Understanding Household Consumption Practices and their Motivations: Opportunities to Foster Sustainability Practices

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ABSTRACT

Understanding household practices, beliefs, relationships among the members, and their preferences are often overlooked in the design of home-based interventions aiming to reduce consumption. We conducted a survey in the United Kingdom (22 responses) and a follow-up interview with 13 households to inform the design of interventions for reducing household consumption by: 1) understanding household consumption practices, and 2) identifying the concerns and challenges for household engagement with sustainability practices. Our findings highlight how the perspectives, understanding, and motives for consumption reduction actively shape household practices and their attempts to curtail consumption. Existing non-negotiable practices led to additional household consumption and we found different strategies households use to reach a shared-decision on food and energy use. Based on our findings, we provide opportunities for motivating and fostering engagement with sustainable practices at home.

CCS CONCEPTS

• **Human-centered computing** → **Collaborative and social computing devices**; **Empirical studies in collaborative and social computing**.

KEYWORDS

Household Consumption Practices, Climate Change, Sustainable HCI

1 INTRODUCTION

Global environmental change presents a significant danger to human wellbeing [60, 113]. Goal 13 of the United Nations (UN) sustainable development goals, which is 'Tracking climate change', urges for immediate action to prevent climate change and its consequences [70]. Research has shown that 72% of carbon emissions are caused by household consumption [42, 105]. Household consumption refers to the amount of resources used by homes to perform their day-to-day activities such as food consumption and waste, heating, water use, etc. [35]. Thus, households are key players in addressing climate change issues [75, 106].

Over the past years, government initiatives (such as performance standards and compulsory labelling [29], providing subsidies and incentives [28], and public communications campaigns [33, 78]) and meter readings [100] have been made to encourage curtailing household consumption. However, such measures could be ineffective due to the lack of awareness and understanding of policies and their implications for sustainability, and people's resistance to change their routines or consumption [101].

In addition, eco-feedback technologies have been designed to provide feedback on resource consumption with the goal of reducing environmental impact [8, 80] including in-house displays (IHD) [108], web-based apps / mobile applications [51], games [107], thermal imaging [92], virtual environments [59], tangible user interfaces [52], and data sculptures [91, 95]. However, most of these interventions have several limitations including the demand for visual attention which can be disruptive as it draws the focus of a person away from the task at hand [63, 113] and detachment from the physical environment [48]. The major focus of these interventions is to inform the households of their consumption [96] which overlooks the underlying factors that influence consumption practices [56]. It has primarily influenced visible consumption practices, however, it has not fully addressed invisible consumption within households that contribute to overall consumption patterns [26]. There is an opportunity to deepen our understanding of domestic practices within specific household contexts which could provide insights into the unique challenges, motivations, and barriers household occupants face. Aligned with [34], we identify that the design of technology interventions to encourage sustainable practices should be driven by user needs rather than seeing the user as the problem.

Hence, a greater understanding of household practices is necessary to move beyond the technicalities of interventions [5] towards encouraging sustainable consumption within the home context [83, 95]. The practice-oriented view suggests that domestic consumption is largely invisible due to deeply embedded social practices occurring within the home where people do not consider themselves as users of resources (such as energy, water, food etc.) but engage in activities which consume these resources [6, 26, 37, 83]. As a result, providing information on consumption via the lens of practices should resonate more clearly with households [93].

To further understand household consumption practices, we present the results of a survey conducted in the United Kingdom (22 responses) and a follow-up interview with 13 households. Through the survey and interviews, we gained an overview of complex household practices, exploring their perspectives, understanding, and motives about consumption. Our work contributes to the growing body of HCI work within computing and sustainable societies. First, we provide an overview of the household consumption practices identifying the experiences related to attempting

to curtail consumption, non-negotiable consumption, accountability of consumption and making inferences of consumption practices among household members, and satisfaction and happiness gained through pro-environmental actions. This complements research investigating household consumption [54, 69, 71], studies related to designing interventions to curtail usage in a home context [13, 51, 53, 91, 95, 100, 108], and the non-negotiability of consumption [9, 38, 73, 97, 111]. Second, based on our findings, we provide design opportunities to support intra-family collaboration [85, 92, 108] and personalisation [17, 89] calling for attention to the importance of understanding the household context and practices to inform the design of interventions to motivate consumption curtailment in a home context [5, 11, 12, 43, 83].

2 RELATED WORK

To situate our work, we consider relevant research in HCI and social norms related to household consumption practices and curtailment efforts. We then conclude by presenting existing challenges in encouraging sustainable practices in a household context.

2.1 Household Efficiency and Curtailment Behaviours

Previous research has studied the consumption patterns of households [9, 38, 73, 97, 111, 114]. Since households' decisions regarding their consumption are frequently influenced by temporal (time of day and day of the week, month, year), spatial (geography, economy, climate), and occupancy factors [114], household consumption patterns exhibit high levels of variation. Environmental problems are especially significant to behaviour change and recent research suggests that effective intervention techniques based on occupant behaviour could help reduce consumption dramatically [7, 59]. Corgnati et al. [10] showed that energy efficiency may be increased only by behavioural and lifestyle interventions, which are also less expensive than technically intrusive physical retrofit methods [39, 68, 72, 84, 90, 102]. By adopting efficiency and curtailment behaviours, households can significantly lower their greenhouse gas emissions. Efficiency behaviours are actions or measures that use resources for a given service (for example, insulating a building, buying an efficient appliance or device, etc.), while curtailment behaviours include lowering the thermostat, turning off the lights, and closing the shower while using soap etc. [94]. However, people's actions could also be motivated by personal and social norms [31].

2.2 Personal and Social Norms and their Role in Changing Pro-Environmental Activities

Understanding and insight into personal and social norms from the social sciences are necessary to address household consumption [31, 82]. On the one hand, people's activities tend to coincide with what they consider to be common among their peers or social groups [27]. On the other hand, people who feel personally responsible for protecting the environment are motivated to take environmental actions because of their own values, not because of outside pressure or rewards. It is important to understand how societal and personal norms affect households' actions towards the environment in order to encourage pro-environmental action [1].

2.3 Satisfaction Gained through Engaging in Pro-environmental Actions

Another method of motivating households to engage in sustainable activities could be using satisfaction gained through engagement with pro-environmental activities [4, 15, 16, 21, 23, 36, 64, 88, 103, 112]. How people perceive their actions to be may thereby affect one's moral self-image [4, 36, 88]. For instance, Xiao and Li [112] noted that the consumers who reported green purchase intention have higher life satisfaction than consumers who do not. Sustainable consumption may serve as a means of showing one's status and identity, which could make people conscious of how their purchases are seen by others [4, 15, 21, 103, 109] as income is one of the key determinants of sustainable consumption, with wealthy households being far more likely to buy sustainable goods [29].

2.4 Existing Challenges in Encouraging Sustainable Practices in a Household Context

Over the last couple of decades, technological interventions have been proposed to foster a reduction in household consumption, from web/mobile applications for monitoring and informing consumption to tangible interfaces [11, 42, 61, 81, 83, 105, 106]. Nonetheless, evidence reveals that after only a short time of usage, household consumption-related interventions are frequently relegated to unobtrusive locations in the home and benefits diminish [49]. This may be due to low user engagement with the intervention generated through having to give full attention to understanding the information [63] and not fitting into the aesthetics of the home [95]. Most interventions are utilitarian, made for studying and analysing statistics, and not for blending in with the home environment [11]. Another phenomenon mentioned in the literature is the asymmetry of intentions which is when an occupant adopts a sustainable practice with a different aim in mind (such as saving money) instead of doing it to mitigate climate change [107]. This illustrates that further research is needed to investigate what motivates households to reduce consumption rather than simply informing them about the consumption data [56]. Another challenge in household consumption is non-negotiability / non-discretionary which refers to people considering certain actions non-discretionary where they perform those actions no matter how much resources are consumed for it [9]. According to Barreto et al. [9] and Strengers [97], people may be reluctant to adjust to a given intervention due to consumption patterns or practices that are non-negotiable. Therefore, further understanding of home consumption patterns is necessary to inform and motivate occupants to curtail overall consumption [56].

Prior work has attempted to make invisible consumption visible through technologies such as web-based apps/mobile applications [6, 65], games [41], virtual environments [25], and data sculptures [91, 95]. However, most prior work on designing technologies for domestic consumption has not explored how household practices inform the design [95]. They design technologies for the houses based on assumptions and have reported observing relapse behaviours and boomerang effects [30]. Further, most research presents data on visible consumption practices [46, 96]. There is an opportunity to

deepen our understanding of contextual domestic practices to provide insights into the unique challenges, motivations, and barriers households face in different contexts.

3 STUDY DESIGN

To investigate households' everyday practices, values, preferences, and experiences around resource consumption and the individual and contextual factors that influence household consumption, we engaged in an exploratory study through a survey (22 responses) followed by 13 semi-structured household interviews.

To understand participants' attitudes related to climate change and gain initial insights into occupant information (members, age groups, role in the family etc.), a Likert scale-based [62] survey was employed as a data collection tool in this research study. A survey approach is well suited for gaining an understanding of thoughts, opinions, and real-life practices, of households [67]. The selection and design of the Likert scale items were adapted from previous scales from the literature (see [98]) to assess participants' attitudes towards climate change and curtailment activities practised in the house. The survey was carried out online via email, and participants were instructed to indicate their agreement or disagreement on a 5-point scale, ranging from strongly disagree to strongly agree, or never to always. The survey results help us structure the follow up interviews to aid further discussion [106].

