Daily behaviour and energy saving strategies

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Abstract

Energy consumption by individuals at certain times of the day leads to peaks in energy demand in the grid. Load shifting strategies and facilitating technologies (e.g. smart meters) have been proposed to avoid these peaks and ensure that demand better matches supply. Households with solar PV have been shown to shift their use to different times of the day. But this mainly follows from a motivation to use their own energy production (Bourgeois et al., 2014). Public awareness of load shifting is relatively low and further barriers may limit public acceptance and could hinder successful implementation (Demski et al., 2014). To achieve load shifting in the public we need to understand peak behaviours and their variations better including perceptions of energy demand associated with these household actions. In a survey (part of the eViz Project, eviz.org.uk), a general public sample (N = 283) reported three household actions relating to one out of seven contexts: morning, evening, regular, important, most energy consuming, summer or winter. Participants ranked these actions on perceived energy use and also listed their current energy saving strategies. Reported actions clearly varied when asked about different times of the day and year. Heating and washing machine use were identified as being particularly important to individuals, something they engaged in regularly and high in energy use. But, these actions weren't necessarily commonly mentioned when asked about regular morning, evening, winter or summer actions. In terms of energy saving strategies, a mismatch was notable between perceived consumption and some energy saving strategies. Light related strategies were overrepresented when compared to how often light was mentioned as a high energy user. And, energy saving strategies for washing machine use were limited although it was identified as a high user. These, and further detailed results, provide important insights into individuals' regular household actions and energy consumption beliefs. This is a starting point to communicating and achieving load shifting to the public in a manner that fits with their current conceptualisation of energy demand.

Introduction

Peak energy demand is a 'pressing international problem' (Strengers, 2012), in particular with regards to electricity. There is pressure to meet current demands and concerns over security of supply (OFGEM, 2014). The issue has also received increased interest as society moves towards higher levels of intermittent energy generation using renewable energy, e.g. wind energy (Demski, Spence, & Pidgeon, 2013). Peak demand tends to be in the morning when people get ready for work or school, and in the evening when people return home (cf. Pout, MacKenzie & Olloqui, 2008), these peaks in energy demand can lead to brownouts, blackouts and increasing costs for consumers. Load shifting strategies and facilitating technologies, such as smart meters, have been proposed to avoid these peaks and ensure that demand better matches supply. For instance, at least in the UK, various forms of demand side management (DSM) have been suggested. This involves controlling, and actively managing fluctuations in demand to avoid peaks. Survey data shows public concerns regarding some of the aspects necessary for the successful implementations of DSM (Demski, Spence, & Pidgeon, 2013). Moreover, the wider concept of energy security tends to be unfamiliar to people (Demski, Poortinga, &

Pidgeon, 2014). But, research into public perceptions of load shifting, and the perceived barriers and opportunities for implementation is limited so far. An area of research which has explored load shifting is research into households with photovoltaic systems (solar PV). To make maximum use of their own supply, households with solar PV have been shown to change their behaviour: they shift their energy consumption towards times of the day when production from solar PV is at its highest (Bourgeois et al., 2014; Keirstead, 2007). Bourgeois et al. (2014) further discuss the barriers and opportunities of load shifting within this context. They note that "the 'shiftability' of an appliance depends more on the household, the resident and the specific situation than the appliance itself" (p. 4). A clearer picture is needed of the behaviour that people do regularly. To achieve load shifting in the public we need to understand peak behaviours and their variations better, including perceptions of energy demand associated with these household actions.

