School of Design and the Built Environment
Curtin University Sustainability Policy Institute

Domestic Practices and User Experiences Pre- and Post-Occupancy in a Low-Carbon Development

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This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University

November 2019

Author’s Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Human Ethics

The research presented and reported in this thesis was conducted in accordance with the

National Health and Medical Research Council National Statement on Ethical Conduct in

Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number HRE2016-0222.

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Jessica Kate Breadsell

Date: 4/11/2019

Statement of contributors

All of the written materials submitted as part of this PhD by publication (hybrid) were conceived and coordinated by Jessica Kate Breadsell. I also undertook the majority of the writing and analysis for each publication.

Jessica Kate Breadsell

Date: 4/11/2019

Everyone is focused on the hardware, and the hardware is great, but in the end it's the squishy meat-sack that messes everything up. Ignoring the human system, if you will, in future plans and designs is only going to lead to failure

Kris Lehnhardt

Abstract

The emergence of low-carbon houses and developments with innovative energy and water efficiency features is a driver of change in the built environment sector. Innovation has occurred through design guidelines or standards but key to the eventual building performance is the occupancy behaviour and practices. Understanding occupancy can be achieved through studying individuals before and after they reside in these homes. This promotes insight into how their interaction with the technology and the social context influences their use of resources. There are two schools of thought concerning how household resource flows can be measured and influenced in the home and in low-carbon developments; namely social practice theory and socio-psychological approaches. In this research, these schools of thought were applied to the individual, home, community and society scale and with a focus on the effect of space and time on domestic practices. The time at which people transition into new households presents a window of opportunity to study and influence household practices to gain insight. The WGV development in Western Australia was used as a Living Laboratory for this purpose. A cohort of 14 household's domestic practices pre- and post-occupancy were measured through qualitative and quantitative data collection. The practices of thermal comfort, personal hygiene, waste management, food shopping, item purchasing, travel, and washing clothes were tracked and contrasted to assess the influence of design and community context on their performance. These results were interpreted through the concepts of interlocking practices and systems of practice, focusing on the space of the home. Immediate decreases in household energy and water use were observed due to design factors. Changes to resident's travel practices were not as significant as expected post-occupancy, while recycling rates increased, influenced by supportive community networks and shopping practices became more localised through the use of smaller food retailers. The user-experiences of the low-carbon development were generally positive and confirmed the community expectations pre-occupancy. Resident's resource use is heavily influenced by their work and socialising routines. This research demonstrates that while some aspects of domestic practices may change when the context changes, entrenched habits and personal practice history prescribe how practices are performed and the subsequent resources consumed. This research contributes to understanding how social practice theory can be applied at different scales in the home, community, and society.

Acknowledgements

I would like to acknowledge, first of all, my primary supervisor Professor Greg Morrison, for all the support, encouragement, advice, knowledge and importantly criticisms along this research journey. Your belief in my ability to get this done was always there and I appreciate that immensely.

Dr Josh Byrne, never did I ever think I would meet, let alone work with you! From your enthusiasm for research, to watching you communicate with people in an exciting but informative way, you have been a wonderful ray of joy in the PhD journey.

Thank you to Dr Christine Eon for collaborating in some of the research, particularly on the development of the HSOP. It has been a delight following your own doctoral journey and seeing where this has all lead. Thank you for the support over many research adventures, especially in Japan.

Thank you to my co-authors for all their insightful conversations and inputs into our publications.

Thank you to the participants of this research who very generously participated throughout the data collection phases of the research. Thank you for welcoming me into your homes and your lives many times and for your excitement about the research.

Access Housing, Ralton Benn, LandCorp, and Warren Phillips I appreciate the considerable involvement you and your teams put into the WGV development and the prompt assistance you always gave when I needed it.

This research would not have been possible without the financial support of the Cooperative Research Centre for Low Carbon Living. Thank you especially for Professor Peter Newman and Professor Greg Morrison for their hard work in acquiring this funding and to the broader CRC LCL team for the numerous training opportunities and forums that allowed for the dissemination of this research.

To my fellow hubbies, Tanya, Jane, Agata, Seb, Lio, Mike, Paula, Portia, Moiz, Roberto and Tim thank you for making the PhD journey a (more) exciting one and for all your support, encouragement, late night chats, World Soccer commentary and assistance navigating the Curtin and CRC LCL world.

To my ever supportive friends, Blake for the belief and the walks, Casey for the understanding and the giggles, my darling Christopher for the food. Thank you for listening to my rambles over wine and Netflix. To Tiana, Jesska, Meeko, Jillian, Stacey and Andrea- do what makes you happy in life, wherever that make take you, my door (virtual or real) is always open for a cup of tea and a hug, as yours has been throughout this journey for me.

To my family for supporting me and (mostly) not asking questions about what I am up to and when I am going to finish! For giving me the start in life that lead me to here and to always believing in me.

Finally, to Hayden, here's to us. Raise a glass to freedom, to a life after a PhD, whatever that looks like.

Dedication

To Alexander Dixon, because he never got the chance

6^{th} September 1895 - 26^{th} April 1915

Courtney's Post, Gallipoli

List of publications included in this thesis

The following publications are the basis of this thesis and are provided as appendices following the exegesis. The publications are referred to in the exegesis in roman numerals. Copyright statements for published materials can be found in Appendix B.

Journal articles

I **Breadsell, J.K.**, Eon, C., & Morrison, G. M (2019). Understanding Resource Consumption in the Home, Community and Society through Behaviour and Social Practice Theories. *Sustainability*. 11(22) 6513; https://doi.org/10.3390/su11226513

II Eon, C., **Breadsell, J**.K., Morrison, G. M. & Byrne, J. (2018). The home as a system of practice and its implications for energy and water metabolism. *Sustainable Production and Consumption.* 13, pp. 48-59; https://doi.org/10.1016/j.spc.2017.12.001

III Eon, C., **Breadsell, J.,** Morrison, G. & Byrne, J. (2019) Shifting Home Energy Consumption Through a Holistic Understanding of the Home System of Practice. In: Newton P, Prasad D, Sproul A, et al. (eds) Decarbonising the Built Environment: Charting the Transition. Singapore: Palgrave Macmillan, pp. 431–447. DOI: 10.1007/978-981-13-7940-6_23

IV Wiktorowicz, J., Babaeff, T., **Breadsell, J.**, Byrne, J., Eggleston, J. & Newman, P. (2018) "WGV: An Australian Urban Precinct Case Study to Demonstrate the 1.5°C Agenda including Multiple SDGs" *Urban Planning* 3(2), pp. 64-81; http://dx.doi.org/10.17645/up.v3i2.1245

V **Breadsell, J**., Eon, C., Morrison, G. & Kashima, Y. (2019). Interlocking practices and their influence in the home. *Environment and Planning B: Urban Analytics and City Science.* 46(8), pp. 1405-1421; https://doi.org/10.1177%2F2399808318824114

VI **Breadsell, J.K**., Byrne, J.J., & Morrison, G. M. (2019). Household energy and water practices change post-occupancy in an Australian Low-Carbon Development. *Sustainability.* 11(20), 5559; https://doi.org/10.3390/su11205559

VII **Breadsell, J**., & Morrison, G. M. (2020). Changes to Household Practices Pre and Post-Occupancy in an Australian Low-Carbon Development. *Sustainable Production and Consumption.* 22, pp. 147-161; https://doi.org/10.1016/j.spc.2020.03.001

VIII **Breadsell, J.K.**, Byrne, J.J., & Morrison, G. M. (2019). Pre and post-occupancy evaluation of resident motivations for and experiences of establishing a home in a low carbon development. *Sustainability.* 11(14) 3970; https://doi.org/10.3390/su11143970

Relevant publications not included in this thesis

During the creation of this thesis, other publications have been published which the author has chosen not to include. These are available as a PDF on request.

Journal articles

Heymans, A., **Breadsell, J.,** Byrne, J., Morrison, G. M., & Eon, C (2019) "Ecological Urban Planning and Design- a Systematic Literature Review" *Sustainability. 11(13), 3723;* https://doi.org/10.3390/su11133723

Co-author's statements

Publication I

I, Jessica Kate Breadsell, contributed 70% to the publication entitled:

Breadsell, J.K., Eon, C., & Morrison, G. M (2019). Understanding Resource Consumption in the Home, Community and Society through Behaviour and Social Practice Theories. *Sustainability*. 11(22) 6513; https://doi.org/10.3390/su11226513

The contribution entailed initial discussions of the paper concept, undertaking the literature review and analysis of the literature, writing and editing of the paper, including major revisions of the paper as the concept evolved over a 3-year period.

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I, as a co-author, endorse that this level of contribution by the candidate indicated above is appropriate.

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Publication II

I, Jessica Kate Breadsell, contributed 30% to the publication entitled:

Eon, C., **Breadsell, J.K.**, Morrison, G. M. & Byrne, J. (2018). The home as a system of practice and its implications for energy and water metabolism. *Sustainable Production and Consumption.* 13, pp. 48-59; https://doi.org/10.1016/j.spc.2017.12.001

The contribution entailed initial discussions of the paper concept, undertaking the literature review, and contributing to the writing and editing of the paper. C Eon undertook the data collection, statistical analysis and the writing of the materials and methods section. J Breadsell contributed to the remaining sections, along with G Morrison and J Byrne.

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Publication III

I, Jessica Kate Breadsell, contributed 30% to the publication entitled:

Eon, C., **Breadsell, J.,** Morrison, G. & Byrne, J. (2019) Shifting Home Energy Consumption Through a Holistic Understanding of the Home System of Practice. In: Newton P, Prasad D, Sproul A, et al. (eds) Decarbonising the Built Environment: Charting the Transition. Singapore: Palgrave Macmillan, pp. 431–447. DOI: 10.1007/978-981-13-7940-6_23

The contribution entailed initial discussions of the chapter concept, undertaking the literature review and analysis of the literature, writing and editing of the paper.

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Publication IV

I, Jessica Kate Breadsell, contributed 20% to the publication entitled:

Wiktorowicz, J., Babaeff, T., **Breadsell, J.**, Byrne, J., Eggleston, J. & Newman, P. (2018) "WGV: An Australian Urban Precinct Case Study to Demonstrate the 1.5°C Agenda including Multiple SDGs" *Urban Planning* 3(2), pp. 64-81; http://dx.doi.org/10.17645/up.v3i2.1245

The contribution entailed undertaking the literature review and writing and editing of sections relating to the abstract, introduction, community engagement, community culture, affordable housing and conclusion.

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Publication V

I, Jessica Kate Breadsell, contributed 80% to the publication entitled:

Breadsell, J., Eon, C., Morrison, G. & Kashima, Y. (2019). Interlocking practices and their influence in the home. *Environment and Planning B: Urban Analytics and City Science.* 46(8), pp. 1405-1421; https://doi.org/10.1177%2F2399808318824114

The contribution entailed initial discussions of the paper concept, undertaking the literature review, methodology design, data collection, data analysis, writing and editing of the paper. Y Kashima shared the Low Carbon Readiness Index that they had developed with colleagues for use in this paper and assisted in the data analysis relating to this. C Eon and G Morrison assisted in the development of the theoretical concept, writing and editing.

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Publication VI

I, Jessica Kate Breadsell, contributed 85% to the publication entitled:

Breadsell, J.K., Byrne, J.J., & Morrison, G. M. (2019). Household energy and water practices change post-occupancy in an Australian Low-Carbon Development. *Sustainability.* 11(20), 5559; https://doi.org/10.3390/su11205559

The contribution entailed initial discussions of the paper concept, undertaking the literature review, methodology design, data collection, data analysis, writing and editing of the paper. J Byrne assisted in the analysis of data related to energy and water use for the households. G Morrison assisted in the development of the theoretical concept and editing.

