Energy and Buildings 158 (2018) 848–860

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Influencing energy and water use within a home system of practice

Christine Eon*, Xin Liu, Gregory M. Morrison, Joshua Byrne

Curtin University Sustainability Policy Institute, Building 209, Level1, Room 133, Curtin University, GPO Box, U1987, Perth, WA 6845, Australia

ARTICLE INFO

Article history:
Received 4 September 2017
Received in revised form 6 October 2017
Accepted 16 October 2017
Available online 18 October 2017

Keywords:
Home system of practice
Monitoring
behaviour
Energy efficiency
Water efficiency
Routines

ABSTRACT

Approaches that attempt to influence resource use in the home often consider the building system alone, without due consideration of occupants and their practices. However, occupants interact with technology and ultimately affect energy and water metabolism in the home. This research used an explanatory design mixed method approach to investigate the energy and water use in eight homes over a two-year period, before and after an intervention based on persuasive behaviour change. Each home was considered as a system of practice and results were analysed in terms of overall resource reduction, changes in practice and changes made to the building systems. It was revealed that five of the homes succeeded in reducing their resource use through the two years. Most changes were achieved through affecting technology as an element of practice. Automation was shown to enable the dis-interlocking of practices from aligned and interlocked routines and can be considered an effective solution to influence resource use in the home.

1. Introduction

Minimizing the negative effect of occupant behaviour on the energy and water metabolism of homes has been the subject of recent research. Approaches based on socio-psychology theories [1–3] that place the individual at the center of the analysis have been extensively discussed in the literature [4–6]. These typically involve methods to persuade change [7], such as information campaigns and feedback, and are delivered through information and communication technologies (ICT) [4,8]. However, this approach ignores the interaction of occupants with the physical infrastructure of the home. As buildings become more energy and water efficient and incorporate technologies such as solar photovoltaic panels (PV) and smart systems, it is expected that the resource use in the home should be reduced. Nevertheless, rebound effects often occur [9,10] and the technologies are forgotten if they do not meet occupant needs or do not become an integral part of user routines [11–13].

Practice theory [14,15] posits that rather than focusing on values, attitudes and social norms, the emphasis should be on influencing the elements that constitute daily practices, which are defined as meaning, skill and technology [16,17]. Meaning is the reason for a practice to be undertaken, which is influenced by personal emotions, perceptions and values [14]. Skill refers to the knowledge of the practice and understanding of its implementation [16]. Technology denotes the physical elements that are involved in the execution of the practice [18]. The three elements of practice are bound together and a modification in any of them affects the performance of the practice and ultimately the use of resources that support it. The continual reproduction of everyday practices forms a routine, where each practice and practices are interdependent. This mutual dependency between everyday practices is termed interlocking [19,20].

Occupants of the same home may have distinct driving-factors for water and energy use [21], different interlocking practices and distinct practice-as-entities; that is, they ascribe different connotations to the elements of practice [22] thus diverging in the manner they perform it [23]. Individuals may also vary their own practices in accordance with the meaning they attribute to them. For instance, the meaning for personal showering can be cleanliness, warmth or relaxation and it follows that the duration of personal showering varies [16,24–26]. A shower that is motivated by the need for cleanliness, would likely be shorter than a shower that is motivated by the need for relaxation, which might be driven by sensorial feelings [27]. Practices also vary according to place and context and the relationships within this context [28]. For instance, the timing of practices usually varies between weekdays and weekend due to realignment of routines and interlocking practices [29]. It is presumed that a change in place, hence a variation in infrastructure, would also affect the performance of individual practices [28]. It has been proposed that the latter are combined in bundles through space and time [20], which suggests that the understanding of resource and technology use in the home requires the home itself to be viewed as a system of practice (SOP).

* Corresponding author.
E-mail address: Christine.eon@curtin.edu.au (C. Eon).

https://doi.org/10.1016/j.enbuild.2017.10.053
0378-7788/

Table 1
Measurement of the grid electricity, gas and water use variation between 2015 and 2016.

Resource	Home							
	1	2	3	4	5	6	7	8
Electricity	constant	constant	decrease	constant	constant	increase	constant	increase
p-value	0.491	0.507	<0.05	0.204	0.165	<0.05	0.707	<0.05
Gas	increase	N/A	decrease	constant	constant	constant	decrease	constant
p-value	<0.05		<0.05	0.578	0.490	0.349	<0.05	0.912
Water	decrease	decrease	decrease	decrease	constant	constant	constant	constant
p-value	<0.05	<0.05	<0.05	<0.05	0.541	0.994	0.124	0.083

Due to the complexities associated with the home SOP, influencing practices can be challenging without a more complete understanding of the home system. Our hypothesis is that resource reduction in homes can be realised through one-off changes in the physical infrastructure of the building or technological innovation rather than through affecting everyday practices. However, automation could enable the dis-interlocking of specific resource intensive practices from the system.