The household interviews were conducted with the aim of gaining a further understanding of perspectives and underlying factors that shape and influence household practices [67]. The semi-structured nature of the interview provided flexibility and depth, allowing participants to offer their unique perspectives and personal stories. The interview protocol included a set of open-ended questions, covering various aspects such as daily routines, and energy / water usage practices etc. Six interviews were conducted in the participant's homes while seven were done online via Microsoft Teams.

This study was conducted between July and October 2022. A £50 voucher was provided per household as a financial incentive. Ethical approval was granted by the ethics committee of the School of Computer Science and Informatics, Cardiff University (approval no: COMSC/Ethics/2022/056).

3.1 Survey

3.1.1 Participant Recruitment. Initially, we circulated details related to the survey and interview on social media, the Cardiff University social media group, and utilised mailing lists requesting households in and around Cardiff, UK to express their willingness to join the study. 21 households were willing to join the study (see Table 1). All houses belonged to the participants. Participants were from different household types (single-user, couple/partners houses, and family homes).

3.1.2 Data Collection. Before the study started, participants were asked to sign an informed consent and send it via email and then participants were emailed the survey. In the first part, participants were asked to answer questions about socio-demographics and awareness of the consequences of climate change. Second, different energy-related beliefs were questioned regarding personal norms, usage curtailment actions taken by people, motives for being

resource-conscious and self-efficacy. The next section focused on existing devices/strategies in the house to measure energy, water consumption, monitor food waste, and approaches used to take environmentally favourable travel methods. This was followed by questions on thermal comfort. Households were instructed to discuss among all members of the house and submit one survey document per house. We received 22 responses to the survey from 21 households (Table 1). The husband and the wife of H9 submitted two separate responses to the survey.

3.2 Household Interviews

3.2.1 Participants. With individuals ranging in age from 18 to 54, we recruited 13 households (with 1 to 6 people per home) to participate in the interview from those that filled out the survey (the rows highlighted in blue from H1 to H13 in Table 1 are the participants for the interview). As this was an exploratory study, we decided on the inclusion criteria to have a wider representation of households across varying socio-economic contexts [2], consumers and prosumers. Three households had solar panels (prosumers) while the other households were concerned about climate change and reducing their consumption making them active consumers. As depicted in Table 1, we recruited participants from a range of diverse income categories as set by the Office of National Statistics, UK [44]. The frequency of the development of new codes significantly decreased after the seventh interview and we reached saturation and stopped at the 13th interview.

3.2.2 Data Collection. In the first part of the interview, we asked the households to describe their daily routines (morning, afternoon, evening and nighttime activities) of utilising energy, water, travel, recycling and reusing, and wasting food, and explain how consumption defers between weekdays and weekends and among seasons. We provided sheets of paper to participants to encourage them to write/draw with us on the sheets, however, they preferred providing verbal comments while the researchers wrote the important comments on the sheet for visibility (Figure 1). Second, households were asked to describe any existing techniques or methods used in their homes to reduce consumption.

3.3 Qualitative Data Analysis

Interview recordings were transcribed to conduct thematic analysis with the aid of NVivo (Version 1.7.1). Our data analysis strategy follows Braun and Clarke's principles for reflexive thematic analysis [19, 20]. Reflexive thematic analysis is a post-positivist method of data analysis that recognises researchers' influence on data interpretation and encourages researchers to reflect on that influence as they build and refine codes. We started by familiarising ourselves with the qualitative data to understand the context and participants. Then we generated initial codes to capture meaningful units of data while critically reflecting on how our personal perspectives may influence the selection and interpretation of codes. We reviewed the codes and looked for patterns, connections, and relationships between them. We collated similar codes together to identify potential themes. We continued revisiting and refining themes and iteratively reviewing the transcripts multiple times to support identifying themes until no new themes emerged. We discussed the results in each round among the research team. Initial examples of

Table 1: Participant demographics information

| Household (H)	Household type. NF - Nuclear family, SH - Shared house between partners, SO - Singe Occupant	No. of occupants	No. of participants in the interview	Age ranges of the participants	Gender of the participants	Mean average annual household income
H1	NF	4	1	18-24	Male	31k to 36k
H2	SH	4	2	25-34	Male , female	43k to 67k
H3	SH	2	2	25-34	Male , female	43k to 67k
H4	SH	2	2	25-34	Male , female	11k to 26k
H5	NF	3	2	25-34	Male , female	11k to 26k
H6	NF	4	2	35-44	Male , female	43k to 67k
H7	NF	2	1	45-54	female	43k to 67k
H8	NF	3	2	25-34	Male , female	43k to 67k
H9 (submitted two responses)	NF	4	2	45-54	Male , female	> 67k
H10	SO	1	1	35-44	female	36k to 43k
H11	NF	6	1	25-34	female	43k to 67k
H12	NF	5	2	35-44	Female, Female	26k to 31k
H13	SH	2	2	25-34	Male , female	> 67k
H14	NF	3		35-44	Male, female	43k to 67k
H15	SH	2		18-24	Male, female	43k to 67k
H16	NF	4		45-54	Male	31k to 36k
H17	NF	4		45-54	Female	31k to 36k
H18	SH	2		25-34	Female	Participant opted not to specify
H19	NF	4		45-54	Female	26k to 31k
H20	NF	3		45-54	Female	Participant opted not to specify
H21	NF	4		45-54	Female	Participant opted not to specify

themes were "Overall household consumption behaviour", "Attitudes around household consumption", "Enablers and barriers of sustainable practices", "Awareness of self-consumption patterns", "Non-negotiable consumption", and "Opportunities for design required to reduce consumption". As soon as we identified that the main concept for further exploration is the challenges and strategies of engaging in sustainable household practices, as it was prevalent in the narratives of the participants, we continued discussing, revisiting and regrouping data into themes. We rearranged the overarching themes and placed sub-themes under the major themes, and these were adjusted after receiving feedback from discussions with the research team. We analysed the empirical material and present our qualitative findings through three main themes highlighting the participants' household practices: 1) Environment-related Curtailment Strategies, 2) Accountability and Decision-making around Consumption Practices, and 3) Concerns and Challenges in Moving towards Sustainable Consumption.

4 FINDINGS

The participants' practices, attitudes, and cooperative household activities influenced their consumption-related actions. In the following subsections, we report the varied experiences of households attempting to reduce their consumption while considering differences in household dynamics and various needs that influence their engagement in sustainable practices. We shall first present our quantitative survey data and then present the qualitative findings of the interviews.

4.1 Quantitative data

The questionnaire data on 'awareness of consequences' (I1 to I3 in Figure 2) regarding climate change and issues created by it (Mean M = 4.53, Standard deviation s = 0.32) shows that all of the participants 'strongly agreed' or 'agreed' that the climate is changing and thought that they could further reduce their household consumption. All participants acknowledged that climate change was a serious issue (16% agree and 84% strongly agree). Over two-thirds (76%) of the participants believed they could further reduce home consumption.
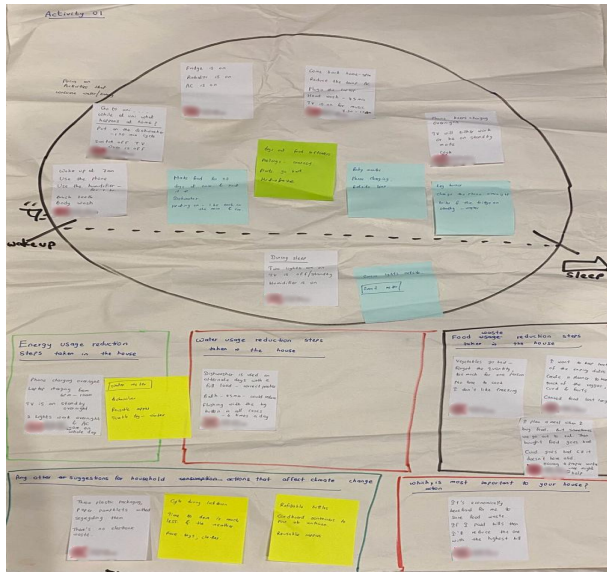
Figure 1: An example picture from the household interviews: exploring the daily routine of activities (first activity) with H8.

Questions on 'personal norms' on individual commitment to reduce consumption (I4 to I8 in Figure 2 with M=4.28, s=0.21) displayed that most of the participants (100% for energy use reduction, 96% for water use reduction, and 92% for food waste reduction) 'strongly agreed' or 'agreed' that they were personally committed to reducing their household's consumption. While 68% of the participants responded 'strongly agree' or 'agree' that they had a bad conscious when certain resources are overly utilised unnecessarily in their homes, 12% responded 'disagreed' or 'strongly disagreed'.

'Curtailment actions in the housing domain' (Figure 3) for consumption reduction in energy (I1 to I8 in Figure 3) showed more varied answers which resulted in a Mean of 3.44 and a standard deviation of 0.77. Washing laundry at lower temperatures was 'rarely' done by 4% of participants, however, 88% of participants 'always' or 'often' filled washing machine to capacity. A similar number of respondents 'never' or 'rarely' kept the TV on when no one is watching (56%) or left the heating on in unoccupied rooms (54%). More than half (58%) did not leave a tap running while brushing their teeth (M = 4.09). Further, 40% of participants 'never' or 'rarely' stood under the shower longer than necessary just to feel comfortable (M = 3.04). In contrast, a higher number of respondents reported they were 'never' or 'rarely' willing to carpool (68%, M = 2.09, I15 in Figure 3) or went on holiday by train (70.9% in I17 in Figure 3).