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Publication VII

I, Jessica Kate Breadsell, contributed 95% to the publication entitled:

Breadsell, J., & Morrison, G. M. (2020). Changes to Household Practices Pre and Post-Occupancy in an Australian Low-Carbon Development. *Sustainable Production and Consumption.* 22, pp. 147-161; https://doi.org/10.1016/j.spc.2020.03.001

The contribution entailed initial discussions of the paper concept, undertaking the literature review, methodology design, data collection, data analysis, writing and editing of the paper. G Morrison assisted in the development of the theoretical concept and editing.

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Publication VIII

I, Jessica Kate Breadsell, contributed 90% to the publication entitled:

Breadsell, J.K., Byrne, J.J., & Morrison, G. M. (2019). Pre and post-occupancy evaluation of resident motivations for and experiences of establishing a home in a low carbon development. *Sustainability.* 11(14) 3970; https://doi.org/10.3390/su11143970

The contribution entailed initial discussions of the paper concept, undertaking the literature review, methodology design, data collection, data analysis, writing and editing of the paper. J Byrne assisted in the writing and editing of sections relating to the WGV precinct features. G Morrison assisted in the development of the theoretical concept and editing.

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Glossary

ABC	Attitude, Behaviour and Choice Model
AC	Air conditioner
CO_2	Carbon Dioxide
GHG	Greenhouse gas
Home	Building fabric and occupants
House	Building fabric
HSOP	Home System of Practice
IHD	In-Home Display
IPCC	Intergovernmental Panel on Climate Change
LCD	Low-Carbon Development
LCRI	Low Carbon Readiness Index
NatHERS	Nationwide House Energy Rating Scheme
PV	Photovoltaic
SHAC	Sustainable Housing for Artists and Creatives
SOP	System of Practice
SPT	Social Practice Theory
WA	Western Australia
WGV	The WGV Development

Chapter 1 Introduction

This chapter outlines the theoretical context of this thesis, justifying the approach and positioning it in the literature and previous case studies. The research question and sub-questions have been developed from the underlying theory and literature and are addressed in a series of seven peer-reviewed publications and one peer-reviewed book chapter. This thesis has applications to Social Practice Theory (SPT) and household domestic practices through a longitudinal study of residents moving into a low-carbon development (LCD) in Western Australia. The overall thesis organisation is presented at the end of the chapter.

1.1 Research Context

This section will discuss the background of the research undertaken in this thesis and outline the theoretical context that forms the basis of the thesis, namely SPT and post-occupancy evaluation.

1.1.1 Background

Cities contribute more than 60% of global greenhouse gas (GHG) emissions as they are epicentres for economic activity and therefore represent a challenge but also an opportunity for technology and policy options (1,2). With rising urbanisation, the land available for residential developments has become more constrained and infill is occurring in many cities around the world (3). Coupled with rising demand for energy and water, increases in income resulting in greater food and appliance purchases, urban residents are exposed to a multitude of different factors in the home that affect their resource use (4).

Worldwide, 10.6 billion tonnes of CO_2 equivalent emissions per year are from the residential and commercial building sector (2). In Australia, almost one-quarter of GHG emissions are from the built environment, with an expected 10 million residential units established by 2020. This is the result of one of the highest population growth rates in the developed world (5). The majority of GHG emissions in buildings are the result of indirect operational electricity use (2,6) and therefore a focus in the literature has been on reducing residential energy usage (3). As technologies and building designs evolve or are mandated to include lower carbon aspects, the user experiences of these residential areas and technologies should be considered (7–12). Traditionally, resource consumption has been viewed as a product of individual decision-making processes or those couched in technological systems (13). Studies have focused on consumption at different scales: individuals, household, community or city level, businesses and countries (14). Studies have also varied from individual resource use in isolation such as energy or water consumption (15–24), material footprint analysis focusing on reducing resource use by a factor of 10 or reducing ecological footprints (4,25–29) through to comprehensive life cycle analysis of products (30–32). The study of household carbon footprint or household carbon emissions has become more popular in recent decades, particularly in the science and engineering domains (33). This includes direct household emissions created in heating, cooling and transport use, and indirect emissions which are embedded in the production of the goods and services that households use, such as food, clothing, and appliances (33). The focus of these studies is to quantify emissions generated by households and use these results to persuade people to reduce their consumption of resources (32). This change is advocated to come about through education, price signals or social influences that lead to a behaviour change (34).

SPT differs from this through the focus on social practice as the unit of analysis, and the understanding that consumption occurs during the performance of social practices (35–37). Understanding the dynamics of everyday consumption practices through a holistic study of household practices, therefore, allows for a comprehensive perspective on altering household resource metabolism (24,38). SPT also allows for a focus on the design and use of technologies in the performance of daily practices such as cooking, washing and cleaning (12,39). Australian new build houses are the largest in the world at an average of 215m^2 and urbanisation and densification is rapidly occurring in cities (40). As Australian's move to smaller homes, like those in LCDs, their possessions and the related household practices may change as well (41–43). Knowledge of how residents routines relating to various domestic practices emerge, develop and change provides an insight into sustainable consumption (36).

Of the multitude of household practices that are performed each day, thermal comfort and personal hygiene practices use the largest proportion of total energy and water used in Australian households (44,45). In Australia, ambient cooling and heating are the most energy-intensive practices in the home, using 40% of domestic energy use (46). Many studies have only focused on household energy or water practices, this prevents a holistic understanding of resource flows in households (47). After water use in the bathroom, laundry practices use the largest amount of water in indoor household practices across Australia (48). Outdoors, water use in gardening practices is also an intensive use of water (49). Other practices utilising resources in and around the home include waste management, food shopping, purchasing of household items and travel practices (50,51).

As urban areas become denser and household construction methods change to incorporate policy requirements for passive solar and low carbon design, more people will be inhabiting low carbon, zero energy or carbon positive buildings (52). Despite a growing body of literature and industry practices that support building low-carbon houses, it is estimated that on average 20% of the expected energy savings in households are not achieved due to occupant practices (53,54). The non-technical measures of household behaviour or practices that can reduce or prevent the rebound effect occurring have been analysed to a lesser extent (18). The residents of LCDs have been described as a special segment of the population with different lifestyles and consumption practices (55). Studies have found that the behavioural and social practice effects of occupants are underestimated when assessing the energy consumption of energy efficient households (18,56). Therefore, further research on household resource practices is required if these effects are to be addressed (57).

1.1.2 Theoretical context

Following on from the development of socio-technical transition theory (58–61), SPT has developed into a widely recognised and utilised theory for understanding people's actions and subsequent resource flows (62). It has since been offered as an alternative approach to the traditional socio-psychological theories to change people's behaviours and associated resource flows (63). The socio-psychological theories are grounded in the theory of cognitive dissonance (64), the theory of planned behaviour (65), the theory of normative conduct (66–69) and the theory of habitual behaviour (70). These theories promote methods that are often applied to modify occupant behaviours by persuasively initiating a change in attitudes and values as well as providing information and breaking established habits (71).

This thesis begins theoretically by examining the socio-psychological approaches to resource consumption reduction and the relevance of SPT in this endeavour (Publication I). It continues by examining the study of practices within the home, which is termed the home system of practice (HSOP) (Publications II & III). Publication IV introduces the LCD that is the case study for the empirical research of this thesis, located in Western Australia. Further publications (V, VI, VII and VIII) examined how a SPT focus on residents of a LCD could be applied in this case study. SPT is centred on the idea that our lives are populated by practices (72). Practices are the mundane, normalised actions that we undertake that consume resources and involve individuals as practitioners performing and transferring practices, instead of being the centre of analysis (51,73–75). Practices can be categorised into elements, which drive the performance of the practice. In Publications I, II and III of this thesis, these elements are defined as meaning, the reason behind the execution of a practice (*e.g.* getting clean); skill, the understanding of how to execute the practice (*e.g.* knowing how to remove dirt from your body); and technology, the objects and infrastructure necessary to undertake the practice (*e.g.* a shower, a bath, a sponge, soap and water). The sequential repetition of practices in a habitual routine leads to interlocking (*i.e.* interconnection) in a system of practice (SOP) (76). Practices are also context-dependent and evolve over time as new technologies emerge (77). It follows that affecting one or more elements of the practice should result in a modification of resource use and enable (as opposed to persuade) occupants to save energy or water while continuing to meet their intrinsic needs (the meaning element of the practice) (34,78).

The ontological position of SPT has developed since 2000 (35,37,83–85,51,72–74,79–82). These studies retrospectively applied a SPT approach to data already collected to draw conclusions on how social practices develop, change and transfer (51,82). Since then, SPT has framed the construction of research collection and analysis of social practices (63). This has been developed at the same time as the methodology of Living Laboratories (86) and hence the two have been applied together in many studies to understand resource flows and social practices (87). Many authors argue that understanding the rhythmic richness of everyday life requires moving from studies of single practices that have dominated the SPT debate to focus on the dynamic interactions between them (88,89). As such, this thesis will explore a number of practices that are performed in the space of the home to understand the interactions between them and the space they occur in.

1.2 Research positioning

Drawing on SPT and post-occupancy evaluation fieldwork methods, this thesis will apply SPT to a Living Laboratory case study. Cohort studies are useful to provide detailed insight but require careful interpretation of the results according to the limitations of the evidence and acknowledge rival hypotheses and explanations (90). This thesis also examines socio-psychological theories in their relationship to SPT and discusses the application of the two schools of thought concerning resource consumption at different scales, in the home, community and society level and how policy can influence this.

Resource flows in the household have been studied using the concept of urban metabolism; urban metabolism follows the consumption of resources and generation of waste as a byproduct (91). This can be applied in the home space through studies of the flows of energy, water, food and associated resources and their outputs with the aim to improve the efficiency of the process while reducing the outputs (92). This system view also needs to consider both the physical system of the home structure and the social system of the occupants, which influence the resource flows through technological and behavioural elements (93) (Figure 1.1).

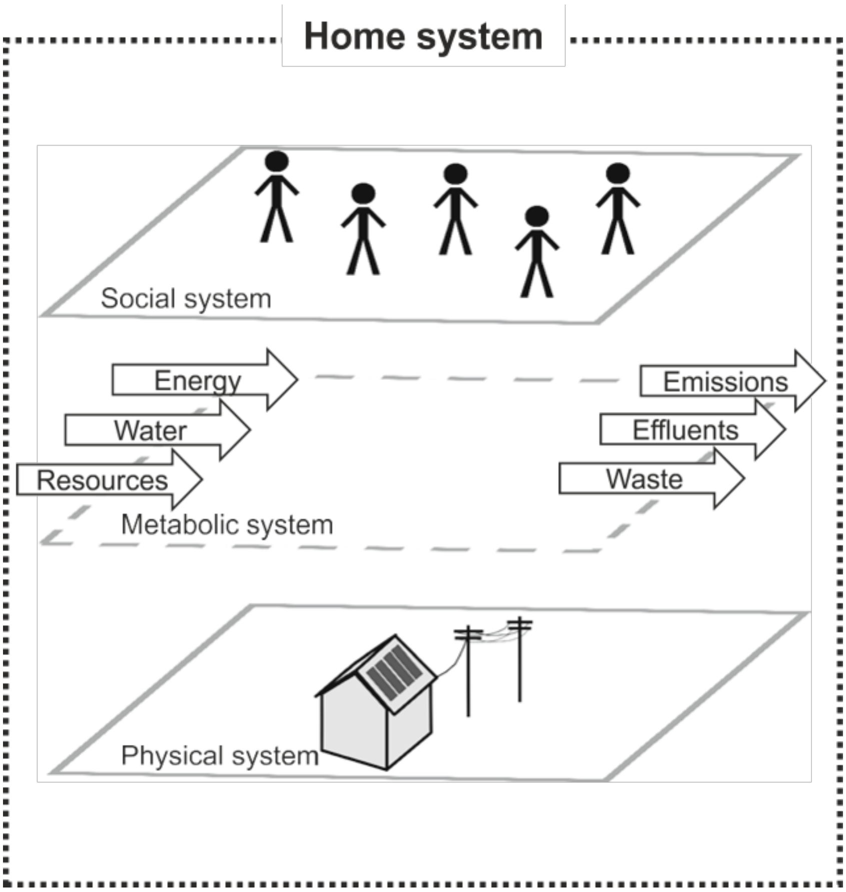

Figure 1-1The 3 levels of the home: the physical system, the metabolic system and the social system (adapted from Publication III)

Individual behaviours and practices are often studied *in-situ* as this provides an easier contact point for the researcher (94). However, these actions are not isolated and occur within contextual influences (89). Changes in the use of resources in the space of the home have often been studied for individual practices, but rarely carried out on a larger scale (47). The consideration of social networks is also vital for understanding how social practices that minimise resource use or engage in sustainable consumption emerge, exist and transfer to other practitioner's, such as those living in LCDs (95). Figure 1.2 highlights the three scales that are discussed in this thesis based on this need: the home scale, community or precinct scale and societal scale.