Time-use surveys provide information on what 'practices' constitute the peaks in energy demand. But Anderson (2014) points out that so far these data tend to be incomplete, which makes it difficult to explore peak demand behaviours in detail. More is known about the perceptions of energy consumption that people hold. Various studies have highlighted that people can have misconceptions around the energy use of household appliances. For instance, the size of the appliance is often used as a measure of energy consumption (Baird & Brier, 1980; Schuitema & Steg, 2005). In a more recent study by Attari, DeKay, Davidson and De Bruin (2010) participants were asked to name the most effective thing they could do to conserve energy. In addition, participants estimated the energy use, and the energy saved, by several household appliances and activities. The results showed a lack of knowledge in estimating comparative energy use and savings. Overall, magnitudes were underestimated and for energy saving there was a focus on curtailment actions (compared to energy efficiency actions). Interestingly, although stronger pro-environmental attitudes increased accuracy (as did high numeracy scores), participants who reported engaging in more energy saving behaviours were less accurate. In a similar vein, a study by Schuitema and Steg (2005) found no relationship between environmental awareness and accuracy in estimating the energy use of household appliances. So, there remains uncertainty in this area of research regarding people's perceptions of energy use and savings.

This research will combine two lines of research: this study takes inspiration from time-use research, more specifically research on the Day Reconstruction Method (cf. Kahneman, Krueger, Schkade, Schwartz, & Stone, 2004), which focuses on recalled activities and associated experiences. In this study a series of questions will be used to examine regular behaviours. At the same time the study builds on previous research into people's estimations of energy consumption. People's current knowledge of load shifting will also be explored to emphasize the need for clearer communication strategies that connect to people's daily behaviour patterns and perceptions of energy use. Our main interest is not whether people can accurately estimate energy use, but to examine the changing nature of these perceptions. We are interested in examining how perceptions of energy use – and in particular the main energy users in the home – change depending on the context of the question. This will not only provide us with additional knowledge on peoples' perceptions of energy consumption in the home, but also on the regular energy-related actions that people take during certain times of the day and year, and which actions are of particular importance to them. We will link these data to responses on the energy saving strategies that participants currently use, and will explore whether these are in line with the main energy users identified by the participants. The results will be largely descriptive in nature, and provide an important step towards increasing our understanding of daily energy patterns and perceptions.

Method

PARTICIPANTS AND DESIGN

An electronic survey was positioned in the Plymouth city council reception waiting area, the survey could be self-administered using a touch screen display. Data was collected over a 7-month period (during winter and spring), in total $N = 715$ responses were collected. The survey was situated in a public area and many participants started but did not complete the survey. After data screening for very incomplete and nonsense answers, $N = 283$ usable responses remained, 46.3 % female, 51.9 % male (1.8 % chose not to provide their gender) with a mean age of 39.96 ($N = 37$ chose not to provide their age). The majority of participants (45 %) rented from a private landlord, the second largest group were homeowners (33 %), 11 % lived in a housing association property, 7 % lived in local authority housing, and 4 % preferred not to declare their living situation. Finally, the level of fuel poverty amongst participants was relatively high compared to the proportion of households living in fuel poverty in the region (i.e. 10 %, Devon County Council, 2012), No: 70.3 %; Yes: 29 %; Rather not say: 0.7 %.

MATERIALS

The survey was entitled the 'Plymouth Household Energy Survey", the introduction page stated: "We all use Energy – Electricity and Gas – everyday. But at Plymouth University we are interested in your thoughts on Energy Use". Participants were provided with consent information and a short explanation on the structure of the survey. Next, one out of seven ranking questions was randomly allocated to each participant[1]. The survey was situated in a public waiting area where participants had limited time to fill in the survey, so each participant was asked only one question to keep the survey as short as possible. For each question participants were asked to rank their answers on energy use, starting with the action that uses most energy:

1. Please name three household actions that you do regularly in the morning ($N = 43$).
2. Please name three household actions that you do regularly in the evening ($N = 45$).
3. Please name three household actions that you do regularly ($N = 42$).

1. The participants did not significantly differ between these seven question conditions, on gender (χ^2 (12, N = 283) = 17.69, p = .125), age (F(6,239) = 1.36, p = .230, n^2 = .03), house type (χ^2 (24, N = 282) = 23.01, p = .519), experience of fuel poverty (χ^2 (6, N = 281) = 4.19, p = .651), and knowledge of load shifting (χ^2 (24, N = 281) = 27.38, p = .287).