Similarly, the final set of questions that were on motives for resource consciousness and self-efficacy to curtail consumption (I9 to I19 in Figure 2) depicted the highest variation (M = 3.24 and s = 0.97). Over two-thirds (76%) of the respondents 'strongly agreed' or 'agreed' to be most concerned about their energy consumption while also paying attention to recycling (78%) and sustainable travel options (52%). Comparatively, only 24% 'strongly agreed' or 'agreed' to paying focus to consider originality when purchasing vegetables and fruits. A considerably higher score (92% 'strongly agreed' or 'agreed') was obtained in considering affordability when taking a consumption-efficient choice.

It was apparent that 80% of participants try to educate each other in the home on reducing the usage of resources. However, knowledge of the ways with the most potential to save resources in the home and confidence in how to do that was considered comparatively low. Particularly, 28% 'strongly disagreed' or 'disagreed' that they were aware of the areas in their home with the most potential for energy savings and, as a result, could optimise their usage without difficulty (I15). The majority (64%) of the participants were not confident in their ability to make energy-conscious choices when purchasing/consuming fruits, vegetables, and food.

Thermal comfort related answers (I18 to I20 in Figure 3) depicted that all participants would 'sometimes', 'often' or 'always' attempt to adapt their clothes to the season (M=4.38, e.g: wearing layers during the winter) and over half of the respondents (54.2%) would not leave the heating on even with no occupants in the house just to make it feel comfortable (M=3.95). Two-thirds of the respondents (75%) considered 'always' or 'often' taking certain actions to preserve climate even when it affects their comfort.

4.1.1 Which Practices are Important? Participants were asked to pick the practices that are important to work on reducing consumption and in terms of making an impact on the overall household consumption from a list of energy consumption, water consumption, food waste, travel, recycling, and sustainable clothing. Respondents were allowed to pick more than one option. 21 out of 22 respondents mentioned that the most important household practice they wish to improve was energy consumption practices while the least important was food wastage. Concerns with travel choices and sustainable clothing options scored 16 (out of 22) while recycling and water consumption closely followed with 14 and 13 respectively. The motivations behind these answers were further explored during the household interviews which lead to certain differences among the answers.

4.2 Qualitative Data

During the interviews, we further explored the participants' answers to choose the practices that are important to them and to work on reducing consumption. Energy consumption practices (electricity and gas) remained to be the most important among the highest number of respondents (9). When further discussing the reasons for this, unsurprisingly, respondents mentioned that the prevailing energy crisis in the UK which leads to rises in energy bills acts as a motivator to reduce consumption. Another reason mentioned was having no method of knowing which appliances in the house use more electricity: *"Gas and electricity usage is the largest consumption and hence they are the types of consumption that are most important to address. They are also likely the easiest to change"* (H4). Two households mentioned food waste as the most important to them. As the reason behind this, H11 mentioned that they *"really hate throwing food away"* while H3 said *"rising costs of food and the interest in reducing food waste"* as motivators. One household mentioned recycling as the most important practice expressing *"as a family, I find the amount of recycling we put out every Friday is a disgrace"*.

Figure 2: Survey responses given via the Likert Scale survey. Statement rates are shown on the rows, with the total percentages of participants responding negatively, neutrally and positively to the statements overlaid on the stacked bar graph.

Reducing water consumption was considered to be of secondary importance compared to energy consumption by three houses as it is *"not as severe consumption"* (H2). In contrast to the survey, travel choices (one participant) and sustainable clothing options (one participant) were not considered important in the presence of other consumption practices.

4.2.1 Environment-related Curtailment Strategies:
Household Attempts to Reduce Everyday Consumption. Participants took certain household measures attempting at reducing consumption starting with simple actions such as turning off lights when leaving a room or turning off water when applying soap in the shower. The mother of H8 got into the bath with her son to reduce water usage to have two separate baths. H12 utilised the bath water to mop the floor of the house instead of draining it. Participants were also being mindful of the time of day they do household activities such as laundry: *"in the morning I sometimes put the washing machine on because I read this article once, it was saying to put it on if you can during the day rather than evening hours because everybody gets home from work"* (H4). H2 put effort into conducting a trial and error collectively with the other members of the household to discover the most efficient setting to utilise on the heater to try and reduce consumption: *"we would have it on for an hour in the morning, for an hour in the evening or have it on continuously throughout the day set at a certain temperature and it would sort of kick back in every time the temperature dropped below"*.

This illustrates how the participants attempted to reduce consumption through day-to-day activities while also understanding what could be done within the home for sustainability that goes beyond day-to-day actions.

Actively Engaging in Recycling and Reusing Practices as a Community. We came across five households that spoke about recycling and one home (H3) particularly engaged in community recycling and reusing via social media. H3 was the home of husband and wife who were a part of *"a group on Facebook called 'Penarth Recycle' in which people post their old items on there"*. This community group on social media was a sharing scheme where people published their unused items so that anyone in need could collect them. During the interview, H3 mentioned that they were painting the back garden and got tins of sample paint. When they completed it they listed the reusable paint on the group and someone came to collect two cans. They also had half of a set of plastic shelves that they left outside their home which was collected by someone. Similarly, H9 was a household of two adults and two children. They actively handed over their soft plastics to the city council and a supermarket in the UK to be recycled and used a separate bin. The parents of H8 had a son and the wife was pregnant with their second baby at the time of the interview. They mentioned that they utilised reusable nappies for their son and also shared baby clothes and toys with their family members and neighbours. The wife of H13 upcycled her clothes so that she would not throw
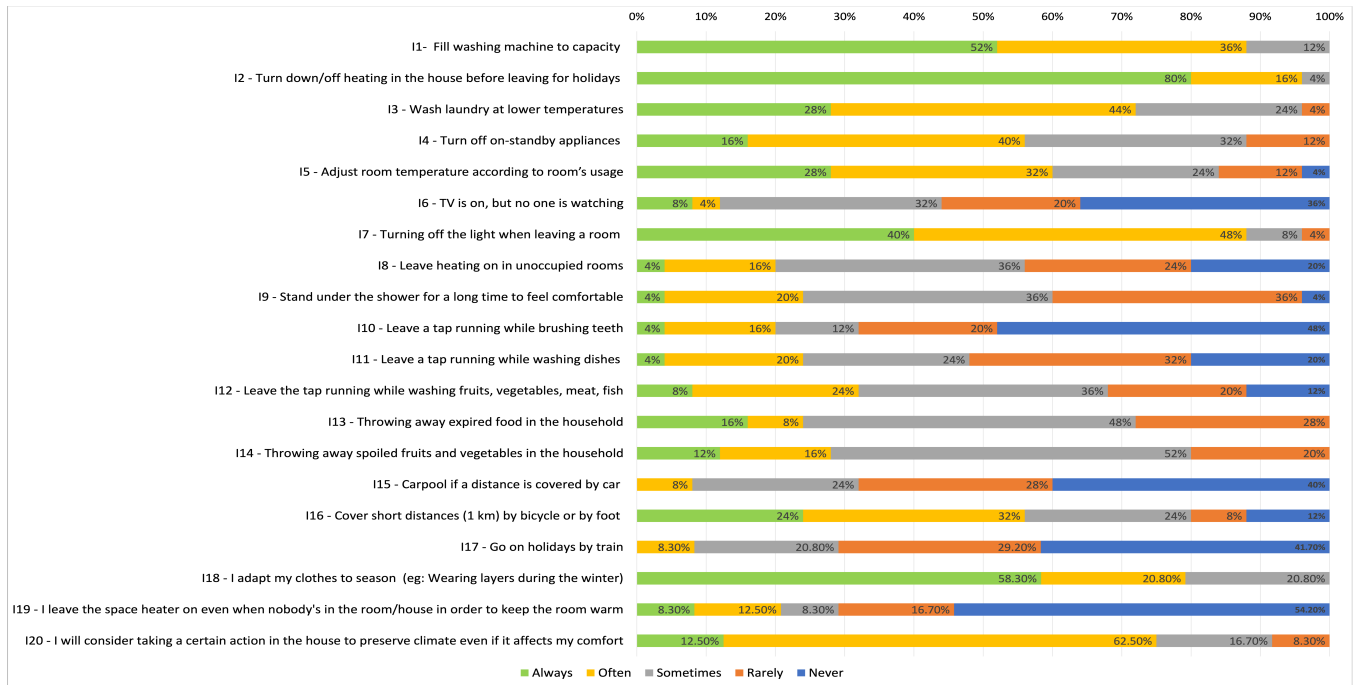
Figure 3: Survey responses given via the Likert Scale with statements for curtailment actions carried out in the household. Statement rates are shown on the rows, with the total percentages of participants responding never, rarely, sometimes, often, and always to the statements overlaid on the stacked bar graph.

away additional clothing *"and it does not go into scrap yards"*. These examples illustrate how people engage in collaborative activities as a community to reduce individual and communal consumption.

Knowledge on Consumption Curtailment Gathered from External Sources or Personal Experiences. Participants seemed to be willingly gathering knowledge on efficient ways to utilise appliances: *"We always try and keep the freezer full because a full freezer I have been told is more efficient because if there is a lot of food in the freezer and that is all frozen, then there is less room for the air. Because that air is what heats up when you open the freezer door quicker than the food"* (H2). H1 explained their personal experiences when they moved to the United Kingdom they bought food in bulk assuming that to be the best option. However, they experienced the majority of the food going to waste, hence, they stopped bulk buying. These experiences illustrate how households gather knowledge on curtailment actions from external sources or through their own experience and put them into practice. H11 actively retrofitted their house to be more energy efficient by building it to be eco-passive and H2 filled the walls with an extra layer of insulation to protect heat. However, H4 renovated the kitchen to entrap more heat while the rest of the house stayed cold: *"In the rest of the house we have limited choices to improve efficiency, and nearly all result in large compromises. They are probably all as big a job as the kitchen, but they would cost less than the kitchen in all likelihood"*.