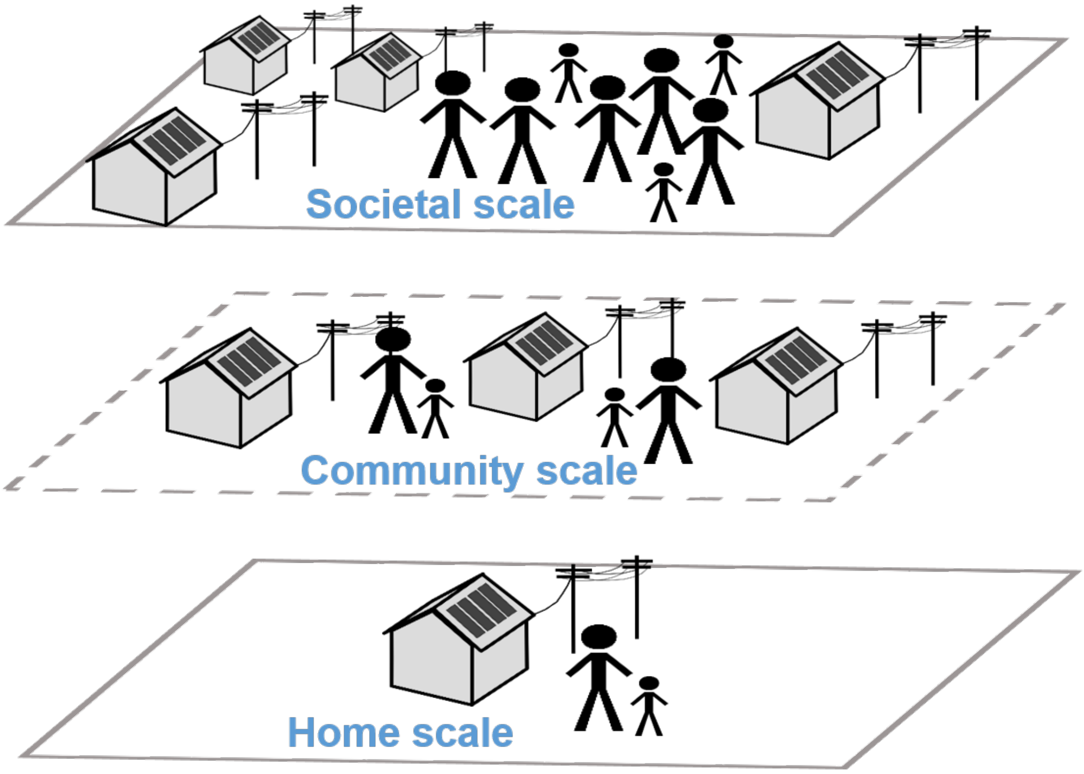

Figure 1-2 The different scales discussed in this thesis: the home scale, the community scale and the societal scale (adapted from Publication I)

1.3 Research question and objectives

In light of the context outlined above, the research question for this thesis is as follows:

How are residents' domestic practices influenced by moving to a low-carbon development and what are the user experiences of living in a low-carbon development?

The case study for this thesis is a cohort of residents in the WGV development[1]. The timing of this move and the active involvement of the researchers in the project allowed for residents practices to be monitored pre- and post-occupancy in the development. This provided a unique opportunity for a longitudinal study of the practices of individuals, households and the community across multiple resource flows including energy, water, waste, transport, food, purchasing practices and social networks. Therefore, to answer the research question, seven sub-questions were

[1] WGV is the full name of the development, it is not an abbreviation. The area in which WGV is located is the suburb of White Gum Valley, in Fremantle, Western Australia.

posed to address both the theoretical aspects and application of methods in the longitudinal case study of residents moving into the WGV development:

1. What are the theories and methods typically used to understand and influence domestic practices and over what scales do these occur?
2. Is there a home system of practice and if so, can it be influenced to enable the reduction of resource consumption in domestic practices?
3. What are the features of the WGV development and how does it relate to precinct urban planning?
4. What are the daily domestic practices and HSOP of residents pre-occupancy in WGV and what impact does the degree of interlocking have on their performances?
5. What changes occur to pre-occupancy energy and water domestic consumption practices post-occupancy in a low-carbon development?
6. What changes occur to individual domestic practices and the Home System of Practice when residents' move into WGV?
7. What are the resident's motivations, perceptions, expectations and experiences of establishing a home in WGV?

Each of these sub-questions is addressed in a peer-reviewed journal article or book chapter as shown in Table 1.1.

Table 1-1 Research sub-questions, publications and objectives

Sub-questions	Publication	Objectives
1. What are the theories and methods typically used to understand and influence domestic practices and over what scales do these occur?	I. Understanding Resource Consumption in the Home, Community and Society through Behaviour and Social Practice Theories Peer-reviewed article	This publication reviewed socio-psychology theories and practice theories as well as methods commonly employed to influence occupants in their homes. The objective of this article was to comment on how these theories can be applied at different scales in the home, community and society.
2. Is there a HSOP and if so, can it be influenced to enable the reduction of resource consumption in domestic practices?	II. The Home as a System of Practice and its Implications for Energy and Water Metabolism Peer-reviewed article III. Shifting Home Energy Consumption Through a Holistic Understanding of the Home System of Practice Book chapter in a peer reviewed book	These publications described how practices are aligned and interlocked in the HSOP and how the HSOP influences overall resource use. It provided insight into the home system and unveils the underlying reasons behind energy and water use.
3. What are the features of the WGV development and how does it relate to precinct urban planning?	IV. WGV: An Australian Urban Precinct Case Study to Demonstrate the 1.5°C Agenda including Multiple SDGs Peer-reviewed article	This publication outlined the design and technology features of the WGV development and the unique community aspects of the project. It also related these aspects to the Sustainable Development Goals and comments on the relationship with precinct urban planning.
4. What are the daily domestic practices and HSOP of residents pre-occupancy in WGV and what impact does the	V. Interlocking Practices and their Influence in the Home Peer-reviewed article	This publication examined the domestic practices and the HSOP of 14 resident's pre-occupancy in the WGV development. This paper focused on the social system of residents and how they interact with specific

degree of interlocking have on their performances?		technologies. The degree of interlocking of their home system is discussed.
5. What changes occur to pre-occupancy energy and water domestic consumption practices post-occupancy in a low-carbon development?	VI. Household Energy and Water Practice Changes in a Low-Carbon Development Peer-reviewed article	This paper compares and contrasts the pre- and post-occupancy energy and water practices of residents and the influences on these.
6. What changes occur to individual domestic practices and the HSOP when residents' move into WGV?	VII. Changes to Household Practices Pre- and Post-Occupancy in an Australian Low-Carbon Development Peer-reviewed article	This paper continues the longitudinal study of resident's HSOP. It examines residents post-occupancy in the WGV development to assess their practices and if innovative technology is used in the intended way and the influence of the community on domestic practices.
7. What are the resident's motivations, perceptions, expectations and experiences of establishing a home in WGV?	VIII. Pre- and Post-Occupancy Evaluation of Resident Motivations for and Experiences of Establishing a Home in a Low-Carbon Development Peer-reviewed article	This publication explored the residents' motivations, perceptions, expectations and experiences of establishing a home in a LCD through a pre-and post-occupancy evaluation study.

1.4 Thesis organisation

Seven peer-reviewed publications and one peer-reviewed book chapter provide the basis for this thesis. The exegesis provides the context for and is an integrated synthesis of, these publications.

Chapter 1 outlines the context of the importance of the built environment and domestic social practices in addressing environmental and climate challenges.

Chapter 2 describes the research design and methodology undertaken in this thesis.

Chapter 3 is a literature review related to the research question, including summaries of those included in the publications.

Chapter 4 provides a summary of the results relating to the seven research questions.

Chapter 5 is a discussion of the results in the context of the thesis research question.

Chapter 6 concludes the thesis and offers recommendations for future research.

The published articles and manuscripts are provided following the exegesis, as well as additional material discussed in the exegesis.

Chapter 2 Methods

This chapter outlines the methodology utilised for this thesis, the case study of the WGV development, the cohort of residents who have been participating in the project, and the data collection and analysis methods. The chapter concludes with a discussion on the scope of the research within the constraints of the experimental design and the case study. Social science related disciplines, methods, concepts, and topics remain underutilised in contemporary resource consumption studies (96). Therefore, this thesis uses a mixed-method design approach, with both qualitative and quantitative data methods, based on Living Laboratory methods (97). The methods for each individual publication are outlined in Table 2.1.

As well as employing Living Laboratory methods which will be outlined in section 2.1 in more detail, the methodology of this thesis is based on Praxiography: the field of practice theory research (98). Praxiography focuses on implicit or tacit knowledge, the knowledge that is rarely verbalized and not easily distinguishable. Practices are the mediator and carrier of such knowledge and as such, they can be studied to unveil the resources utilised in their performance (35,51,73). This can be through observation of the practice and discussion with the practitioners themselves to understand and interpret the implicit background knowledge and meanings (51). A time of change is ideal for studying practices because participants are more actively aware of how the new situation can be accommodated into existing practices (99). Studying a situation of change can allow learnings of old practices and newly emerging practices to occur (98).

Table 2-1 Research methods reported in the publications

Publication		Methods
I.	Understanding Resource Consumption in the Home, Community and Society through Behaviour and Social Practice Theories	Narrative literature review and critical analysis
II.	The Home as a System of Practice and its Implications for Energy and Water Metabolism	Explanatory mixed-method design: • Real-life house performance monitoring • Statistical tests: Generalised additive models, Wilcoxon signed-rank test and Mann-Whitney test • Longitudinal semi-structured interviews • Thematic analysis
III.	Shifting Home Energy Consumption Through a Holistic Understanding of the Home System of Practice	Narrative literature review and critical analysis
IV.	WGV: An Australian Urban Precinct Case Study to Demonstrate the 1.5°C Agenda including Multiple SDGs	Narrative literature review and critical analysis Mixed-method design: • Semi-structured and structured interviews with residents and community stakeholders • Modelling of house and precinct resource performance
V.	Interlocking Practices and their Influence in the Home	Explanatory mixed-methods design: • Longitudinal structured interviews • Cultural probes, survey and workbook • Thematic analysis
VI.	Household Energy and Water Practice Changes in a Low-Carbon Development	Explanatory mixed-methods design: • Longitudinal structured interviews • Cultural probes, survey and workbook • Thematic analysis • Real-life house performance monitoring • Statistical tests

VII.	Changes to Household Practices Pre- and Post-Occupancy in an Australian Low-Carbon Development	Explanatory mixed-methods design: • Longitudinal structured interviews • Cultural probes, survey and workbook • Thematic analysis
VIII.	Pre- and Post-Occupancy Evaluation of Resident Motivations for and Experiences of Establishing a Home in a Low-Carbon Development	Narrative literature review Document analysis Explanatory mixed-methods design using post-occupancy methods: • Longitudinal structured interviews • Cultural probes, survey and workbook Thematic analysis

2.1 Living Laboratories

Studying behaviours and practice in real-life settings allows us to capture real motivations and needs of users (100). The ideas behind the development of Living Laboratories vary depending on their purpose (86,100). The definition of a Living Laboratory is varied but has been described as a methodology (100), as well as a place (101). It can also be termed a Living Lab, or an Urban Living Lab (102,103). There can be some differences associated with each term, a Living Laboratory or Living Lab is defined by the European Network of Living Labs as user-centred, based on user co-creation and integrating research and innovation processes into real-life communities and settings (104). Urban Living Labs are similar but can be focused more on participatory projects in localized contexts (102). Three key features of Living Laboratories are consistent across the literature, that they involve co-creation, user awareness and real-life settings (105). The following definition also encompasses knowledge, social and technical innovations and it is this definition that is used in this thesis:

"A Living Laboratory is a real-life place for user co-creation of innovations in knowledge, products, services and infrastructures (86)."