4. Please name three household actions that are important to you, and rank them on energy use ($N = 43$).
5. In your opinion, which three household actions consume most energy in the home ($N = 31$).
6. Please name three household actions that you do regularly in the winter ($N = 44$).
7. Please name three household actions that you do regularly in the summer ($N = 35$).

Next participants were asked to describe the things that they do to save energy, in case participants' currently did not do anything to save energy they could tick a box to indicate this. Finally, participants were asked how much, if at all, they would say that they know about load shifting to reduce peak time energy use (item based on Demski et al., 2013). A debrief was provided explaining the purpose of the study.

Results

KNOWLEDGE ABOUT LOAD SHIFTING TO REDUCE PEAK TIME ENERGY USE

Overall, knowledge about load shifting to reduce peak time energy use was relatively low. The majority of participants noted that they had never heard of load shifting (see Figure 1). Knowledge of load shifting did not depend on gender, χ^2 (8, $N = 281$) = 6.91, $p = .547$, age (for this analysis four age groups were computed), χ^2 (12, $N = 245$) = 16.87, $p = .155$, or perceived fuel poverty, χ^2 (4, $N = 279$) = 6.14, $p = .189$.

PATTERNS OF DAILY HOUSEHOLD BEHAVIOURS AND PERCEPTIONS OF ENERGY USE

The first analyses focused on examining the difference in responses when participants were asked about the household actions that consume most energy in the home (Q5), the household actions that participants find important (Q4), and the household actions that they engage in regularly (Q3). For all questions participants ranked their answers on energy use, with highest energy use first. Table 1 displays the responses that were most commonly mentioned for each question and rank. It can be seen that what is perceived as using a lot of energy in the home varies depending on the context of the question. Actions related to central heating and the washing machine were mentioned consistently across the three questions. With regard to Q5, the household action that was seen as consuming most energy was central heating: it came out as the top answer for rank 1, 2 and 3 (see Table 1). It was also the top answer on rank 1 for Q4 (household actions that are important), and for rank 2 of Q3 (regular household actions). The washing machine was most commonly mentioned on rank 2 for Q3 and Q4, and – although not displayed in the Table – for Q5 it was the second most commonly mentioned answer for rank 1.

Other actions seemed to be more specific to the question, for instance the kettle was perceived as a regular action that uses a lot of energy but it was not necessarily seen as consuming most energy in the home, or as a particularly important action. Similarly, the fridge freezer was seen as important and somewhat high on energy use, but it did not come up when asked about regular energy using actions, or actions that consume most energy.

Because the analysis in Table 1 only focuses on the most commonly mentioned answers for Rank 1, 2 and 3, some actions may not appear in the table even though they have been mentioned by a high number of participants overall. To explore the types of actions mentioned for each question in more detail a thematic analysis was conducted which identified recurring themes in the data (across the three ranks). Based on this analysis responses could be coded into eight categories: Eat and drink (e.g. kettle, cooking, fridge freezer); Personal hygiene (e.g. shower, bath, hair dryer); Entertainment (e.g. television, laptop, games console); Heating/cooling (e.g. central heating, boiler, fan); Lighting; Household cleaning (e.g. washing machine, dishwasher, hoover), General energy (e.g. gas, electricity); Other. Some interesting patterns come out when exploring the similarities and differences between the questions (see Figure 2). Compared to the other two questions, responses to Q4 (household actions that are important) had a clear focus on Eat and Drink. Responses for the other two questions were more varied with a similar number of responses for more than one category. For instance, responses to the Heating category are relatively high for Q5 compared to the other two questions, and responses in the Household Cleaning category are relatively high for Q3 compared to the other two questions.