This research is a longitudinal investigation of variations in energy and water use as well as resource intensive practices in eight homes for two years, the year before and the year after an intervention designed for persuasive behaviour change. This research contributes to the understanding of the home SOP and the interactions between occupants and technologies.

2. Methodology

The dynamics of change are followed through an explanatory design mixed method approach, consisting of detailed quantitative and qualitative data collected over the two-year period.

2.1. Project participants

Eight homes located in the City of Fremantle, Australia, were selected as part of this research. The selection process was conducted through a media advertisement in the local newspapers and a mail drop. Interested households were further scrutinized to provide a variety of home demographics (Table 1). The selected homes possess energy and/or water efficient design elements that distinguish them from the average Australian household (Appendix A). These homes also follow principles of passive solar design to varying degrees [30], that is, they are oriented North and use direct sunlight as well as thermal mass for warmth in winter. In summer, the use of shading devices as well as natural breezes can prevent these homes from becoming too hot. Operating such a home can be challenging as it requires occupants to understand the design principles and to actively open and close windows and curtains at the right times of the day to maintain comfortable internal temperatures.

2.2. Research design

The homes were converted into Living Laboratories (LLs) to provide home insight [31] for a period of two years, from December 2014 to December 2016. LLs are real-life places where innovative technologies are co-created by multiple stakeholders, with prototyping and testing in the real life context [32–35]. The LLs in this research generated insight into the everyday practices of households as well as their interaction with technologies. The first year of research established a baseline and an understanding of user practices. Participants were not disturbed during this period. At the beginning of the second year, homes were subjected to a targeted persuasive behaviour change intervention [7] that remained until the end of the project.

This research focuses on understanding barriers to change as well as resource intensive practices in the home, such as garden irrigation, personal showering, the use of ambient cooling and heating as well as the use of a pool pump. An explanatory design mixed method approach [36] was chosen to conduct data analysis, following up from previous LLs research [31,37,38]. Qualitative data from semi-structured interviews were used to interpret quantitative data from a home monitoring system. This section describes the quantitative data collection, the behaviour change program, the qualitative data collection and finally, the methodology used to analyse the data.

2.2.1. Quantitative data collection

Monitoring equipment was installed in the participant homes to measure gas, grid electricity, mains water and rainwater use as well as internal temperature in the living area and solar electricity generation over the two years (Appendix B). Sensors were connected to existing meters, transmitting pulses to a data logger (Schneider Electric COM'X 200). The latter collected the data at 15 min intervals and transmitted csv files to the researchers remotely, through a 2G wireless internet connection. At the start of the second year, data was also transmitted daily from the data logger to an online platform (Power Monitoring Expert 7.2) that was programmed to enable data visualization. Solar electricity use was not measured through the monitoring system; instead the data was obtained through electricity bills requested from the households at the end of each calendar year. However, one of the homes (home 5) chose not to provide their bills to the researchers. Detailed weather data including external temperature, rainfall, relative humidity and solar radiation was obtained from a nearby weather station (Vaisala WXT520).

2.2.2. Behaviour change intervention design

The persuasive behaviour change program was designed based on an analysis of 34 peer reviewed articles targeting energy and water reduction in the home. Best practices were analysed according to the percentage reduction of water or energy use in the homes. The most successful interventions [39–42] encompassed a combination of strategies based on established socio-psychology theories [1–3] including social interaction (e.g. coaching, audits, community courses), goal setting, prompts, comparison with other households, targeted information provision and real-time feedback delivery through ICT. The effectiveness of feedback systems to reduce long term resource use is unclear; some researchers have shown that they generate positive outcomes [43–46] while others believe them to only be relevant in the short term [7,11,12]. Nevertheless, individual response varies with approach and therefore mixing technical and social approaches may lead to improved consumer engagement enabling change [47].

The behaviour change program in the eight LLs was initiated with a home visit at the start of the second year of quantitative data collection, which corresponded to the onset of the hot months of the Australian summer (December 2015). Initially household members were shown a historical summary of their energy and water use relating to the previous year and asked to comment on reasons for using more or less energy or water in one month in com-