A similar definition presented by (106) suggests that the current discourse is converging to a unified meaning of the term Living Laboratories. Different types of places and spaces can facilitate or hinder innovation (106). The attributes of local knowledge and user influence affect the nature of innovation in a place and space

(107). It is therefore important to capture the heterogeneous nature and manifestation of social and technical innovation for real-life Living Laboratories in different settings (108). The heterogeneity of innovation in Living Laboratories may be revealed through scaling effects which are due to different interpretations of the physical boundaries of a Living Laboratory. A typology of Living Laboratories might include three scales; urban, dedicated and embedded (109).

The urban Living Laboratory has a boundary ranging from the city district to the whole metropolitan area and is seen as an approach to dealing with challenges such as the low carbon city, blue/green infrastructures and social uplift (26). At the district level, this approach has been proposed as a means to design a new university campus where the user focus is business, society and academia (110).

Dedicated Living Laboratories are place-specific, usually a dedicated building, and are used for prototyping products and services (111). Embedded Living Laboratories are existing residences or workplaces that are studied to provide insight into user practice (112).

Embedded Living Laboratories are the ideal place to observe and learn the practices used to complete a determined task, understand the effects of behaviour and relationships on resource consumption, co-create innovative solutions to problems and test innovative technologies or approaches (86). They can be implemented on a variety of scales, allowing them to be used in the investigation of behaviours and practices across all levels of society.

Living Laboratories enable researchers to measure both qualitatively and qualitatively, the effect of different interventions upon resource usage both quantitatively and qualitatively (102). Through interactions between researchers and users, better insight is obtained into lifestyles, needs and attitudes and tailored solutions being developed in conjunction with the user (113). This co-creation process enables the development of innovation that is useful, bridging some of the limitations found in the design or in the technology of buildings or homes (53,54). Living Laboratories can help to overcome a limitation of many research studies which tend to see homes as a single unit instead of a place with specific objects and multiple people interacting with one another (100). This is particularly relevant to the study of practices, as practices cluster into particular themes, and is evident in the temporal and spatial aspects which will be discussed further in section 3.1.3, and featured in Publication I. Practices related to cooking, eating and leisure often have low flexibility in the home environment while practices relating to domestic cleaning have been found to have higher flexibility in temporal spaces (114). Practices involving lighting, heating and cooling have already begun to be automated in households but residents are not yet the co-managers of their energy consumption that has been the promoted ideal (114). Resident's practices are dictated by long-held routines, habits and practices that need to be studied in relation to these technologies if effective outcomes are to eventuate (94).

Previous studies have found that the traditional methods employed to understand practices and behaviour, including diaries, surveys and interviews, have not captured the nuances of daily practices and if not integrated with quantitative data, fail to provide correct explanations for practices (115). Living Laboratories employ a variety of methods depending on the time stage that the Living Laboratory is in and the needs of the research (112). Three phases in Living Laboratory research can be identified, as shown in Table 2.2. During the first phase of the Living Laboratory, a baseline of participant's practices is established through questionnaires, sensor data collection, diaries, network analysis and re-enactment of practices (112). In the second phase of the Living Laboratory, probes of new technology or innovations are introduced into the Living Laboratory that are then co-created with the participants to develop prototypes for testing. Whilst this is occurring, methods that can be used to explore the practices being enacted include questionnaires, diaries, cultural probes, interviews and re-enactments (Publication I). The final phase of the Living Laboratory occurs with large scale field trials with many participants testing the prototypes.

Table 2-2 The 3 phases of research in Living Laboratories [Adapted from (106)*]*

Phase	**Insight research**	**Prototyping**	**Field testing**
Assignment	Analysis of resource flows and routines of actions situated in the context	Scenario and prototype development in the Living Laboratory	Testing and evaluation of the prototype in real-life applications
Methods	Sensor technology, interviews, Material Input per Service Unit analysis, observations, network analysis, user reenactment	Design-orientated scenarios, co-creation workshops, *In-situ* tasks	A stakeholder analysis of diffusion, sensor technology, diaries, interviews, workshops

This research has used the WGV development as an embedded Living Laboratory, with data collection occurring during the insight phase of the Living Laboratory along with the testing of prototypes, namely the technological innovations of the WGV development, as well as exploring the community and social network aspects of daily life in the LCD. Therefore, it combines all the stages of the Living Laboratory for this cohort.

2.2 Project participants

The longitudinal case study for this thesis is the WGV development as an embedded Living Laboratory, and a subsection of the resident's moving into it. Section 2.2 details the built environment features of WGV and the residents who are part of this research.

2.2.1 The WGV Development

This section outlines the built environment design features of the WGV development and draws upon Publication IV of this thesis. This addresses the research question: what are the features of the WGV development and how does it relate to precinct urban planning?

In this thesis, a LCD refers to a group of households that form part of a development with design performance requirements beyond the Australian National Construction Code (e.g., 7+ star NatHERS thermal performance) and with the inclusion of a solar PV system (116). This standard can be met through natural ventilation, the orientation of the dwelling to take advantage of the sun, shading through awnings and verandas and building materials used, including double-glazing. The WGV development is an example of a LCD, located in the suburb of White Gum Valley, Fremantle, Western Australia.

WGV is an infill residential development that evolved into a demonstration housing project. Perth has a Mediterranean climate with an average of 8.8 hours of sunshine per day, ideal for solar energy and storage technologies (117). The average outdoor temperature is between 10 °C and 27.3 °C annually (118). WGV is located in the suburb of White Gum Valley, a low-density suburb of Fremantle, which is undergoing redevelopment as the first generation of housing from the 1950s, is being replaced or restored with a denser and more sustainable housing product. The project has been led by LandCorp (now Development WA), the Western Australian government's land development agency, with a charter to demonstrate innovation in urban planning and development. The development aims to offer an example of innovation in sustainable housing featuring a range of innovations and is an attempt to demonstrate net zero-carbon as well as other sustainability goals set by urban planning processes such as community engagement and the One Planet Living accreditation process (119). We have considered the contribution of the WGV development to the IPCC 1.5 °C agenda that seeks to achieve deep decarbonisation while also delivering the UN Sustainable Development Goals (Publication IV). Solar photovoltaics and battery storage are incorporated into WGV, with peer-to-peer trading of energy occurring between apartments (120). The multiple sustainable development features such as water-sensitive design, a shared water bore system, energy efficiency, social housing, heritage retention, landscape and community involvement have been designed to provide inclusive, safe, resilient and sustainable living and have been assessed under the SDG framework in Publication IV.

WGV is also an important demonstration of how to turn a middle suburban redevelopment site into a commercially viable product at medium density, an agenda of interest across Australia and similar car-dependent cities in North America (121–

123). The residential development is situated on the site of a former school that was closed in 2008 and provided a site of 2.3 ha with approximately 80 housing units built in a medium-density format and with a highly mixed tenure. The multitude of dwelling types are connected through their innovative technology systems so that a home is no longer a single dwelling but part of a system (as discussed in (124)). The first residents began moving into WGV in mid-2017. Figure 2.2 shows an aerial view of the WGV development taken in 2018.

Figure 2-1 Aerial view of the WGV development in 2018. The SHAC development is located on the bottom right with one of the two buildings featuring solar PV panels on the roof. The Evermore development is located bottom left with both buildings featuring solar PV panels on the roof. The semi-detached house is located in the middle on the right, facing the vacant enclosed block. The single house participating in this research is located in the top left corner (photo obtained from Josh Byrne & Associates with permission).

There are three different building typologies located in WGV: four multi-residential buildings, one semi-detached house and 23 detached houses. Two of the multi-residential buildings do not have any residents included in this research: the Gen Y Demonstration Housing project, which is a practical demonstration of sustainable and cost-effective housing to suit living in the 21st century and a Baugruppen Model of a housing co-op, a form of social housing that is privately funded. The other building typologies that contain participants of this research are discussed below, with their details found in Appendix A.

In Australia, it is estimated that 13% of the population is living under the poverty line, many of these are children and old aged pensioners (125). WGV addresses the lack of affordable and diverse housing in Perth through a range of dwellings and the inclusion of 15% affordable housing stock in the development (126). The Sustainable Housing for Artists and Creatives (SHAC) development consists of 12 one- and two-bedroom apartments in two separate blocks facing a shared courtyard, as shown in Figure 2.3. There are also two studio spaces for artists to use as work and meeting spaces. There is a 20 kW solar panel system and a 40 kWh shared battery system for the SHAC development. The SHAC development is a community housing development built by Access Housing, who then lease the apartments back to members of SHAC at a subsided rate in accordance with the National Rental Affordability Scheme. The partnership between LandCorp (Development WA), Access Housing and SHAC was formed to deliver a community housing development specifically for local artists and their families at WGV. This initiative aims to support the local creative industry and encourage greater diversity and culture within the community. The partnership provides affordable housing for artists who work in the cultural and artistic centre of Fremantle but have been priced out of the residential housing market and were travelling long distances (upwards of 50 km, and often not using public transport) to work and cultural events, many living with friends or family at very low rental prices. In this research, five households from SHAC participated in the pre- and post-occupancy data collection.

Figure 2-2 Communal area of the SHAC development in 2019 (Photograph taken by the author)

The Evermore development consists of 24 one, two- and three-bedroom apartments in two separate blocks facing a shared courtyard as shown in Figure 2.4. These apartments have been built and sold at market rates by a local developer and feature a shared 53.6 kW solar PV system and 150 kWh battery system. In this research, seven of the households in Evermore participated in the pre-occupancy data collection and five continued with the post-occupancy data collection.

Figure 2-3 The Evermore development in 2019 (Photograph taken by the author)

There is one semi-detached or duplex housing type in the WGV development and both household residents are participating in this research. This building consists of two dwellings sharing a common wall, with a shared 5 kW solar PV system, a Heating, Ventilation & Air-Conditioning heat pump for hot water heating, an in-floor heating fan coil, and a 7 kL rainwater tank. There are two adult residents in each dwelling, with a shared outdoor space, laundry space and entertaining space on top of the garage. Figure 2.5 shows the dwelling.

Figure 2-4 Semi-detached house with a shared front courtyard, garden, garage and space above the garage (Photograph was taken by the author in 2019)

The final type of dwelling at WGV is the detached house. There are 23 houses in WGV and one resident participated in this research. Each house has flexibility over design in accordance with the design guidelines of the development. The participating resident's house features a 3.5 kW solar PV system, a 3 kL rainwater tank and solar hot water system with an electric booster. This is a two-storey brick house with a front and side enclosed courtyard and double garage. An image has not been included to preserve the privacy of the participant.