The data for the remaining four questions allows us to explore peoples' perceptions of energy use further by linking it to – and examining – specific daily behaviour patterns. As can be seen in Table 1, in contrast to the regular, important, and

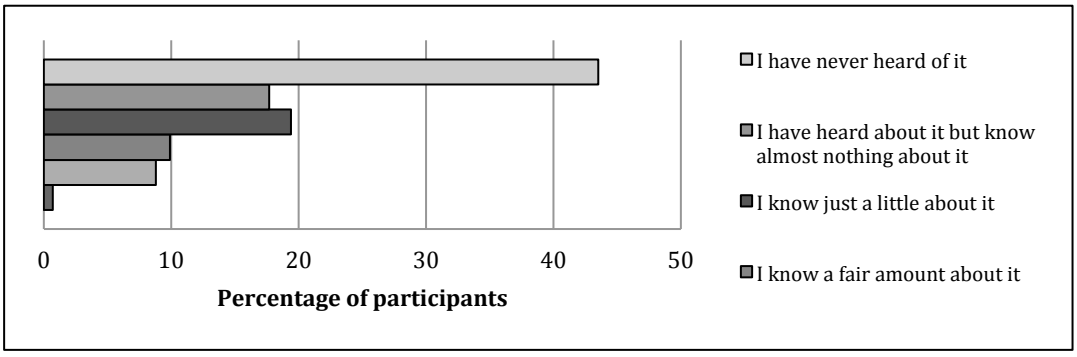

Figure 1. Responses to the item: How much, if at all, would you say you know about load shifting (to reduce peak time energy use)?

Table 1. Most commonly mentioned answer for Rank 1, 2 and 3 for each question (% of participants).

Rank	Q1: Morning (N = 43)	Q2: Evening (N = 45)	Q3: Regular (N = 42)	Q4: Important (N = 43)	Q5: Consume most (N = 31)	Q6: Winter (N = 44)	Q7: Summer (N = 35)
1	Kettle (37 %)	Television (31 %)	Kettle (21 %)	Central heating (26 %)	Central heating (29 %)	Central heating (50 %)	Washing machine (29 %)
2	Kettle (26 %)	Television (24 %)	– Washing machine – Central heating – Television (17 %)	Washing machine (16 %)	Central heating (19 %)	Lighting (20 %)	Shower (26 %)
3	– Kettle – Television (14 %)	Television (18 %)	Lighting (19 %)	Fridge freezer (14 %)	– Central heating – Television – Cooking (13 %)	Cooking (11 %)	Television (14 %)