4.2.2 Accountability and Decision-making around Consumption Practices.

Accountability of Consumption and Making Inferences Among Household Members. It was evident that participants were generally aware of their own and other household members' daily practices while consuming resources in the house and were familiar with family routines. For instance, H11 mentioned that *"my partner and I are good with water, but the kids - the two big ones if they have a shower, they are terrible. They just have the longest baths"*. Similarly, the wife of H9 spoke about how her husband was "horrible at switching off lights before (indicating he never switched the lights off) leaving the room but now it is the kids who do that". H1 was aware that their consumption patterns varied according to the time of day and day of the week: *"the weekends we all spend together, obviously. (...) everything is mostly working during the weekends [most appliances are switched on and working]"*. The wife of H4 acknowledged her poor food preparation practices and took accountability for it: *"I will totally own up to the fact that I am rubbish at making lunches (...) I do not think I will ever get better. I am also pretty bad at portion sizes so I make too much then there are leftovers"*.

Reaching Cooperative / Shared Decisions on Household Consumption. H9 explained that they do not focus too much on the best-before date mentioned on the food items: *"we are not particularly bothered about the best-before date. If it looks and smells and tastes okay, then it is fine"*. The household went beyond the standard expiration date of food in the packaging to decide to consume the food.

H8 was a household with parents and a son. They explained how they compared their electricity consumption with that of their

friends with children and decided within the household that they consume less compared to a similar household: *"I think compared to other households with a child - do we use a similar amount? Do we use more? No. We probably think we are relatively good. I know other friends that always have the television on in the house all day from the moment they wake up until time to go to sleep and they might have, like the radio working and things like that, that we do not tend to do"*. This illustrates how H8 went beyond the meter readings of their home to make an in-house decision on where their consumption is compared to another similar house.

4.2.3 Concerns and Challenges in Moving towards Sustainable Consumption.

Negotiating Different Cultural Conventions around Consumption Practices. In one instance, we came across the case of a household (H2) where the husband and wife lived and were hosting a Ukrainian refugee family. Only the husband and wife of H2 participated in the interview as they were the homeowners and the host family would not stay for long. H2 mentioned that they attempted to reduce water usage wherever possible, for instance by only using the dishwasher. However, the guest family used the sink to wash their dishes irrespective of the husband of H2 showing them how to use the dishwasher numerous times. This lead H2 to have increased water use. They continued to explain that they thought *"Western cultures probably don't waste as much water as maybe other cultures do. That might be a bit of a patronizing thing to say. But I think they are used to washing with a sink because they come from a state that provided water for them, whereas here, because we pay for our own water, we do things in a slightly more efficient way. So that would be a really striking comparison"*. This instance reveals how people may have different views and practices according to their cultural conventions and the infrastructure they have access to which may influence consumption disparities.

Children and Household Consumption. H11 with three children indicated that their children are less careful than adults regarding consumption: *"I went into my 11-year-old's room a couple of months ago and she had fallen asleep with her laptop open, plugged into the TV, and I was like, 'oh, that's been on like 12 hours!' To watch it all day! Then on 2 screens! That is a lot of energy"*. However, although H11 was conscious of this extra consumption, it appeared as though they were not willing to alter such actions, *"I think it is a normal kid thing [being careless in consumption]. I was the same when I was a kid"*. H11 indicated that the method of prompting to save resources differs for children than adults. In view of this, parents utilise these methods as incentives to encourage their children to waste fewer resources: *"we say energy is so expensive and we cannot afford to go on holiday if you keep doing that. So that is their incentive"* (H11). This suggests that a collective effort is needed to reduce home energy/water consumption. Further, the wife of H11 mentioned that she was a "climate warrior" before she got married and was pregnant (recycled more) – but now she cannot do the climate activities she used to do as she has children.

Lack of Time, Associated Workload and Technological Desires. H2 was a household with a husband and wife while the wife's mother lived not too far from them. They discussed how the wife's mother used a strategy of manually recording the dates of expiry of the food on a notepad attached to her fridge door and *"looks down the list and works out which stuff needs eating first"*. Interestingly they mentioned, *"I don't know how she does it because that's a lot of preparation"*. The couple expressed their unwillingness to perform such a task manually by attributing this to the difference in workloads between them and their mother: *"she [mother] has got all the time in the world. And I do not know how we would find the time to do all that"*. It was intriguing how these thoughts lead them to think of smart refrigerators that *"can order food for you once you run out"* and expressed that they would rather have an appliance as such doing the work for them. They also displayed knowledge of how such appliances function: *"it knows how much milk is in your fridge based on the weight of the bottle in your fridge"*.

Anxiety in New Homes and Geographical Location Influencing Consumption. We came across H9, a family of two parents, two children and their pet dog, who moved into their detached home recently. As they were unaware of the energy/water use of the new home, they were anxious about how the energy consumption would be during the winter: *"I think it will be really interesting to see what happens when we have to turn the heating on. Because we have not lived in a detached house, it does not have cavity wall insulation and I have no idea how much gas it will use. It is quite frightening actually to be going into the winter"*. While anxiety played a role in their thought process towards consumption, they also mentioned that the climate in Wales affected their thinking. It appeared that living in Wales made them feel at ease about water usage as the wife of H9 stated, *"it rains a lot in Wales so we are not short of water. So there is that kind of 'it is not our problem' sort of attitude"*.

Non-negotiability, Imperious Attitudes and Household Consumption. Activities such as washing and brushing teeth were perceived as non-negotiable *"I need to brush my teeth. I need to wash my face, I need to shower. I need to wash my hands. I need to wash my dishes. I need to wash my clothes. None of that can just not happen and it is hard to cut down on those things"* (H3). Additionally, participants held different opinions/ attitudes about consumption activities in the household. Certain members of the household held superior views about their consumption activities, for instance, *"I am the only one in the family that does anything to try and conserve water"* as the wife of H9 proudly noted with open hands while her facial expressions displayed satisfaction and happiness. The wife of H13 happily mentioned *"I do work out quite frequently and one of the benefits of working out is you do not have to turn the radiator on as much"*.

5 DISCUSSION

Our findings through quantitative data provided an extra understanding of households' awareness and attitude towards climate change, personal norms, and resource-conscious motives. This helped obtain an initial understanding of the household context

and consumption practices which were further discussed during the interviews.

5.1 Opportunities: Designing for Curtailment of Household Consumption

One strategy used in the technologies that promote sustainable consumption in the home [45, 53, 57, 58, 65, 77, 79, 80, 91, 95] is to provide residents with feedback on their usage. This feedback is expected to drive households to improve their consumption practices which may not always be successful and may not result in a long-term shift towards sustainable practice [49]. Simply informing households of their consumption is not always sufficient to drive sustainable actions as the home is a complicated setting that is intended for all but is also influenced by occupants' unique requirements and preferences [24]. It is a place that many people commonly share, each with different interests and goals [5]. The people, activities, technologies, physical locations, social, and communicative aspects that define a place as a home make it challenging to conduct research therein [5]. However, little consideration has been given to having a deeper understanding of the dynamics and practices in the home context and what exactly triggers or motivates changes in household practices [56]. This merits future research to study what motivates sustainable action in the home.

There is no one-size-fits-all approach to encouraging people to reduce household consumption, as individual motivations and circumstances vary [94]. Past research has shown that information nudging can help households to reduce consumption, however, the effectiveness varies depending on aspects such as information content, delivery mode and study area [87]. While nudges generally aim to change the decision environment in order to affect behaviour, motivation functions on a deeper level, tapping into individuals' own impulses and reasons for taking an action [99]. Since it derives from personal values and self-determination, motivation is frequently regarded as a more sustainable and long-term strategy for change in practices [86]. Combining nudges with motivation may be successful in practice: nudges may provide early indications or reminders to assist people in overcoming inertia or making decisions that are consistent with their motives - motivation, on the other hand, may enhance the internal desire and commitment to maintain behaviour change. This merits future research to investigate further the use of motivation in encouraging households to engage in sustainable actions and also explore combining nudges with motivation to study the effect in a household context. In summary, while motivation is important, it should be complemented by addressing household-specific contextual factors. In the following subsections, we shall discuss five opportunities for design to enhance motivation in promoting sustainability in households. We propose that a combination of these opportunities tailored to specific home contexts may be more effective than relying on a single approach to promoting reducing household consumption.

5.1.1 Personalised Communication: Tailoring Interventions to Diverse Household Contexts and Needs. Our quantitative study showed varied answers regarding the household curtailment actions taken by different respondents. The qualitative study displayed discrepancies among households in terms of routines, activities, decisions,

and preferences. Therefore, in order to motivate households and enhance their uptake of sustainable actions, we need to gather further comprehension of each household's consumption patterns, preferences, motivations, and tailor communication efforts accordingly to foster engagement and change in practices [17]. Tailored communication and content shall resonate with the specific characteristics, motivations, needs and interests of each household [58] more than generalised information [89]. It will benefit to offer specific recommendations and actionable steps [40] in the household context that occupants can take to reduce their environmental impact while aligning those recommendations with individual households' priorities, resources, and constraints.