WGV thus provides a practical demonstration of several new housing models that can be replicated to provide affordable housing for a range of people. The various dwelling typologies of the WGV project were also explored in an effort to address the problem of the missing middle of medium density housing, where cities like Perth have a plethora of either low-density single-family homes in outer suburbs or higher-density apartments in inner areas, but not a significant proportion of medium density dwellings (123). This project demonstrates a solution where the gap between single homes and apartment blocks can be bridged through some increase in density while also integrating well within the landscape of low-density housing in the surrounding area. The diversity of housing options was a key way that WGV was inclusive of the local community and could be identified as facilitating the achievement of the United Nation's Sustainable Development Goals (Publication IV).

The analysis of the housing design and energy and water flows throughout the WGV development is covered by other researchers on the project and as such is outside the scope and research questions posed by this thesis. The missing element of ongoing research was an understanding of how the residents are experiencing the development and their means of interaction with the technology features included. This provided the opportunity to study the residents and households in a longitudinal study across the dwelling typologies. The characteristics of the residents (while remaining anonymous) participating in this research are listed in Table 2.3, along with details about their previous dwelling and occupancy. The tenancy status of the occupants has been listed in this table, although it is not directly analysed in this thesis. This table is repeated in various versions in publications V to VIII of this thesis. Residents were self-selected through an open invitation sent to those who had already purchased property in WGV or were intending to become a tenant through SHAC (n = 27). An original sample size of 16 individuals in 15 dwellings was part of the pre-occupancy data collection; however, one household decided to rent out their apartment in WGV, and another decided to leave the study. Their results are only included in Publication V which was published prior to their exit from the research. A cohort study of 14 residents inhabiting 13 homes (n = 14) was used for Publications VI through VIII, with data collected both pre-and post-occupancy in WGV. Three households had sustainability features in their pre-occupancy dwellings.

Table 2-3 Research participants. Household B and O separated into two apartments in Evermore post-occupancy featuring 1 adult and 1 teenager in each, with both adults continuing participation.
** indicates that this household was not included in the post-occupancy evaluation*

House code	Residents (participants)	Occupancy lifestyle	Pre-WGV dwelling type	Pre-WGV dwelling sustainability features	Dwelling in WGV
A	1 adult	Works full-time	Townhouse, own	None	Evermore, own
B and O	2 adults, 3 teenagers (2 adult participants)	1 adult full-time, 1 adult part-time, teenagers study full-time & part-time work	House, own	1.1kWh Solar panel system, rainwater tank, vegetable patches, 3 compost bins, 2 worm farms	Evermore, own
C	1 adult, 2 teenagers (1 adult participant)	Adult 4 days a week, teenagers part-time work	House, own	Solar PV system, garden bore	Evermore, own
D	2 adults, 2 teenagers (Mother is a participant)	Self-employed, full-time artist & teacher	House, rent	None	SHAC, rent
E*	2 adults, 2 teenagers (Mother is a participant)	Adult 4 days a week, son works night shifts part-time	House, rent	None	Did not move to WGV
F	2 adults (Both participants)	Both work full-time	House, rent	None	Semi-detached house, own
G	3 adults (mother & 2 children) (Mother is a participant)	Mother is a part-time shift-worker, 18 yo full-time student, 22 yo seeking full-time work	House, rent	None	House, own
H	1 adult, 1 teenager part-time (Father is a participant)	Self-employed, full-time creative	Semi-detached house, rent	None	SHAC, rent
I	1 adult	Retired	Unit, rent	None	Evermore, own
J	1 adult	Self-employed, full-time artist & casual tutor	Apartment, rent	None	SHAC, rent

K*	2 adults (1 female adult participant)	Full-time fly in-, fly out-professional	Apartment, rented with flat-mate	None	Evermore, own
L	3 adults, 1 child (3 years) (Mother is a participant)	Self-employed, part-time artist & teacher, another part-time job	Staying with parents, who own house	Solar PV system	SHAC, rent
M	3 adults and 2 adult (1 adult participant)	Works full-time	Staying with two different friends, who own houses	None	Semi-detached house, own
N	2 adults (1 adult participant)	Self-employed, full-time creative	Staying with a friend, who rents house	None	SHAC, rent

2.2 Research design

The literature review outlined in Chapter 3 and considered in Chapter 1, identified a lack of longitudinal and comprehensive analysis of individual and household resource flows, especially for residents in LCDs. It also highlighted a lack of user experiences of LCDs, particularly from a social aspect. Consequently, the research was designed in two phases, to be undertaken before and after the residents move into WGV. This allowed for a greater understanding of the influences on the interlocking of practices and track how resident's practices change with the move to a LCD. The data collection tasks and analysis were replicated pre- and post-occupancy to ensure consistency and are outlined in Table 2.4. In undertaking this research, a conscious decision was made to control for space in analysing practices. The household was chosen as the boundary to study practices in, although travel practices and shopping practices that revolve around the household were also examined. This has resulted in time being prioritised over space when examining practices (89). This study, therefore, supports the investigation of holistic, longitudinal studies of resource use in LCDs, which is lacking in the literature (11,47). The methods are based on those used in Living Laboratories as outlined in (112).

The objective of the first round of data collection before residents had moved into WGV was to understand the standard domestic practices of the residents and how these involve resources. It also explored resident's associations with home, through establishing their motivations, perceptions and expectations of what their life would be like when they moved to WGV. This phase was undertaken between April 2017 and June 2017 for the SHAC residents and between December 2017 and March 2018 for Evermore and single house residents.

The objective of the second round of data collection after the residents had moved into WGV was to understand how their daily domestic practices have or have not changed since the move. It also explored how their experience of living in the dwellings and the development as a whole influenced their relationship with their home and community living. This phase was conducted between December 2018 and March 2019 for all residents.

Table 2-4Research design, material and analysis used in the thesis

Data collection tasks	Overview of material generated	Analysis
Task 1: Desktop study	The theoretical context of socio-psychological and social practice theories influencing home resource flows; planning context of WGV	Understanding the theoretical and planning context of practices in the home and of the WGV development
Task 2: Interviews Replicated pre-and post-occupancy	Resident’s domestic practices and household contexts	Constructing the resident’s context and daily practices as told by the resident
Task 3: Survey Replicated pre-and post-occupancy	Resident’s domestic practices and perceptions of sustainability	Constructing the resident’s context and daily practices through short answer questions and likert-scale questions
Task 4: Workbook Replicated pre-and post-occupancy	Resident’s social networks, discussion of sustainability topics and 2 weeks of transport and hygiene practices diary	Constructing the resident’s context and daily practices in relation to transport and hygiene practices to compare to those reported in the survey and interview
Task 5: Text Probes Replicated pre-and post-occupancy	Short questions sent *via* text or email periodically over 2 weeks to capture data on residents' current practices and associations with home and community	Constructing resident’s context, daily practices and experiences to compare to those reported in the survey, interview and workbook
Task 6: Resource consumption data Replicated pre-and post-occupancy	Electricity, gas and water consumption levels at timestamped intervals and provided in bills to residents. Temperature and relative humidity of dwellings was recorded for 3 months once residents had moved into WGV	Constructing the resident’s resource consumption profiles and to compare to the resident’s self-reported comfort levels.

2.2.1 Quantitative data collection

Collecting quantitative data in the pre-occupancy phase of the research was more limited than in the post-occupancy phase. Before residents moved into the WGV development, the only quantitative data available to the researchers was electricity, gas and water bills. These were requested for the previous year however, there was a lot of variety in the bills provided due to residents not keeping them or only having access to a portion of the water bill.

The quantitative data collection in phase two of the research, once residents had moved into WGV, was more streamlined and extensive. Household levels of electricity and water consumption were provided once the residents moved into the dwellings. These were at 5-minute intervals for all participating households except for Evermore residents, which were at 15-minute intervals due to a programming decision. The water consumption data was also divided into the source (rainwater or mains water) for the semi-detached and detached dwellings studied. Over a 3-month period, the households also contained a temperature and relative humidity sensor logging at 5-minute intervals. The quantitative data is presented in Publication VI of this thesis.

2.2.2 Qualitative data collection

Detailed data on the performance of practices requires more than just the quantitative data collected at a household level, it also requires understanding the meaning, skills and technologies involved in the performance of those practices (127). The use of interviews allows people to express their experiences in a multitude of ways (128). In addition, other Living Laboratory methods allow for a greater understanding of practices performed in the household, which is essential for understanding the complex formation of the social practices, however, they may take more time than interviews and observations to compile. Therefore, this thesis complements the quantitative data with an extensive range of qualitative data collected through the following methods: structured interviews, workbook, cultural probes and a survey.

Structured interview

The structured interview explored the resident's motivations and experiences surrounding the move to WGV and their daily domestic practices. The interview questions were developed around meta-questions for pre- and post-occupancy that are shown in Table 2.5 (129). The questions in the structured interview asked residents how they kept thermally comfortable, the routines they went through each day and how their lives had changed since moving to WGV. The interviews were conducted by the same interviewer (130) for approximately one hour and were undertaken in the residents' pre- and post-occupancy residence, except for one which was conducted at an independent venue. In households with multiple adults, only those moving into WGV were interviewed. Children, including those over 18 and still living at home, were not interviewed due to uncertain circumstances surrounding their residency arrangements once their parents moved into the WGV development. The interview also featured an audit of the main appliances in each household. Interviews were chosen as a method in this thesis as they are a reasonably familiar methodology to participants and allow for the researcher to frame the conversation to cover the relevant topics and explore a topic in more detail if required (112). The interview meta-questions used in pre- and post-occupancy interviews are in Appendix B.

Table 2-5 Meta-questions influencing the interview questions

Meta-questions pre-occupancy interview	**Meta-questions post-occupancy interview**
What daily practices influence home resource metabolism?	Why did or did not the participants change their routines/practices and which contextual or motivational factors were most influential?
How do the home structure (both built and perceived) influence practices?	To what extent did the design of the homes contribute to these changes?
What routines and habits do they have including those related to sustainability or resource consumption?	To what extent are these new behaviours and practices transferable to other people's lives or situations?
How do they think their lives will change when they move into sustainable housing?	How can the design of low carbon housing be improved to enable sustainable practices?
What appliances do they use most often and how do these fit in with their practices?	
What automatic systems do they have and how do these fit in with their practices?	
What influences people to move into low carbon dwellings?	
What role do social networks have on resource use?	

Workbook

A workbook was completed over two weeks, allowing residents to complete a social network table, a travel diary and a hygiene diary. The workbooks are contained in Appendix C for pre-occupancy and Appendix D for post-occupancy. An image of the pack is shown in Figure 2.5. The social network table asks participants to list the ten most important people in the life, their location (in the same dwelling or suburb), how frequently they talk to them and if they influenced their decision to move to WGV. The second table then asks participants to list who they talk to about sustainability topics, where they live, if they influenced their decision to move to WGV, how frequently they talk and what about. This is to develop an understanding of how sustainability is communicated in the resident's lives and who influences a decision to move to a LCD. The lists were compared after the second phase of data collection to assess if the resident's communication patterns have changed with the new community. The method is based on the name generator method discussed in (131,132). The travel and hygiene diary are used to capture the mundane routine aspect of these practices that may be forgotten or not focused on during the structured interviews (38). Both diaries are filled in for two weeks to show the daily repetition of practices. The travel diary contains columns for date, time, length of travel, mode of travel, who residents travel with and the purpose of the travel. This diary allowed for the comparison of travel practices pre- and post-occupancy in WGV to determine any changes. The hygiene diary asks residents to record each time they undertake a personal hygiene practice such as having a shower or washing their face with a towel before heading out. The information collected includes the time, duration, method and purpose of the hygiene practice. This data is the primary data source in the pre-occupancy round of data collection to monitor water use through practices in the household. In the post-occupancy data collection phase, the hygiene diary is used to correlate the self-reported hygiene practices with those identified through the water data collected from each dwelling. This also allowed the capture of hygiene practices that do not involve the traditional use of a shower or bath and the reasons behind them being used. This is data that can be missed through only analysing the dwelling water output and provides valuable insight into hygiene practices. Workbooks could be viewed as less intimidating for participants who may not wish to reveal detailed information about some practices (such as personal hygiene practices) in a face-to-face interview (112).