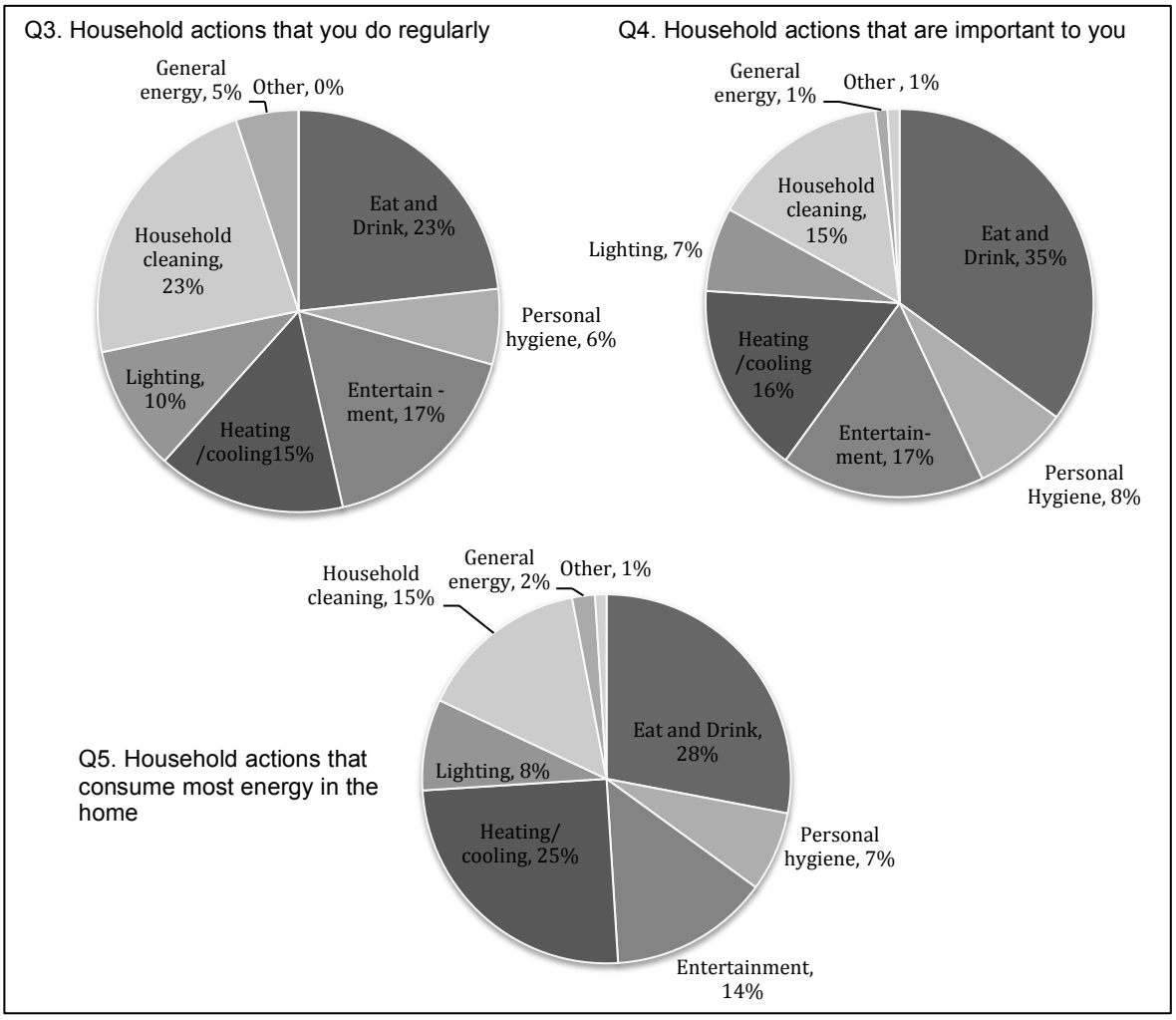

Figure 2. Thematic analysis for Q3, Q4 and Q5. Numbers indicate the responses within that category displayed as the percentage of the total number of responses – N = 120 for Q3, N = 123 for Q4, N = 88 for Q5.

high consuming actions discussed before, for ***regular morning*** (Q1) and ***evening*** (Q2) actions the focus moves away from heating. When asked about regular energy consuming actions conducted in the morning the kettle was identified as the main energy user, it was mentioned most often at rank 1, 2 and 3. For evening actions on the other hand, the television was identified as consuming most energy (being mentioned most commonly at rank 1, 2 and 3). Overall (see Figure 3), responses for morning actions tended to fall within the Eat and Drink category, the second largest category was Personal Hygiene. The latter category has had relatively few responses in the questions discussed so far, and is also small for regular evening actions. So, energy-related Personal Hygiene actions seem to be particularly associated with the morning. For regular evening actions, most responses fell into the Entertainment category – again a category that has been relatively small so far. As can be seen in Table 1, in terms of high energy users, there was a lot of agreement amongst participants for ***regular winter actions*** (Q6). Half of the participants provided the same answer for rank 1: central heating, followed by lighting for rank 2, and cooking for rank 3. There was less agreement for ***regular summer actions*** (Q7), the washing machine was most commonly mentioned for rank 1, shower for rank 2, and the television for rank 3.

