Q study is an effective research method to study subjective topics, such as home energy use. However, the results present a 'snap shot' in time, using data from today's context. As such, the insights from this study may not necessarily be applicable under different circumstances. For example, there may be substantial differences between how households in the UK view their own energy use compared to other parts of the world. However, the methodology does not aim for generalisability in a quantitative sense, instead it aims to identify individual viewpoints from within a complex topic. 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.

Conclusions

To better understand the energy efficiency gap, this research identified household viewpoints towards energy and linked those viewpoints with preferences towards energy efficiency technologies and behaviour. An original contribution of this research was to investigate household viewpoints towards energy in a broad study and link those viewpoints to specific technologies/behaviours, as opposed to researching a specific type of viewpoint, such as environmentalism, or technology, such as wind or solar power.

The results revealed a range of nuanced viewpoints, which mapped onto three main household themes: energy use in terms of the environment, energy in relation to money and apathy towards energy. Interestingly, there were only a small number of strong correlations between distinct energy viewpoints and specific energy efficiency technologies or behaviours. This result supports other research showing that being environmentally aware and actively concerned about energy efficiency may not in itself lead to a stated desire or intention to install energy-efficient technologies (Frederiks et al., 2015).

To widen the research applicability, this study design could be repeated in fringe communities, as opposed to 'typical' neighbourhoods. The findings from such studies would allow for similarities/differences to be identified between samples. Together, the investigation of viewpoints in typical neighbourhoods, as well as fringe communities, would allow for a more holistic interpretation of the data and improve the applicability of the recommendations. Another area for further research 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 energy performance of the built environment and reduce national greenhouse gas emissions.

Appendix

Table 7 Q statements and factor arrays

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
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 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
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
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

Table 7 (continued)

Q statements		Cardiff factors				Man. Factors	
		1	2	3	4	1	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
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 8 Technologies and energy efficiency 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	

Table 9 Rotated factor loadings with significant loading Q-sorts

	Cardiff factors					Manchester factors	
Q-sort	1	2	3	4	Q-sort	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
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
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

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