Figure 2-5 An example workbook, showing the front and back of the postcard with the probe question, the survey and diary contained within and a pen

Survey

The survey section was designed to complement the interview topics with traditional qualitative Likert scale questions around attitudes, values and the frequency of practices and a range of short-answer questions about their resource uses and habits. The workbook for the pre-occupancy data collection contained the survey questions, which were moved into an electronic survey system for the post-occupancy data collection. The survey questions are contained in Appendix C for pre-occupancy and Appendix D for post-occupancy.

The 5[2]-and 7[3]-point Likert scale survey questions included questions of resource use of water, energy, food, travel and waste products. Short answer questions that were designed to be deliberately open-ended were also included[4]. Questions relating to the management of household waste were included covering waste disposal and reuse/recycling habits of the households, involving food, paper, plastics, glass, wood,

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[2] 5-scale Likert question example: How comfortable are you finding the house in relation to temperature? Very comfortable, mostly comfortable, neutral, mostly uncomfortable or very uncomfortable?

[3] 7-scale Likert question example: How often do you use the public outdoor areas in WGV? Every day, a few times a week, about once a week, a few times a month, once a month, less than once a month, or never?

[4] An example of a short answer question is: Do you have difficulties in getting to places?

metals, and technology waste, to assess if these practices changed post-occupancy in WGV. Questionnaires on the domestic appliances used in the household that consume resources and the frequency of use were also included. The Low Carbon Readiness Index developed by (133,134) was included in the survey questions. This Index reveals individual, household and perceived societal norms through the 10 questions shown in Table 2.6. The results of this Index are included in Publication V.

Table 2-6 Low Carbon Readiness Index questions applied in this research and the norms being assessed by them (adapted from (133,134)*).*

Question	**Norm being assessed**
1. Living in a comfortable and attractive home is an important goal for me.	Individual
2. I work hard to reduce my greenhouse gas emissions whenever possible.	Individual
3. I feel very good when I am successful in reducing my greenhouse gas emissions.	Individual
4. I would feel very bad if I failed to reduce my greenhouse gas emissions.	Individual
5. Most people work hard to reduce their greenhouse gas emissions whenever possible.	Perceived norms
6. Most people think it is very important to reduce their greenhouse gas emissions.	Perceived norms
7. I have friends and family outside the home who can give me advice about, or practical support for doing things that reduce greenhouse gas emissions.	Perceived norms
8. Members of my household keep track of what is happening in the household to make sure the goal of reducing greenhouse gas emissions in the household is achieved	Household
9. Members of my household remind each other to behave in a way that helps achieve this goal of reducing greenhouse gas emissions in the household	Household
10. Our household income is high enough to satisfy nearly all our important desires.	Household

Cultural Probes

Cultural Probes are simple, flexible tools that allow researchers to learn about users and their actions in real-time (135). This may be in the form of a text message, email or note asking participants to take a picture of how, for example, they kept cool on the day in question (Figure 2.6). Probes are used in this research to investigate practices residents are undertaking at various times. Text probes were sent periodically through the two weeks that the workbook was being filled in to gain *in* *situ* qualitative contextual data on current practices, minimizing the impact of recall difficulties during interviews [53]. The text probe method is a combination of cultural probe methods developed over the past two decades that request participants to take photos of objects during their daily life with a disposable camera (135–137). The advent of mobile phones has allowed a significant advance in this method. Text messages are a low-effort, quick and familiar method for the participant, thereby increasing the response rate. Examples of the questions used are, “Tell me how you have kept warm today?” or “In a picture or a few words, tell me what home means to you?” This method is a more personal collection of data as it is asking residents to participate at any time over the two weeks. However, it was chosen to support the longitudinal nature of the research and to overcome the static capture of data through interviews or surveys. The text probes were well received by the participants in this research, will high response rates both pre- and post-occupancy (see Appendix C and D). They also confirmed information about practices that was revealed in the interviews. In a larger scale study, text probes could be sent through bulk SMS services to reduce the time spent for researchers to individually send the message.

Figure 2-6 An example of a cultural probe and response sent via text message

Postcard probes were also used in this research (135). These postcards had a short answer question written on them for the residents to answer and return with the workbook. An example is shown in Figure 2.5. Postcards were chosen in addition to the text probes due to the age group of participants including many who would be familiar with sending postcards themselves.

The text and postcard probe questions and response rate are contained in Appendix C for pre-occupancy and Appendix D for post-occupancy.

2.3 Data analysis

Data analysis occurred after the first round of data collection pre-occupancy and again after post-occupancy in WGV. While domestic practices are the focus of the analysis of this thesis, household-level energy and water data were also analyzed to be able to account for some residents not moving into the LCD in the same house and family structure (i.e. children not moving in with their parent's post-occupancy in

WGV, thus affecting comparison of pre-and post-occupancy household energy and water consumption levels).

2.3.1 Quantitative analysis

The data was analysed through a comparison of the energy and water use changes pre- and post-occupancy and by normalising this to the Perth metropolitan average. The pre-occupancy data is limited due to residents not having access to a year's worth of complete bills; however, all post-occupancy energy and water use have been collated. As all the dwellings use bore water for irrigation, a daily landscaping contribution was added to the household total. For the semi-detached and detached households, this figure was provided by monitoring data. For the apartment households, a daily landscaping contribution was arrived at by dividing the total outdoor water use by the number of apartments in the dwelling. Data on personal hygiene practices was provided through a personal hygiene diary which noted time, duration and meaning for the practice. These results were graphically presented to reveal trends in total shower times and averages. Meanings were grouped into themes, based on the reason given by the resident in the diary. The Likert scale data was analyzed through a graphical representation of the results to view trends, which were then compared with the qualitative data.

2.3.2 Qualitative analysis

Qualitative data obtained through the structured interviews, surveys, workbooks and cultural probes were analysed using NVivo software. Themes and nodes were identified as shown in Table 2.7. A shortlist of initial themes was drawn up before the thematic analysis based on the researchers' notes from the interviews and altered as the analysis occurred. This list was not altered post-occupancy to ensure consistency of analysis. Themes included affordability, comfort, control, convenience, energy, health, ownership, privacy, stability, thermal comfort, time, employment, cooking, fresh air, routine, washing, animals, children and sense of community. The number of meaning elements was rationalised to a limited degree by grouping similar answers together, as done in (138).

Table 2-7 Themes and associated nodes identified in the thematic analysis

Theme	Node	Theme	Node
General	Affordability	Practice theory	Cleaning
	Comfort		Cooking
	Control		Employment
	Convenience		Food shop
	Energy		Fresh air
	Environmentalism		Freshness
	Health		Habit
	Ownership		Monitoring of usage
	Privacy		SPT- meaning
	Stability		SPT- skill
	Thermal comfort		SPT- technology
	Time		Routine
	Transport		System of Practice
	Waste		Washing
	Water		
Physical	Animals	Social	Children
	Appliances		Friends or Family
	Blinds		Local
	Lighting		Repairs
	Recycling		Sense of community
	Second-hand		
	Space- constraining		
	Space- enabling		
	Sunlight		

2.4 Research constraints

This research encountered several constraints, some related to the experimental design methodology and others related to the case study of the WGV development.

2.4.1 Experimental design constraints

The workbook methodology is a unique set of data collection methods compiled for this research. While the method is based on Living Laboratory methods, these were altered to combine the cultural probes with the detailed workbook diaries which had not been combined in other Living Laboratory research (112,136). The development of this method resulted in two sets of workbooks produced during the pre-occupancy data collection phase. The SHAC residents were the first to receive the workbooks and slight alterations were made before the other participants received their workbooks to improve readability and ensure only relevant questions were asked. This involved the inclusion of the Low Carbon Readiness Index, additional questions using the Likert scale model, alteration to the social network question to include a record of influences on sustainability discussions and the decision to move to WGV, as well as the inclusion of sections to record the bill data where previously this had been sought separately. A suggestion was made by one of the participants to have an electronic version of the workbook for participants. This had been originally considered but was discarded during the methodology planning stage due to the more personal nature of the physical workbook, the physical reminder that it would provide to fill in the transport and personal hygiene logs each day. Another consideration was the age of some of the participants and how familiar and able they were with accessing an electronic diary each day. However, as the survey was only to be conducted once and after some positive responses from the residents, it was decided to move these questions to an online survey distribution platform for the post-occupancy phase of data collection to allow for easier distribution and analysis.

The text message questions were sent to all the participants except one who requested the message *via* email for financial reasons. These messages were sent over the same two-week period that residents were filling in the travel and hygiene diary to minimise the time period that residents were involved and to provide as an indirect prompt to fill this diary in. Response rates were a 90% pre-occupancy and an 89% post-occupancy.
Some participants did not return the postcards in the workbooks or they failed to answer the question written on them. The completion rate is shown in Appendix C for pre-occupancy and Appendix D for post-occupancy. There was a 75% completion rate pre-occupancy and a 54% response rate post-occupancy. This method was chosen to test the willingness of participants to engage in this manner and to alter the forms of data collection throughout the two weeks.

The methods chosen were deliberately more intensive than the traditional observations and questions from psychology methods that are usually utilised to understand domestic behaviours and practices. This was in an attempt to understand the complex formation of the social practices and allow them to be contrasted to those that are present post-occupancy in WGV (139). Many learnings were identified during the first data collection phase that provided the possibility for alterations in the second phase. However, the interview, survey, workbook and probe questions were kept almost identical to ensure research consistency and allow for the emergence of unexpected findings. The text messages and postcards were used to supplement the information provided in the interviews with residents to assess their practices and were not used as the only confirmation source for the performance of a practice.

2.4.2 Case study constraints

As this research is based on the format of a cohort study, control houses were not selected (90). The limited sample size may influence the ability to make broader generalisations about the findings to the larger population but this method does allow for a detailed understanding of domestic practices and how these change post-occupancy in a LCD and this change was a key aim of the research questions.

Without intensive monitoring of the residents, accurate individual energy and water use is difficult to estimate. The author originally divided the household level data by the number of occupants in the household but this resulted in discrepancies with the qualitative findings reported by residents. For instance, household C had 3 adults pre-occupancy, 2 teenage sons and their mother. The individual data showed high consumption levels per individual, however, the interview revealed that the mother had low energy and water consumption levels, while the sons would have long showers, use the tumble dryer, use their computers extensively and leave the lights on. This highlights the intra-home heterogeneity in the performance of practices. To address this, the energy and water use has been analysed at a household level, with comments made on possible intra-home influences on practices.

The design of the research requires participants who would inhabit the WGV development within the timeframe of the research to allow data collection to be undertaken. This restricted some resident’s participation in the research. Some residents who did not have a sufficiently stable housing situation before moving into the WGV development did not want to participate due to the difficulty in gathering data when in a transient situation. This may have reduced the ability to examine differences in practices of affordable housing or low socio-economic residents and additional effort in gathering a cohort of residents in future research should be a focus.