The focus on heating in Q6 (winter) also comes out when looking at the responses overall (see Figure 4), whereas the answers are varied for Q7 (summer) – here there is not one category that received most responses. However, compared to the other questions (except Q1, morning actions), Personal Hygiene is a relatively large category.

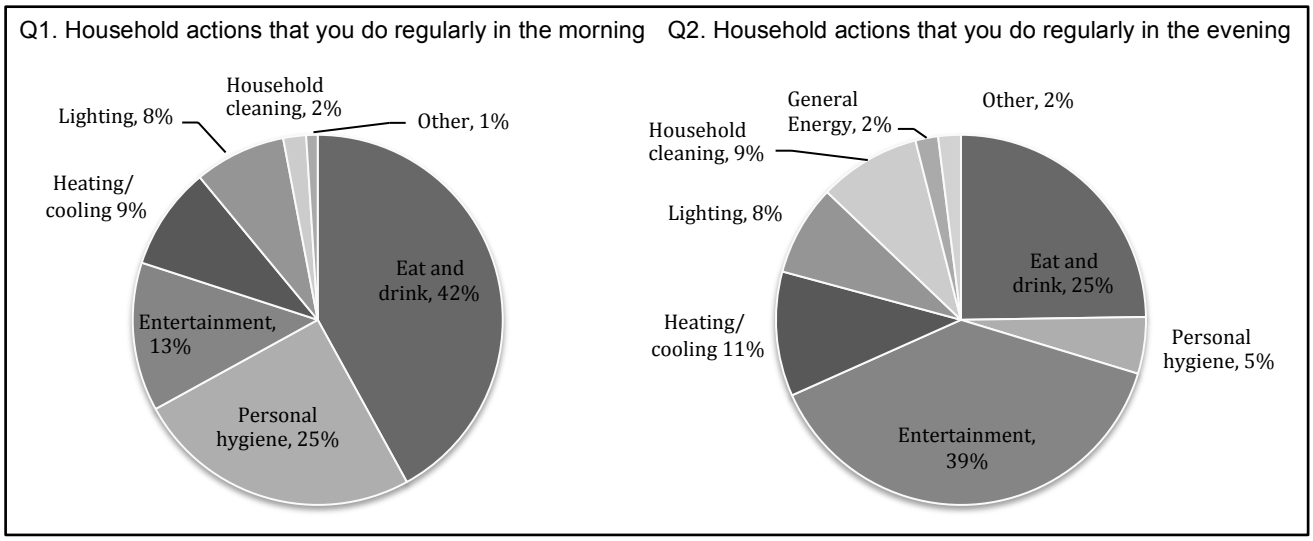

Figure 3. Thematic analysis for Q1 and Q2. Numbers indicate the responses within that category displayed as the percentage of the total number of responses – N = 118 for Q1, N = 126 for Q2.