5.1.2 Using Satisfaction as a Push Towards Sustainability. It is argued that environmentally conscious people are happier and have higher life satisfaction [4, 15, 16, 21, 23, 36, 64, 88, 103, 112]. When people engage in pro-environmental activities, they see themselves as good people [64, 103]. This satisfaction people get when engaging in pro-environmental activities could be used to motivate them to engage in more sustainable actions [32]. Research has shown how both positive and negative emotions influence engagement in pro-environmental activities. Negative emotions, for example (e.g., feeling angry, guilty, frustrated, embarrassed or regretful) have been shown to reduce people's desire to use public transportation and recycle at home [23]. Furthermore, positive emotions (such as happiness or optimism) are a significant predictor of green product purchases [18, 66]. According to Venhoeven et al. [103], the moral nature of environmentally friendly practices may elicit positive emotions because engaging in these practices can signal that one is environmentally friendly and thus a good person. From those negative emotions, it has been proposed that guilt may be used as a motivator in campaigns promoting pro-environmental actions [50]. However, such techniques should be used with caution as an individual intervention method using guilt to induce changes in practices are unlikely to be beneficial and may result in denial of the seriousness of the climate change issue or of one's own responsibility towards it [14]. However, the wish to avoid experiencing negative emotions could be used to motivate people to move towards sustainable practices [50]. This merits future research to study enhancing user engagement through positive feelings (or the wish to avoid negative feelings) in designing interventions for reducing consumption [83].

5.1.3 Appreciating and Encouraging Inter-Household Collaboration. The collaboration among household members is largely invisible to the outside world. Our quantitative data showed that participants engage in educating household members regarding sustainable actions which suggests collaboration directs to people assisting each other [110]. We noticed during the interviews that H4 retrofitted their kitchen while the rest of the house stayed cold. On the one hand, this could be because the household decided to have a tradeoff between overall cost and the immediate need to retrofit. On the other hand, the reason for this may be explained by the fact that one can dream of kitchens, talk about them and show them to others [51]. Therefore, the reason not to insulate the house but the kitchen could indirectly be explained by conspicuous (visible) consumption theory [51]. Payy et al. [76] stated that the kitchen is a gathering point in the household. They argue that when people

gather in a kitchen to prepare food, it is about more than simply providing food for the group, it is also about spending time together, supporting one another, sharing stories, and helping a shared meal gradually come together. Cooking with others requires coordination and cooperation in the kitchen. Therefore, the kitchen could be a potential design space because it offers a special area for focusing on the design options for social and natural user interaction.

5.1.4 Investigate Association Between Parents and Children. The association between children and the parents of the household may influence changes in curtailment efforts [9, 38, 73, 97, 111]. Families with children use more energy in the home than those without, and this tends to increase as children grow older, which is thought to be due to older children's increased use of information and communication technology and consumer electronics [38]. On the other hand, the mother of H11 spoke about how her children would influence her actions if she kept the tap on while brushing teeth. It has long been established that children can hold a measure of influence over their parents' decisions [73, 111]. Wang et al. [104] asserted that children are important stakeholders in promoting and combating climate change demonstrating greater knowledge of how people save energy and the reasons why, and representing a breakthrough in changing adults' entrenched thinking and motivating parents to save energy. The engagement and influence of children should be further investigated to determine how children could actively participate and take on responsibility for curtailing home consumption.

5.1.5 Making Aware of and Motivate to Reduce Non-negotiable Consumption. Participants in the study conducted by Strengers [97] were unwilling to reduce electricity and water consumption through the usage of electrical appliances. Similarly, Barreto et al. [9] claimed that the non-adoption of their proposed system was partially rooted in families' non-negotiability of their routines. However, due to the perceived non-negotiability of household practices and/or the seeming irrelevance of the generated feedback, householders may be led to utilise the interventions targeting curtailment irregularly and cause disinterest in it [97]. This disinterest may occur due to the disconnection between resource consumption data gathered by interventions and the perceived non-negotiability of everyday practices [55]. Since such actions are perceived to be compulsory, displaying general consumption data to users and informing them of such non-negotiable consumption might not be effective. As discussed above, future research needs to move beyond informing households of non-negotiable consumption and further motivate occupants via feedback, incentives, and emotional engagement to reduce compulsory consumption.

5.2 Reflections on Study Design - Future Directions

We did not use a large representative sample of UK households in this study. However, it is not unusual for qualitative research to employ sample sizes similar to that used in our study (see [22, 47, 50, 74]. The aim of this qualitative research is not generalise the findings but to understand specific contexts, explore different perspectives, and generate detailed explanations of household practices

and experiences. Further, these findings could inform the design of approaches that could be applied in similar contexts.

Although we recruited participants through the university network, our participants had different backgrounds and experiences as well as we got diversity in terms of household size, location, and socioeconomic status. Further, we had three households (who were not part of the university) that were recruited through snowball sampling where existing participants helped identify and refer additional participants. Most participants indicated that they were willing to reduce consumption and were concerned about climate change. Although this answer may potentially vary on a larger sample of households, the people who willingly engage in such surveys are naturally concerned about climate change. Future work may benefit from incorporating a diverse range of participants from various backgrounds, socioeconomic statuses, cultures and perspectives.

Although surveys have benefits as a data collection tool as we explained, online surveys commonly suffer from two limitations: the population to which they are distributed cannot be described, and respondents with biases may select themselves into the sample [3]. Therefore, future research may also benefit from using prospective quantitative data collection methodologies apart from surveys to further explore the climate change attitudes and norms related to household sustainable practices.

6 CONCLUSION

This paper discussed the importance of understanding household consumption practices to pay attention to the contextual factors associated with a home to motivate and encourage households to engage in sustainable activities. We started by justifying the need for further understanding of household practices. Then, we review existing interventions that could provide methods of curtailing home consumption and their limitations. Our findings from the quantitative study highlighted that the households are aware of the climate change issue and feel committed to taking measures against it. Our qualitative study highlighted the household curtailment practices and challenges faced while engaging in sustainable activities. Most household climate action-related interventions have only focused on providing consumption information to the user. However, our study showed that we should move beyond simply informing towards having a deeper understanding of the dynamics and practices beyond the individual activities to account for all the different elements that are part of a household. We position the paper to contribute to the emerging discourse centred around designing HCI technology for sustainability.

REFERENCES

[1] Wokje Abrahamse, Sarah Darby Darby, and Katherine McComas. 2018. How to communicate energy and environment with energy consumers?

[2] P Allmark. 2004. Should research samples reflect the diversity of the population? *Journal of Medical Ethics* 30, 2 (2004), 185–189. https://doi.org/10.1136/jme.2003.004374 arXiv:https://jme.bmj.com/content/30/2/185.full.pdf

[3] Chittaranjan Andrade. 2020. The Limitations of Online Surveys. *Indian Journal of Psychological Medicine* 42, 6 (2020), 575–576. https://doi.org/10.1177/0253717620957496 arXiv:https://doi.org/10.1177/0253717620957496 PMID: 33354086.

[4] Karl Aquino and Americus Reed. 2003. The self-importance moral identity. *Journal of personality and social psychology* 83 (01 2003), 1423–40. https://doi.org/10.1037/0022-3514.83.6.1423

[5] Lynne Baillie and David Benyon. 2008. Place and Technology in the Home. *Comput. Supported Coop. Work* 17, 2–3 (apr 2008), 227–256. https://doi.org/10.1007/s10606-007-9063-2

[6] Amartya Banerjee and Michael Horn. 2014. Ghost Hunter: Parents and children playing together to learn about energy consumption. *TEI 2014 - 8th International Conference on Tangible, Embedded and Embodied Interaction, Proceedings*, 267–274. https://doi.org/10.1145/2540930.2540964

[7] Juan David Barbosa and Elie Azar. 2018. Modeling and implementing human-based energy retrofits in a green building in desert climate. *Energy and Buildings* 173 (2018), 71–80. https://doi.org/10.1016/j.enbuild.2018.05.024

[8] Mary Barreto, Diego Casado-Mansilla, Augusto Esteves, and Filipe Magno de Gouveia Quintal. 2022. Designing Smart Plugs for Interactivity and Energy Sustainability via a Survey and Thematic Analysis. In *Nordic Human-Computer Interaction Conference* (Aarhus, Denmark) (*NordiCHI '22*). Association for Computing Machinery, New York, NY, USA, Article 13, 12 pages. https://doi.org/10.1145/3546155.3546681

[9] Mary Barreto, Evangelos Karapanos, and Nuno Nunes. 2013. Why don't families get along with eco-feedback technologies? A longitudinal inquiry. *ACM International Conference Proceeding Series*. https://doi.org/10.1145/2499149.2499164

[10] Verena M. Barthelmes, Cristina Becchio, Valentina Fabi, and Stefano P. Corgnati. 2017. Occupant behaviour lifestyles and effects on building energy use: Investigation on high and low performing building features. *Energy Procedia* 140 (2017), 93–101. https://doi.org/10.1016/j.egypro.2017.11.126 Beyond NZEB Buildings (AiCARR 50th International Congress, Matera (I), 10-11 May 2017).

[11] Lyn Bartram. 2015. Design Challenges and Opportunities for Eco-Feedback in the Home. *IEEE Computer Graphics and Applications* 35, 4 (2015), 52–62. https://doi.org/10.1109/MCG.2015.69

[12] Lyn Bartram, Johnny Rodgers, and Kevin Muise. 2010. Chasing the Negawatt: Visualization for Sustainable Living. *IEEE computer graphics and applications* 30 (05 2010), 8–14. https://doi.org/10.1109/MCG.2010.50

[13] Lyn Bartram, Johnny Rodgers, and Rob Woodbury. 2011. Smart Homes or Smart Occupants? Supporting Aware Living in the Home. 52–64. https://doi.org/10.1007/978-3-642-23771-3_5

[14] T Bedford, Patricia Collingwood, Andrew J Darnton, David Evans, B Getersleben, Wokje Abrahamse, and Tim Jackson. 2011. Guilt: an effective motivator for pro-environmental behaviour change?

[15] Daryl J. Bem. 1967. Self-perception: An alternative interpretation of cognitive dissonance phenomena. *Psychological review* 74 3 (1967), 183–200.