Only 7 out of 14 homes provided complete energy, water and gas consumption data during the first round of data collection, which hindered analysis of their standard HSOP and subsequent comparison to their practices in WGV. This was due to residents not having access to these bills anymore or the difficulty in obtaining these figures from the water and electricity regulator. In Perth, the water bill is divided into payment for water used in the bill period and service charges. Tenants of houses are often only paying for the water used in the billing period and therefore there was a discrepancy in the figures obtained from residents where they were not able to identify which part of the payment was for water used and for service charges. This incomplete data has not been included in the relevant publications, as it does not provide an accurate reflection of household energy and water consumption levels. This has reduced the households with available pre-occupancy data and influenced the extent to which the authors could comment on the possible impact of rebound effects (Publication VI). To address this in future research, studies could apply for access to water and energy meter data for a period pre-occupancy if the resident and utility supplier are willing.

For some residents, it was difficult to secure a time to undertake the structured interview and the two weeks required for the workbook containing the travel and personal hygiene diaries. One interview was conducted during a car ride with the participant to source materials for his house at WGV. One participant reported difficulty finding the time to fill in the workbook and to ensure this was completed, the author arranged a one half-hour timeslot with the participant to fill in the workbook, not discussing questions or answers with the participant, only ensuring it was completed, at the request of the participant.

Other constraints related to participants leaving the case study before the completion of the data collection phases. This occurred multiple times throughout the study, reducing the diversity of participants. One resident interviewed in the pre-occupancy data collection phase did not move into the WGV development and their data was removed before any articles were published. Two other residents who participated in the pre-occupancy data collection phase and had their results included in an article published (Publication V), withdrew before the post-occupancy data collection phase and their results were removed from all other publications before submission. One of these residents did not move into WGV and leased their dwelling instead while the other moved in but withdrew from the research. Two participants who had been residing in the same dwelling pre-occupancy in WGV and were included in Publication V as living in the same dwelling moved into separate dwellings in WGV for the post-occupancy round of data collection. This resulted in an additional house code being created for the remaining publications. Finally, one resident who completed the first round of data collection and moved into WGV, subsequently moved out of the development before the second round of interviews were conducted. As the resident had been living in WGV for over a year, and energy and water data had been collected for 7 of the previous months, the resident decided to participate in the interview and survey phase of the data collection and hence their results are included in the publications. This provided valuable insight into the perception of someone who had lived in, and then moved out of the WGV development and provided a reflection of the influence this had on daily practices and associations with home and community, as discussed in Publications VI through VIII.

Chapter 3 Literature Review Summary

This chapter provides a summary of the literature as reviewed in Publications I, II, III, V, VI, VII and VIII. This section addresses the research question:

What are the theories and methods typically used to understand and influence domestic practices and over what scales do these occur?

In section 3.1, a review of the behavioural and SPT literature at different scales is discussed as has been highlighted through Publications I, II and III. Section 3.2 discusses the academic literature surrounding domestic practices that are discussed in Publications V, VI, and VII. Finally, section 3.3 discusses the research that has been conducted around the meaning of home that supports the research in Publication VIII.

3.1 Understanding Resource Consumption in the Home, Community and Society through Behaviour and Social Practice Theories

3.1.1 Introduction

The reduction of resource consumption in households is considered by many as a cost-effective step towards urban sustainability (140). This section reviews socio-psychology theories and social practice theory (SPT) as well as methods commonly employed to influence occupants in their use of resources. The objective of this article is to discuss how these different theories can be successful to promote sustainable consumption at various scales. The term sustainable consumption refers to the consumption of more efficiently or ethically produced goods where consumers consider environmental and social aspects before purchase (141). Reducing resource consumption to more sustainable levels has been identified as a vital path to address the pressing issues of climate change, over-exploitation of dwindling resources and subsequent environmental impacts (142).

Sustainable consumption may be encouraged through changes in multiple practices including housing, food, waste or mobility practices or individual actions involving energy and water consumption. The reduction of resource use in households is considered by many as a cost-effective step towards urban sustainability (140). Improved building envelope design and technology are known to significantly reduce energy and other resource demands in households, however, they are not the only influencing factors (42,143). Individuals are a key player in making everyday decisions and influencing usage through their behaviours and practices, which in turn are influenced by place, technologies, interpersonal relationships, society and information (75). The implementation of strategies based on behaviour change has been a key approach to promoting resource efficiency in residential buildings. Finding optimal behaviour change methods, in particular, targeting energy conservation has been the focus of research since the 1970s (144). However, traditional socio-psychological approaches to enforcing sustainable consumption have failed to drive society-wide changes which are deemed necessary to limit environmental impacts (3,107).

The ideas behind changed behaviour for environmental sustainability in the home have generally been based on social theories (64–66). Typically, socio-psychology approaches consider cognitive dissonance, social norms, information provision and feedback to instigate change (71). Since human-computer interactions became accessible, scientists have started deploying them on a regular basis for the delivery of eco-feedback and information; this can be referred to as persuasive sustainability (34). This model has been sustained by economists and psychologists and has permeated its way into both the UK and the Australian policy context (63,145). Human-computer interactions are now being deployed in smart technology and homes around the world in an effort to persuade residents to alter their behaviours and practices, and subsequent resource consumption. Change in policy and societal resource use is difficult as policymakers insist that any alternative approaches are translated into the language and terminology that they are already familiar with through behaviour change programs (139,146).

SPT is an alternative theory to socio-psychology and has been prominent in sustainable consumption debates recently. SPT originates in social theory (79) but offers an alternative approach to promoting a reduction in resources consumed. SPT scholars argue that resource consumption depends largely on the practice used to carry out activities (147). A practice is a routinised action that is composed of a number of interconnected elements: meaning, skill and technology (75) (Publication II). In SPT, the practice is the unit of analysis, and change can be made to practice through the alteration of one or more of the elements. The innovation of a product or procedure can, therefore, act as an enabler of sustainability, especially when designed in conjunction with users. This is referred to as non-persuasive sustainability (34), although in our research group we prefer the term enabling sustainability.

Socio-psychology theories view resource consumption as something that individuals use depending on their personal values as well as norms, which are influenced by society. SPT approaches focus on the practices and bundles of practices that resources are involved in when these practices are performed (147). There has been a provocative debate in the literature around the merging of socio-psychology theories with SPT for use in resource consumption studies and policy contexts, termed the Chalk and Cheese Debate (63,148,149). Each theory has its own qualitative and quantitative methods which allude to different conclusions and recommendations (98). In publication I, it is argued that rather than being antagonising theories, both theories have a place when applied within the home space. SPT provides a valuable addition along with socio-psychology theories in understanding the complex dynamics between resource consumption and human actions (150–154).

Sections 3.1.2 and 3.1.3 provide a narrative literature review of socio-psychology theories and SPT respectively, that consider domestic resource use and consumption. A narrative literature review is an established approach to exploring the literature surrounding a topic in both the socio-psychology and SPT domains, allowing in-depth insights to be obtained (90). The search terms used include social practice theory, practice theory, socio-psychology theory, psychology theory, the theory of planned behaviour, cognitive dissonance, social norms, habitual behaviour, habits in the home, and timing of routines. The topics have been further explored through starting with seminal papers and exploring the references as needed. This review is followed by a discussion of the Chalk and Cheese debate (63,148,149) and a review of the position of the literature surrounding the influence of scale and time on the performance of behaviours and practices.

3.1.2 Socio-Psychology Theories

Socio-psychology is the study of people's interactions with the wider society and examines how individual behaviours, thoughts and attitudes are influenced by others; either consciously or subconsciously through social and cultural norms. Several socio-psychology theories have been developed since the 1920s and are still employed today to explain individual behaviour. These theories are frequently used for the development of pro-environmental behaviour change programs and include the theories of planned behaviour, cognitive dissonance, social norms and habitual behaviour. There is often an assumed linear relationship between information/awareness, attitudes and respective behaviours (139) and it is also often assumed in socio-psychological literature that individual change may result in social and resource use change (155).

The theory of planned behaviour predicts that behaviour is preceded by the attitude towards the behaviour (*i.e.* beliefs and evaluation of the outcomes), subjective norms (*i.e.* the perception of the behaviour by others) and perceived behaviour control (65). This means that an individual who is concerned about carbon emissions, for example, might not act to reduce these due to a lack of perceived personal impacts. On the other hand, the likelihood of engagement leading to behaviour change may increase if an individual is consciously supportive of the cause or if the individual simply agrees to take action (156). This is in accordance with the theory of cognitive dissonance which posits that people are uncomfortable to find themselves in a situation in which their attitude and behaviour are inconsistent and will, therefore, make changes towards correcting this discrepancy (64). These adjustments can be made through changing behaviour, changing beliefs or creating new cognitive elements aligned with the behaviour (64). This need for consistency is recognized as an opportunity to encourage behaviour change through triggering individuals' values and self-concepts, effectively making them aware of potential dissonances (157).

Whilst personal values and beliefs affect people's behaviours, individual conduct is also influenced by the behaviours and judgment of the wider society. These unspoken social rules are referred to as social norms, which are of two kinds: descriptive and injunctive (66). Descriptive norms define what the customary behaviour is in a given situation. Injunctive norms, on the other hand, prescribe how one should behave either by approving or disapproving of the behaviour. For example, a study on littering showed that people are more inclined to drop litter in littered locations. In contrast, clean environments tend to remain unlittered for longer periods of time (66). Social norms are even more effective when encouraged by a peer in the form of social intervention (158).

The theories of planned behaviour and cognitive dissonance consider individuals as purely rational, evaluating outcomes as well as the costs and benefits of certain decisions, however, daily habits can prevent long-lasting change (159). Habits are prompted to meet a specific goal and if the goal is met in a satisfactory manner, the tendency is for individuals to repeat the same behaviour on the following occasion when the same goal is being sought (70). Repetition requires less mental effort, which can lead to unintentional habits forming and once habits are established, future actions are likely to be guided by them, regardless of values, attitudes or norms. Due to the unconscious nature of habits, habitual behaviours are only reviewed when provoked or in the event of a change in context (159). This change in context for modifying behaviours is also what SPT advocates as a way to influence resource consumption.

Most interventions from socio-psychology theories fall into three categories, referred to here as social, technological and knowledge-based interventions. Social interventions involve some form of social interaction, such as face-to-face meetings, audits or workshops. Unilateral impersonal communication such as letters, emails, bills or marketing campaigns have been categorized as knowledge-based interventions. Technological interventions are methods that rely on technology and do not involve any kind of social interaction. That is, in-home displays (IHDs), websites and automatic messages which deliver feedback, norms, prompts and goal setting. IHDs can break down energy usage by the appliance and show energy consumption in different formats, catering to different audiences while providing real-time and long-term feedback. Some researchers argue that this method enables the interaction of households with the data and therefore higher engagement (160) and appliance control (161), leading to a significant reduction of electricity consumption (162,163). However, arguments against the deployment of IHD's focus on the fact that displays are designed by researchers and do not necessarily correspond to what the user wants to see, reverting to the background situation after a novelty period (34). Brynjarsdottir and colleagues argue that this technology is trying to persuade the user to change rather than providing solutions to change (34). In addition, the deployment of IHDs to influence behaviour assumes that the user has previous knowledge of interaction with this technology and that the user makes this part of everyday practice. Ongoing research concentrates on how to improve IHDs;

however, there are marked differences in individual use even within households so a one-size-fits-all approach seems hard to design (163–165). There appears to be a level that residents reach in their behaviour changes influenced by the IHDs after which more change is resisted because it disrupts routinised practices in a way which is uncomfortable or unworkable (164,166).

3.1.3 Social Practice Theory

SPT was proposed in the early 2000s as an alternative to socio-psychology theories (35,72,168,73–75,79,80,83,84,167). SPT posits that the world is populated by social practices and their interconnected elements (145). Human behaviour is not the result of rational choice but of the many half-conscious and highly routinised actions people take in their everyday life (169).