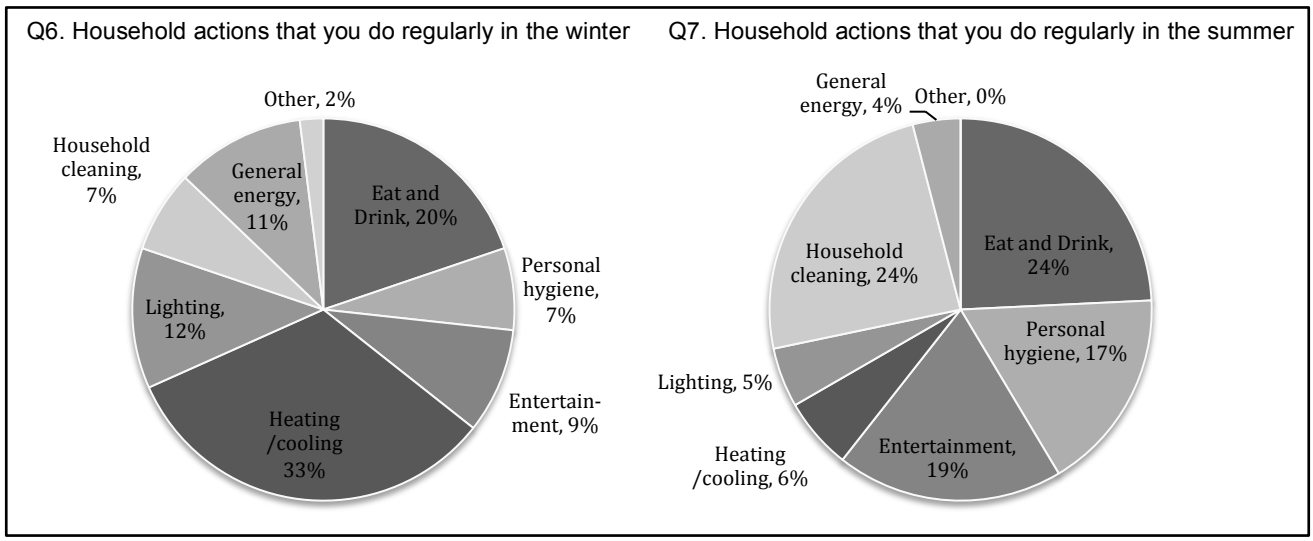

Figure 4. Thematic analysis for Q6 and Q7. Numbers indicate the responses within that category displayed as the percentage of the total number of responses – N = 128 for Q6, N = 95 for Q7.

ENERGY SAVING STRATEGIES

Participants were asked to describe the things they currently do to save energy; 249 participants provided one or more energy saving strategies, in total 657 strategies were provided. Again a thematic analysis was conducted to identify recurring themes. The majority of reported strategies related to Lighting (26 % of all strategies) or Heating (22 %). For the former, this mainly concerned switching off lights (64 % of lighting strategies), and using energy saving light bulbs (33 % of lighting strategies). For Heating, the majority of strategies concerned heating behaviours (94 % of heating strategies), such as turning the heating off when not needed and shutting doors and windows. Water related strategies (i.e. reducing the amount of time in the shower/bath), and General turn off or switch off (i.e. "Turn things off if not being used") both consisted of approximately 11 % of all strategies. The remainder of the strategies could be grouped into smaller categories: structural or building changes (10 % of all strategies; i.e. insulation and draught proofing), electrical appliances (8 % of all strategies, i.e. efficient use of appliances), eat or drink (6 % of all strategies; i.e. not using the kettle, other cooking behaviours), alternative methods of saving energy (3 % of all strategies; i.e. go out, avoiding peak times), other energy or environmental actions (2 % of all strategies; i.e. transport related), other (2 % of all strategies; i.e. don't know). Some interesting patterns can be observed when comparing the energy saving strategies with the energy use perceptions provided above. Firstly, heating is identified as a high energy user, in line with this people have developed many strategies to save energy related to heating. But, secondly, there is a mismatch between the energy use perceptions and strategies for some of the other behaviours. On the one hand, lighting strategies seem to be overrepresented when compared to how often lighting is identified as a high energy user. On the other hand, strategies seem to be lacking even though they were often mentioned as high energy users, e.g. the washing machine and behaviours surrounding eat and drink.