[16] Daryl J. Bem. 1972. Self-Perception Theory. Advances in Experimental Social Psychology, Vol. 6. Academic Press, 1–62. https://doi.org/10.1016/S0065-2601(08)60024-6

[17] René M.J. Benders, Rixt Kok, Henri C. Moll, Gerwin Wiersma, and Klaas Jan Noorman. 2006. New approaches for household energy conservation—In search of personal household energy budgets and energy reduction options. *Energy Policy* 34, 18 (2006), 3612–3622. https://doi.org/10.1016/j.enpol.2005.08.005

[18] Megan J. Bissing-Olson, Kelly S. Fielding, and Aarti Iyer. 2016. Experiences of pride, not guilt, predict pro-environmental behavior when pro-environmental descriptive norms are more positive. *Journal of Environmental Psychology* 45 (2016), 145–153. https://doi.org/10.1016/j.jenvp.2016.01.001

[19] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3 (01 2006), 77–101. https://doi.org/10.1191/1478088706qp063oa

[20] Virginia Braun and Victoria Clarke. 2021. One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative Research in Psychology* 18, 3 (2021), 328–352. https://doi.org/10.1080/14780887.2020.1769238 arXiv:https://doi.org/10.1080/14780887.2020.1769238

[21] Kirk Brown and Tim Kasser. 2005. Are Psychological and Ecological Well-Being Compatible? The Role of Values, Mindfulness, and Lifestyle. *Social Indicators Research* 74 (11 2005), 349–368. https://doi.org/10.1007/s11205-004-8207-8

[22] Kelly Caine. 2016. Local Standards for Sample Size at CHI. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) (*CHI '16*). Association for Computing Machinery, New York, NY, USA, 981–992. https://doi.org/10.1145/2858036.2858498

[23] Giuseppe Carrus, Paola Passafaro, and Mirilia Bonnes. 2008. Emotions, habits and rational choices in ecological behaviours: The case of recycling and use of public transportation. *Journal of Environmental Psychology* 28, 1 (2008), 51–62. https://doi.org/10.1016/j.jenvp.2007.09.003

[24] Fernando Casado, M. Hidalgo, and Patricia García Leiva. 2017. Energy efficiency in households: The effectiveness of different types of messages in advertising campaigns. *Journal of Environmental Psychology* 53 (08 2017). https://doi.org/10.1016/j.jenvp.2017.08.003

[25] Hung-Ming Chen, Chun-Wei Lin, Shang-Hsien Hsieh, Hsuan-Fu Chao, Chuin-Shan Chen, Ruei-Shiue Shiu, Shiang-Ru Ye, and Yu-Chang Deng. 2012. Persuasive feedback model for inducing energy conservation behaviors of building users based on interaction with a virtual object. *Energy and Buildings* 45 (2012), 106–115. https://doi.org/10.1016/j.enbuild.2011.10.029

[26] Marshini Chetty, David Tran, and Rebecca E. Grinter. 2008. Getting to Green: Understanding Resource Consumption in the Home. In *Proceedings of the 10th International Conference on Ubiquitous Computing* (Seoul, Korea) (*UbiComp '08*). Association for Computing Machinery, New York, NY, USA, 242–251. https://doi.org/10.1145/1409635.1409668

[27] Robert B Cialdini and Melanie R Trost. 1998. Social influence: Social norms, conformity and compliance. (1998).

[28] ORGANISATION FOR ECONOMIC CO-OPERATION and DEVELOPMENT. 2006. *The Political Economy of Environmentally Related Taxes.* Retrieved April 2, 2023 from https://www.oecd.org/env/tools-evaluation/thepoliticaleconomyofenvironmentallyrelatedtaxes.htm

[29] ORGANISATION FOR ECONOMIC CO-OPERATION and DEVELOPMENT. 2008. *PROMOTING SUSTAINABLE CONSUMPTION: GOOD PRACTICES IN OECD COUNTRIES.* Retrieved April 2, 2023 from https://www.oecd.org/greengrowth/40317373.pdf

[30] Stefano De Dominicis, Rebecca Sokoloski, Christine Jaeger, and Paul Schultz. 2019. Making the smart meter social promotes long-term energy conservation. *Palgrave Communications* 5 (05 2019), 51. https://doi.org/10.1057/s41599-019-0254-5

[31] Judith I.M. de Groot, Krista Bondy, and Geertje Schuitema. 2021. Listen to others or yourself? The role of personal norms on the effectiveness of social norm interventions to change pro-environmental behavior. *Journal of Environmental Psychology* 78 (2021), 101688. https://doi.org/10.1016/j.jenvp.2021.101688

[32] Raymond De Young. 2000. Expanding and evaluating motives for environmentally responsible behavior. *Journal of Social Issues* 56 (01 2000), 509–526.

[33] Tawanna Dillahunt, Olga Lyra, Mary Barreto, and Evangelos Karapanos. 2017. Reducing children's psychological distance from climate change via eco-feedback technologies. *International Journal of Child-Computer Interaction* 13 (05 2017). https://doi.org/10.1016/j.ijcci.2017.05.002

[34] Carl DiSalvo, Phoebe Sengers, and Hrönn Brynjarsdóttir. 2010. Mapping the Landscape of Sustainable HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Atlanta, Georgia, USA) (*CHI '10*). Association for Computing Machinery, New York, NY, USA, 1975–1984. https://doi.org/10.1145/1753326.1753465

[35] Angela Druckman and Tim Jackson. 2010. AN EXPLORATION INTO THE CARBON FOOTPRINT OF UK HOUSEHOLDS.

[36] David Dunning. 2007. Self-Image Motives and Consumer Behavior: How Sacrosanct Self-Beliefs Sway Preferences in the Marketplace. *Journal of Consumer Psychology* 17, 4 (2007), 237–249. https://doi.org/10.1016/S1057-7408(07)70033-5

[37] Johanne Mose Entwistle, Mia Kruse Rasmussen, Nervo Verdezoto, Robert S. Brewer, and Mads Schaarup Andersen. 2015. Beyond the Individual: The Contextual Wheel of Practice as a Research Framework for Sustainable HCI. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (Seoul, Republic of Korea) (*CHI '15*). Association for Computing Machinery, New York, NY, USA, 1125–1134. https://doi.org/10.1145/2702123.2702232

[38] Michael J. Fell and Lai Fong Chiu. 2014. Children, parents and home energy use: Exploring motivations and limits to energy demand reduction. *Energy Policy* 65 (2014), 351–358. https://doi.org/10.1016/j.enpol.2013.10.003

[39] Jesica Fernández-Agüera, Samuel Domínguez-Amarillo, Carmen Alonso, and Fernando Martín-Consuegra. 2019. Thermal comfort and indoor air quality in low-income housing in Spain: The influence of airtightness and occupant behaviour. *Energy and Buildings* 199 (2019), 102–114. https://doi.org/10.1016/j.enbuild.2019.06.052

[40] Marta Ferreira, Miguel Coelho, Valentina Nisi, and Nuno Nunes. 2021. Climate Change Communication in HCI: a Visual Analysis of the Past Decade. 1–1. https://doi.org/10.1145/3450741.3466774

[41] Jan Fijnheer, H. Oostendorp, Geert-jan Giezeman, and Remco Veltkamp. 2021. Competition in a Household Energy Conservation Game. *Sustainability* 13 (10 2021), 11991. https://doi.org/10.3390/su132111991

[42] Jan Fijnheer, H. Oostendorp, and Remco Veltkamp. 2019. Household Energy Conservation Intervention: a Game versus Dashboard Comparison. *International Journal of Serious Games* 6 (09 2019), 23–36. https://doi.org/10.17083/ijsg.v6i3.300

[43] Geraldine Fitzpatrick and Greg Smith. 2009. Technology-Enabled Feedback on Domestic Energy Consumption: Articulating a Set of Design Concerns. *IEEE Pervasive Computing* 8, 1 (2009), 37–44. https://doi.org/10.1109/MPRV.2009.17

[44] Office for National Statistics. 2019. *Income estimates for small areas, England and Wales financial year ending 2018.* https://www.ons.gov.uk/census

[45] David Fredericks, Sandra Woolley, and Zhong Fan. 2019. Visualising the Invisible: Augmented Reality and Virtual Reality as Persuasive Technologies for Energy Feedback. https://doi.org/10.1109/SmartWorld-UIC-ATC-SCALCOM-IOP-SCI.2019.00225

[46] Jon Froehlich, Leah Findlater, and James Landay. 2010. The design of eco-feedback technology. *Conference on Human Factors in Computing Systems - Proceedings* 3, 1999–2008. https://doi.org/10.1145/1753326.1753629

[47] Benjamin Gardner and Charles Abraham. 2007. What drives car use? A grounded theory analysis of commuters' reasons for driving. *Transportation Research Part F: Traffic Psychology and Behaviour* 10, 3 (2007), 187–200. https://doi.org/10.1016/j.trf.2006.09.004

[48] Julie Goodhew, Sabine Pahl, Timothy Auburn, and Steve Goodhew. 2014. Making Heat Visible. *Environment and Behavior* 47 (09 2014). https://doi.org/10.1177/0013916514546218

[49] Murray Goulden, Ben Bedwell, Stefan Egglestone, Tom Rodden, and Alexa Spence. 2014. Smart Grids, smart users? The role of the user in demand side management. *Energy Research & Social Science* 2 (06 2014), 21–29. https://doi.org/10.1016/j.erss.2014.04.008

[50] Ella Graham-Rowe, Donna C. Jessop, and Paul Sparks. 2014. Identifying motivations and barriers to minimising household food waste. *Resources Conservation and Recycling* 84 (2014), 15–23.