Discussion

This paper presented a methodology combining two lines of research: examining regular behaviours as well as the associated perceptions of energy consumption. Importantly, our focus was not on the accuracy of the responses, but, by using a series of similar questions, to explore differences in energy use perceptions. When asked to think about energy use in the context of regular, important, high consuming, regular morning or evening, and regular summer or winter household actions – not only was there variation in the household actions identified as the main energy user in the home, but the responses also varied with regard to the type of actions that were mentioned. As an example of the former, central heating and washing machine use were identified as the main energy users when asked for regular, important and high consuming actions. But they were not necessarily mentioned when it came to regular morning and evening actions, so when making 'regular actions' more specific and focusing on certain time points responses change as well. And, as an example for the latter, certain types of actions were more often mentioned in particular contexts. Responses regarding personal hygiene came up especially when participants were asked to think about energy use regarding regular summer and morning actions. Compared to the other questions, responses related to entertainment were most commonly mentioned when thinking about energy regarding regular evening actions. So, apart from providing an overview of some of the daily behaviours and related energy perceptions that people hold, the data show how people's perceptions of the main energy users in their home vary depending on the context they are asked to think about. Moreover, the results on participants' energy saving strategies shows that the strategies that people use to save energy are not always in line with the actions they identify as high energy users. Some limitations to the research need to be acknowledged; firstly, data for each of the seven questions was provided by a different set of participants. But attempts were made to keep the groups as similar as possible, and control measures show no major differences between group characteristics. Secondly, because of time and funding constraints it was not possible to collect data from a representative sample, so care should be taken when attempting to generalise the results to the wider population.

Understanding people's daily behaviour and perceptions of energy demand could help in the design of communication strategies to encourage load shifting that fit with the public's current conceptualisation of energy demand. When taking this approach it is important to note that recent papers have also called for moving beyond the individual as well. For instance, Strengers (2012) suggests that by servicing the electricity grid and preserving current services we might be creating expectations that fuel peak demand.

References

Anderson, B. (2014) The rhythms and components of 'peak energy' demand. In proceedings from *Behave Energy Conference 2014*, Oxford, UK.

Attari, S.Z., DeKay, M.L., Davidson, C.I., & De Bruin, W.B. (2010). Public perceptions of energy consumption and savings. *PNAS, 107* (37), 16054–16059.

Baird, J.C., & Brier, J.M. (1981). Perceptual awareness of energy requirements of familiar objects. *Journal of Applied Psychology, 66* (1), 90–96.

Bourgeois, J., Kortuem, G., Bourcier, J., Van der Linden, J., Price, B.A., & Baudry, B. (2014). Energy demand shifting in residential households: The interdependence between social practices and technology design. In proceedings from *Behave Energy Conference 2014*, Oxford, UK.

Demski, C., Poortinga, W., & Pidgeon, N. (2014). Exploring public perceptions of energy security risks in the UK. *Energy Policy, 66*, 369–378.

Demski, C., Spence, A., & Pidgeon, N. (2013). *Transforming the UK Energy System: Public Values, Attitudes and Acceptability – Summary findings of a survey conducted August 2012.* UKERC: London.

Devon County Council. (2012). *Public Health Outcomes Report.* Devon County Council, UK.

Kahneman, D., Krueger, A.B., Schkade, D.A., Schwarz, N., & Stone, A.A. (2004). A survey method for characterizing daily life experience: The day reconstruction method. *Science, 306,* 1776–1780.

Keirstead, J. (2007). Behavioural responses to photovoltaic systems in the UK domestic sector. *Energy Policy, 35* (8), 4128–4141.

OFGEM. (2014). *Electricity Capacity Assessment Report 2014.* OFGEM [Office of Gas and Electricity Markets], UK.

Pout, C., MacKenzie, F., & Olloqui, E. (2008). *Final report: The impact of changing energy use patterns in buildings on peak electricity demand in the UK.* Building Research Establishment Client report for the Department of Energy and Climate Change, Garston, UK.

Schuitema, G., & Steg, L. (2005). Percepties van energieverbruik van huishoudelijke apparaten (Perception of energy use of domestic appliances). In: Bronner, A.E., Dekker, P., de Leeuw, E., de Ruyter, K., Smidts, A., Wieringa, J.E. (Eds.), *Ontwikkelingen in het marktonderzoek*. Jaarboek 2005 (Developments in Marketing Research. Yearbook 2005). De Vrieseborch, Haarlem, The Netherlands, pp. 165–180.

Strengers, Y. (2012). Peak electricity demand and social practice theories: Reframing the role of change agents in the energy sector. *Energy Policy, 44*, 226–234.

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