[51] Kirsten Gram-Hanssen. 2008. Consuming technologies – developing routines. *Journal of Cleaner Production* 16, 11 (2008), 1181–1189. https://doi.org/10.1016/j.jclepro.2007.08.006 The Governance and Practice of Change of Sustainable Consumption and Production.

[52] Rajat Gupta, Laura Barnfield, and Matthew Gregg. 2018. Exploring innovative community and household energy feedback approaches. *Building Research & Information* 46, 3 (2018), 284–299. https://doi.org/10.1080/09613218.2017.1356130 arXiv:https://doi.org/10.1080/09613218.2017.1356130

[53] Anton Gustafsson and Magnus Gyllenswärd. 2005. The Power-Aware Cord: Energy Awareness through Ambient Information Display. In *CHI '05 Extended Abstracts on Human Factors in Computing Systems* (Portland, OR, USA) *(CHI EA '05)*. Association for Computing Machinery, New York, NY, USA, 1423–1426. https://doi.org/10.1145/1056808.1056932

[54] Anders Rhiger Hansen. 2018. 'Sticky' energy practices: The impact of childhood and early adulthood experience on later energy consumption practices. *Energy Research & Social Science* 46 (2018), 125–139. https://doi.org/10.1016/j.erss.2018.06.013

[55] Tom Hargreaves, Michael Nye, and Jacquelin Burgess. 2010. Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors. *Energy Policy* 38, 10 (2010), 6111–6119. https://doi.org/10.1016/j.enpol.2010.05.068 The socio-economic transition towards a hydrogen economy - findings from European research, with regular papers.

[56] Helen He and Saul Greenberg. 2012. Motivating Sustainable Energy Consumption in the Home. (04 2012).

[57] Tiffany Holmes. 2007. Eco-visualization: Combining art and technology to reduce energy consumption. *Creativity and Cognition 2007, CC2007 - Seeding Creativity: Tools, Media, and Environments*, 153–162. https://doi.org/10.1145/1254960.1254982

[58] Steven Houben, Connie Golsteijn, Sarah Gallacher, Rose Johnson, Saskia Bakker, Nicolai Marquardt, Licia Capra, and Yvonne Rogers. 2016. Physikit: Data Engagement Through Physical Ambient Visualizations in the Home. 1608–1619. https://doi.org/10.1145/2858036.2858059

[59] Peeraya Inyim, Mostafa Batouli, Maria Presa Reyes, Triana Carmenate, and Ali Mostafavi. 2018. A Smartphone Application for Personalized and Multi-Method Interventions toward Energy Saving in Buildings. *Sustainability* 10 (05 2018). https://doi.org/10.3390/su10061744

[60] IPCC. 2022. *Climate change: a threat to human wellbeing and health of the planet. Taking action now can secure our future.* Retrieved February 28, 2022 from https://www.ipcc.ch/2022/02/28/pr-wgii-ar6/

[61] Chantal Iribagiza, Taylor Sharpe, Jeremy Coyle, Pie Nkubito, Ricardo Piedrahita, Michael Johnson, and Evan A. Thomas. 2021. Evaluating the Effects of Access to Air Quality Data on Household Air Pollution and Exposure—An Interrupted Time Series Experimental Study in Rwanda. *Sustainability* 13, 20 (2021). https://doi.org/10.3390/su132011523

[62] Ankur Joshi, Saket Kale, Satish Chandel, and D Kumar Pal. 2015. Likert scale: Explored and explained. *British journal of applied science & technology* 7, 4 (2015), 396.

[63] David Jáuregui and Nadine Couture. 2019. Tacsel: Shape-Changing Tactile Screen applied for Eyes-Free Interaction in Cockpit.

[64] Tim Kasser and Kennon Sheldon. 2002. What Makes for a Merry Christmas? *Journal of Happiness Studies* 3 (02 2002), 313–329. https://doi.org/10.1023/A:1021516410457

[65] Cecilia Katzeff, Rebecka Milestad, Jorge Luis Zapico, and Ulrica Bohné. 2020. Encouraging Organic Food Consumption through Visualization of Personal Shopping Data. *Sustainability* 12, 9 (2020). https://doi.org/10.3390/su12093599

[66] Nicole Koenig-Lewis, Adrian Palmer, Janine Dermody, and Andreas Urbye. 2014. Consumers' evaluations of ecological packaging – Rational and emotional approaches. *Journal of Environmental Psychology* 37 (2014), 94–105. https://doi.org/10.1016/j.jenvp.2013.11.009

[67] Jonathan Lazar, Jinjuan Heidi Feng, and Harry Hochheiser. 2017. In *Research Methods in Human Computer Interaction (Second Edition)* (second edition ed.), Jonathan Lazar, Jinjuan Heidi Feng, and Harry Hochheiser (Eds.). Morgan Kaufmann, Boston, 1–24. https://doi.org/10.1016/B978-0-12-805390-4.00001-7

[68] Xianting Li, Chong Shen, and Chuck W. F. Yu. 2017. Building energy efficiency: Passive technology or active technology? *Indoor and Built Environment* 26, 6 (2017), 729–732. https://doi.org/10.1177/1420326X17719157 arXiv:https://doi.org/10.1177/1420326X17719157

[69] Wenling Liu, Gert Spaargaren, Nico Heerink, Arthur P.J. Mol, and Can Wang. 2013. Energy consumption practices of rural households in north China: Basic characteristics and potential for low carbon development. *Energy Policy* 55 (2013), 128–138. https://doi.org/10.1016/j.enpol.2012.11.031 Special section: Long Run Transitions to Sustainable Economic Structures in the European Union and Beyond.

[70] Suhuai Luo and Jiaming Li. 2009. A smart fridge with an ability to enhance health and enable better nutrition. *International Journal of Multimedia and Ubiquitous Engineering* 4 (05 2009).

[71] Sherilyn MacGregor, Catherine Walker, and Tally Katz-Gerro. 2019. 'It's what I've always done': Continuity and change in the household sustainability practices of Somali immigrants in the UK. *Geoforum* 107 (2019), 143–153. https://doi.org/10.1016/j.geoforum.2019.09.013

[72] Lise Magnier and Jan Schoormans. 2015. Consumer reactions to sustainable packaging: The interplay of visual appearance, verbal claim and environmental concern. *Journal of Environmental Psychology* 44 (09 2015). https://doi.org/10.1016/j.jenvp.2015.09.005

[73] Mishaal Maikoo, Debbie Ellis, and Pepu Chitakunye. 2013. The influence of children in family decision making: Perceptions of South African parents.

[74] Eleanor Mann and Charles Abraham. 2006. The role of affect in UK commuters' travel mode choices: An interpretative phenomenological analysis. *British journal of psychology (London, England : 1953)* 97 (06 2006), 155–76. https://doi.org/10.1348/000712605X61723

[75] Yogesh Kumar Meena, Krishna Seunarine, Deepak Ranjan Sahoo, Simon Robinson, Jennifer Pearson, Chi Zhang, Matt Carnie, Adam Pockett, Andrew Prescott, Suzanne K. Thomas, Harrison Ka Hin Lee, and Matt Jones. 2020. *PV-Tiles: Towards Closely-Coupled Photovoltaic and Digital Materials for Useful, Beautiful and Sustainable Interactive Surfaces.* Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3313831.3376368

[76] Jeni Paay, Jesper Kjeldskov, and Mikael B. Skov. 2015. Connecting in the Kitchen: An Empirical Study of Physical Interactions While Cooking Together at Home. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing* (Vancouver, BC, Canada) *(CSCW '15)*. Association for Computing Machinery, New York, NY, USA, 276–287. https://doi.org/10.1145/2675133.2675194

[77] James Pierce, William Odom, and Eli Blevis. 2008. Energy aware dwelling: a critical survey of interaction design for eco-visualizations. 1–8. https://doi.org/10.1145/1517744.1517746

[78] UN Environment Programme. 2005. *Communicating sustainability: how to produce effective public campaigns.* Retrieved April 2, 2023 from https://www.oecd.org/env/tools-evaluation/thepoliticaleconomyofenvironmentallyrelatedtaxes.htm

[79] Filipe Quintal, Clinton Jorge, Valentina Nisi, and Nuno Nunes. 2016. Watt-I-See: A Tangible Visualization of Energy. In *Proceedings of the International Working Conference on Advanced Visual Interfaces* (Bari, Italy) *(AVI '16)*. Association for Computing Machinery, New York, NY, USA, 120–127. https://doi.org/10.1145/2909132.2909270

[80] Filipe Quintal, Lucas Pereira, Nuno Nunes, Valentina Nisi, and Mary Barreto. 2013. WATTSBurning: Design and Evaluation of an Innovative Eco-Feedback System. https://doi.org/10.1007/978-3-642-40483-2_32

[81] Ukasha Ramli. 2021. Social Norms Based Eco-Feedback for Household Water Consumption. *Sustainability* 13, 5 (2021). https://doi.org/10.3390/su13052796

[82] Majken K. Rasmussen, Esben W. Pedersen, Marianne G. Petersen, and Kasper Hornbæk. 2012. Shape-Changing Interfaces: A Review of the Design Space and Open Research Questions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Austin, Texas, USA) *(CHI '12)*. Association for Computing Machinery, New York, NY, USA, 735–744. https://doi.org/10.1145/2207676.2207781

[83] Majken K. Rasmussen, Mia Kruse Rasmussen, Nervo Verdezoto, Robert Brewer, Laura L. Nielsen, and Niels Olof Bouvin. 2017. Exploring the Flexibility of Everyday Practices for Shifting Energy Consumption through Clockcast. In *Proceedings of the 29th Australian Conference on Computer-Human Interaction* (Brisbane, Queensland, Australia) *(OZCHI '17)*. Association for Computing Machinery, New York, NY, USA, 296–306. https://doi.org/10.1145/3152771.3152763

[84] Lucia Reisch, Ulrike Eberle, and Sylvia Lorek. 2013. Sustainable food consumption: an overview of contemporary issues and policies. *Sustainability: Science, Practice and Policy* 9, 2 (2013), 7–25. https://doi.org/10.1080/15487733.2013.11908111 arXiv:https://doi.org/10.1080/15487733.2013.11908111

[85] Jennifer A. Rode. 2010. The Roles That Make the Domestic Work. In *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work* (Savannah, Georgia, USA) *(CSCW '10)*. Association for Computing Machinery, New York, NY, USA, 381–390. https://doi.org/10.1145/1718918.1718984

[86] Wendy Rodgers and Christina Loitz. 2009. The role of motivation in behavior change: How do we encourage our clients to be active? *ACSM's Health & Fitness Journal* 13 (01 2009), 7–12. https://doi.org/10.1249/FIT.0b013e3181916d11

[87] Enni Ruokamo, Teemu Meriläinen, Santtu Karhinen, Jouni Räihä, Päivi Suur-Uski, Leila Timonen, and Rauli Svento. 2022. The effect of information nudges

on energy saving: Observations from a randomized field experiment in Finland. *Energy Policy* 161 (2022), 112731. https://doi.org/10.1016/j.enpol.2021.112731

[88] Sonya Sachdeva, Rumen Iliev, and Douglas L. Medin. 2009. Sinning Saints and Saintly Sinners: The Paradox of Moral Self-Regulation. *Psychological Science* 20, 4 (2009), 523–528. https://doi.org/10.1111/j.1467-9280.2009.02326.x arXiv:https://doi.org/10.1111/j.1467-9280.2009.02326.x PMID: 19320857.

[89] Marja Salo, Ari Nissinen, Raimo Lilja, Emilia Olkanen, Mia O'Neill, and Martina Uotinen. 2016. Tailored advice and services to enhance sustainable household consumption in Finland. *Journal of Cleaner Production* 121 (2016), 200–207. https://doi.org/10.1016/j.jclepro.2016.01.092

[90] Angela Santangelo and Simona Tondelli. 2017. Occupant behaviour and building renovation of the social housing stock: Current and future challenges. *Energy and Buildings* 145 (2017), 276–283. https://doi.org/10.1016/j.enbuild.2017.04.019

[91] Kim Sauvé, Saskia Bakker, and Steven Houben. 2020. Econundrum: Visualizing the Climate Impact of Dietary Choice through a Shared Data Sculpture. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS '20)*. Association for Computing Machinery, New York, NY, USA, 1287–1300. https://doi.org/10.1145/3357236.3395509

[92] Elizabeth Scott and Robert Scott. 2015. From contract to status: Collaboration and the evolution of novel family relationships. *Columbia Law Review* 115 (03 2015), 293–374.

[93] L. Stankovic, V. Stankovic, J. Liao, and C. Wilson. 2016. Measuring the energy intensity of domestic activities from smart meter data. *Applied Energy* 183 (2016), 1565–1580. https://doi.org/10.1016/j.apenergy.2016.09.087

[94] Alain D. Starke, Martijn C. Willemsen, and Chris C.P. Snijders. 2020. Beyond "one-size-fits-all" platforms: Applying Campbell's paradigm to test personalized energy advice in the Netherlands. *Energy Research & Social Science* 59 (2020), 101311. https://doi.org/10.1016/j.erss.2019.101311

[95] Brigitte Stegers, Kim Sauvé, and Steven Houben. 2022. Ecorbis: A Data Sculpture of Environmental Behavior in the Home Context. In *Designing Interactive Systems Conference* (Virtual Event, Australia) *(DIS '22)*. Association for Computing Machinery, New York, NY, USA, 1669–1683. https://doi.org/10.1145/3532106.3533508

[96] Yolande Strengers. 2014. Smart Energy in Everyday Life: Are You Designing for Resource Man? *Interactions* 21, 4 (jul 2014), 24–31. https://doi.org/10.1145/2621931

[97] Yolande A.A. Strengers. 2011. Designing Eco-Feedback Systems for Everyday Life. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI '11)*. Association for Computing Machinery, New York, NY, USA, 2135–2144. https://doi.org/10.1145/1978942.1979252

[98] Bernadette Sütterlin, Thomas A. Brunner, and Michael Siegrist. 2011. Who puts the most energy into energy conservation? A segmentation of energy consumers based on energy-related behavioral characteristics. *Energy Policy* 39, 12 (2011), 8137–8152. https://doi.org/10.1016/j.enpol.2011.10.008 Clean Cooking Fuels and Technologies in Developing Economies.

[99] Carmen Tabernero and Bernardo Hernández. 2011. Self-Efficacy and Intrinsic Motivation Guiding Environmental Behavior. *Environment and Behavior* 43, 5 (2011), 658–675. https://doi.org/10.1177/0013916510379759 arXiv:https://doi.org/10.1177/0013916510379759

[100] Christine Thomas and Veronica Sharp. 2013. Understanding the normalisation of recycling behaviour and its implications for other pro-environmental behaviours: A review of social norms and recycling. *Resources, Conservation and Recycling* 79 (2013), 11–20. https://doi.org/10.1016/j.resconrec.2013.04.010 SI: Resourceful Behaviours.

[101] Bruno Turnheim, Frans Berkhout, Frank Geels, Andries Hof, Andy McMeekin, Björn Nykvist, and Detlef van Vuuren. 2015. Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges. *Global Environmental Change* 35 (2015), 239–253. https://doi.org/10.1016/j.gloenvcha.2015.08.010

[102] Chris van Dronkelaar, Mark Dowson, Catalina Spataru, and D. Mumovic. 2016. A Review of the Regulatory Energy Performance Gap and Its Underlying Causes in Non-domestic Buildings. *Frontiers in Mechanical Engineering* 1 (01 2016). https://doi.org/10.3389/fmech.2015.00017

[103] Leonie A. Venhoeven, Jan Willem Bolderdijk, and Linda Steg. 2016. Why Acting Environmentally-Friendly Feels Good: Exploring the Role of Self-Image. *Frontiers in Psychology* 7 (24 Nov. 2016). https://doi.org/10.3389/fpsyg.2016.01846

[104] Jiaqi Wang, Ruyin Long, Hong Chen, and Qianwen Li. 2022. How do parents and children promote each other? The impact of intergenerational learning on willingness to save energy. *Energy Research & Social Science* 87 (2022), 102465. https://doi.org/10.1016/j.erss.2021.102465

[105] Thomas L. Webb, Yael Benn, and Betty P.I. Chang. 2014. Antecedents and consequences of monitoring domestic electricity consumption. *Journal of Environmental Psychology* 40 (2014), 228–238. https://doi.org/10.1016/j.jenvp.2014.07.001

[106] Devon Wemyss, Francesca Cellina, Evelyn Lobsiger-Kägi, Vanessa de Luca, and Roberta Castri. 2019. Does it last? Long-term impacts of an app-based behavior change intervention on household electricity savings in Switzerland. *Energy*

Research & Social Science 47 (2019), 16–27. https://doi.org/10.1016/j.erss.2018.08.018

[107] Lorraine Whitmarsh. 2009. Behavioural responses to climate change: Asymmetry of intentions and impacts. *Journal of Environmental Psychology* 29, 1 (2009), 13–23. https://doi.org/10.1016/j.jenvp.2008.05.003

[108] Lorraine E. Whitmarsh, Paul Haggar, and Merryn Thomas. 2018. Waste Reduction Behaviors at Home, at Work, and on Holiday: What Influences Behavioral Consistency Across Contexts? *Frontiers in Psychology* 9 (2018). https://doi.org/10.3389/fpsyg.2018.02447

[109] Harold Wilhite, Hidetoshi Nakagami, Takashi Masuda, Yukiko Yamaga, and Hiroshi Haneda. 1996. A cross-cultural analysis of household energy use behaviour in Japan and Norway. *Energy Policy* 24, 9 (1996), 795–803. https://doi.org/10.1016/0301-4215(96)00061-4

[110] Willem Willemsen, Jun Hu, Gerrit Niezen, and Bram Vlist. 2011. Using Game Elements to Motivate Environmentally Responsible Behaviour.

[111] George Wilson and Katie Wood. 2004. The influence of children on parental purchases during. *International Journal of Consumer Studies* 28 (09 2004), 329 – 336. https://doi.org/10.1111/j.1470-6431.2004.00393.x

[112] Jing Jian Xiao and Haifeng Li. 2012. Sustainable Consumption and Life Satisfaction. *Social Indicators Research* 104 (04 2012), 323–329. https://doi.org/10.1007/s11205-010-9746-9

[113] Xingxing Zhang, Jingchun Shen, Tong Yang, Llewellyn Tang, Luying Wang, Yingqi Liu, and Peng Xu. 2019. Smart meter and in-home display for energy savings in residential buildings: a pilot investigation in Shanghai, China. *Intelligent Buildings International* 11, 1 (2019), 4–26. https://doi.org/10.1080/17508975.2016.1213694 arXiv:https://doi.org/10.1080/17508975.2016.1213694

[114] Kaile Zhou and Shanlin Yang. 2016. Understanding household energy consumption behavior: The contribution of energy big data analytics. *Renewable and Sustainable Energy Reviews* 56 (2016), 810–819. https://doi.org/10.1016/j.rser.2015.12.001