Individuals do not use resources such as water or energy directly, but rather with the objective of achieving a desired social outcome; an everyday practice such as cleaning, shopping or dining. In order to understand domestic resource consumption, it is therefore important to comprehend the practices involved in achieving daily objectives (150). SPT views practice as the unit of analysis, being one of the mundane activities that make up most of our daily lives such as cooking, cleaning, laundering, personal hygiene and keeping thermally comfortable (170). Practices are formed by three interconnected elements: technology, skills and meaning (Publication II & III). Technology is the artefacts that are used in the performance of the practice, skills are the know-how or competencies necessary to execute the practice and meaning is the understanding, assumptions, values and symbolic meanings associated with the practice, including the attitudes and feelings (171). A change in practice can be achieved by altering one or more of these elements. The three-element model has been praised for its effectiveness in examining all the elements of practice, including non-human, material elements; different forms of intellectual and embodied knowledge; and cultural differences (172). This allows for objects to be studied at the same ontological level as individuals, without the individual being the principal unit of analysis as it is in socio-psychology theories. Practices are social in the sense that they can be shared by many different individuals, through connected elements of meanings, technology and skill even if they are in different locations or across different time spans. It is through the repetition of practices that they become embedded in everyday life (36,173). SPT moves beyond the single behaviour analysis of socio-psychology and examines the relationships between practices and their existence across space and time (147) (Publication II & III). Practices can interlock with others to form bundles of practice or systems of practice (SOP) that can have socially shared knowledge, meaning, skills or technology (57,73,76). This occurs when there are multiple practices taking place at the same time or in a similar order, such as a morning routine of having a shower, making breakfast and driving to work in the same way each workday. When multiple SOPs exist in the space of the home, this can be termed a Home System of Practice (HSOP) (Publication II, III & V).

Everyday practices have a dynamic nature because as technologies, infrastructures and meanings change over time, existing social practices become obsolete and new practices become embedded in new routines (77). Modern technology may influence the way a practice is performed. For example, capsule-based coffee machines imply that consumers buy the manufactured coffee capsules for the coffee making practice (98). Consumption is interwoven in practices as a by-product of undertaking the practice and can be hard to change due to their habitual and interlocking nature (73,146,174). SPT argues that change in practice should occur through three main ways: a change in an element of the practice; disconnecting a practice from its interlocking counterparts or bundles, or inserting a new practice entirely to replace the old one (175).

A change in an element of a practice could be through changing the meaning (altering the need that an individual aims to fulfil and how this relates to their perception of their lifestyle, comfort and wellbeing); changing a skill (through education and training) or changing the technology used to carried out the practice (through the introduction of new technologies). This also applies to sustainable consumption practices (107,175). Skills or meanings may be learnt or influenced through changes in context (*e.g.* visiting a local farmers market instead of a supermarket to purchase food), and technology can be modified to reduce the use of resources (*e.g.* low-flow showerheads instead of regular ones) (Publication VI). It is posited that it is the realm of changing the meaning element that socio-psychological theories have an opportunity to share insights with SPT.

In the context of the home, changes in resource consumption have often been studied for individual practices (13,22,183,171,176–182) (Publication VI). However, individual practices form part of the HSOP and should not be targeted in isolation. The HSOP is a network of the practices performed by home occupants on a daily basis forming part of a routine (Publication II). Routines, composed of practices which are reproduced in a sequential manner (*e.g.* shower, breakfast and drive to work), overlap and interlock with one another (Publication II & III), creating a home equilibrium (Figure 3.1a). These practices have specific temporal and spatial characteristics (89), which means that when performing a practice in a specific location such as the home, occupants must consider other occupants' own practices and routines so as to coordinate them from space and time-space perspective. For instance, the practice of showering is dependent on the shower being unoccupied at a particular moment in time.

Intervening in the HSOP to alter resource consumption can be done through changing an element of the practice as previously discussed; however, this requires all occupants to adopt the change. The introduction of new practices (*e.g.* checking an IHD) require established routines to become destabilised (Figure 3.1b) and realign, finding a new equilibrium (Figure 3.1c). Unless a realignment of everyday practices occur, new practices might not become embedded in the HSOP and fulfil a specific role. Consequently, the home occupant might not adopt them.

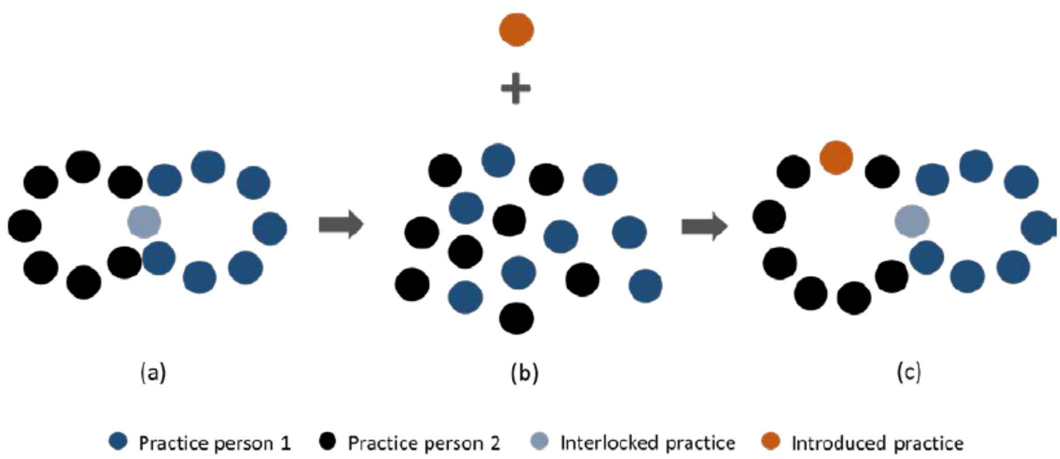

Figure 3-1 Equilibrium of practices in the home. (a) Original home equilibrium; (b) Destabilisation of the home equilibrium through the introduction of a new practice; (c) Realignment of practices and establishment of a new home equilibrium (Publication III).

Encouraging resource reduction and efficiency can help to promote sustainable consumption, but this encouragement assumes that behaviours are static over time and are the result of conscious customer decisions and available technology (147). It also ignores the often surprising links between seemingly unrelated practices (150). SPT is useful for targeting inconspicuous practices and those that are deeply rooted in the normal living behaviour of individuals (150,184). Practices are dependent upon the institutional arrangements, household context, economic influences and cultural traditions of the environment that the practice exists in (35). Hence, the scale implications of practices and behaviours need to be considered when discussing their influence over resource consumption. The reproduction of practices and their proximity in space and/or time influences their degree of interlocking (175) (Publication II & V). Consecutive practices that are part of a daily sequential personal routine are highly interlocked. For instance, morning weekday personal showers are highly interlocked with the practice of breakfast, which is in turn highly interlocked with the practice of transport to work. It is posited (175) that practices are highly interlocked when they occur at a similar time and at the same place (Figure 3.2) (Publication II, III, V). For instance, person 1 (P1) having a personal shower in bathroom 1 will influence person 2 (P2)'s shower in bathroom 1 if it is carried out at a similar time because P1 and P2's showers are limited by P1 and P2's own interlocked routines. Practices that occur at different times and in different places may not show the same degree of interlocking. Practices may be lightly or indirectly interlocked if they occur at the same time but in different places. For instance, the water heating technology may not work if P1 and P2 have personal showers at the same time but in two separate bathrooms, indirectly interlocking the two showering practices. Conversely, practices that occur at the same place but at different times may also indirectly affect each other.

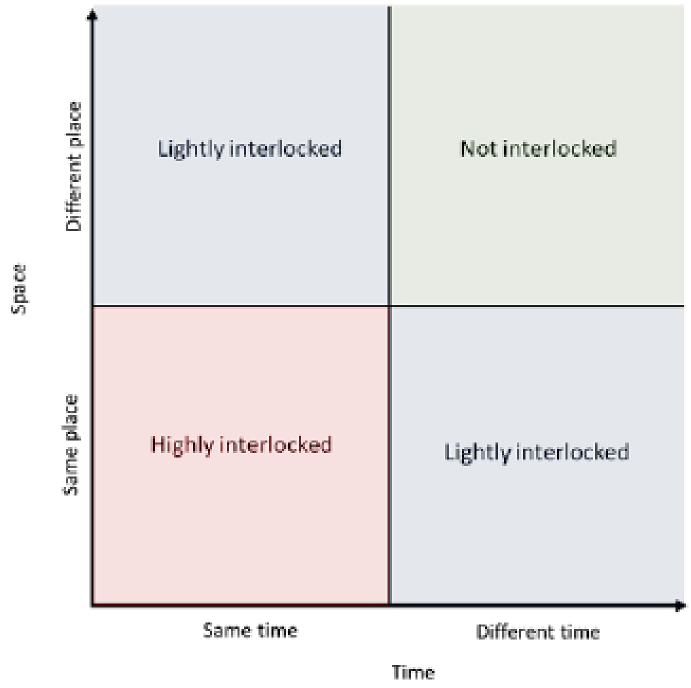

Figure 3-2 Interlocking degree of practices according to their reproduction in space and time.

3.1.4 Chalk and cheese debate

The merger of SPT with other theories has been attempted previously (185–188); these attempts focus on the individual and use SPT to deliver unique insights into daily practices. For instance, researchers have sought to merge theories of governmentality and SPT (189) to produce complementary insights bridging some of the weaknesses found in each of the theories. However, the latter approach has been either top-down or too focused on mundane daily practices to result in workable policy insights. Social practices have also been examined alongside transition theory, utilising an understanding of the multi-level perspective to place practices at different socio-technical levels (190–192). Building end users have been examined through facility management and SPT (193). Some of the founders of contemporary SPT including the research of Foulds and Macrorie utilise sociotechnical systems to understanding everyday practices (194,195). However, the merging of socio-psychology theories and SPT has been a focus of disagreement termed the chalk and cheese debate.

Shove in her original (2010) article argues that psychological or behaviour change models have received too much engagement by policymakers and this has resulted in ineffective resource consumption policies being implemented (63). The argument is made that psychological theories are confusing because while they posit that there are many factors influencing behaviours, they also claim that behaviours are deeply embedded in social situations, institutional contexts and cultural norms, locking consumers into particular habits. Shove (63) outlines that the Attitude- Behaviour-Choice (ABC) model of policymaking (based in socio-psychology) has failed because of the value-action gap between individuals' reported environmental values and their behaviours. Shove also argues that the ABC approach fails to take into consideration the practices of everyday life that affect the resources used by consumers (63). According to her, behaviour change theories are based around the incorrect assumption that social change is dependent upon values and attitudes which drive the behaviour that individuals choose to adopt (146).

In rebuttal, Whitmarsh and colleagues argued that the dismissal of psychological models is ill-conceived (149). They also note that other authors (196) refer to the C in the ABC as context rather than choice. Context considers the broader situation that the individual is situated in while choice focuses on the individual state of mind and actions. Indeed context is vital in understanding social practices as it influences the elements of a practice and how technology is used (163).

Finally, Whitmarsh and colleagues argue that if a pure SPT approach was to be incorporated into policy, individuals would run the risk of being excluded from societal decision making and participation, due to the focus of analysis moving to the practice itself, instead of the individual and their state of mind (149).

In response, Shove (148) argues that the two schools of thought have fundamentally different ontologies. The SPT ontology is that the world is populated by social practices and their interconnected elements, while socio-psychology theories are focused on individuals and their behaviours (145). While we acknowledge this to be true, we do not discount the usefulness of both theories in providing insight into resource consumption patterns and practices of individuals, homes, communities and societies (197). In fact, researchers are beginning to incorporate these theories into new models. Nevertheless, they require more empirical evidence to determine their success in reducing domestic resource consumption (155,198). The theoretical differences between the two schools of thought are less relevant when considering interventions and policy recommendations (199).

The following section examines the different scales for application of these two schools of thought, whereby the socio-psychological approach can offer useful insights for influencing the meaning of practices and SPT can offer insights into the material and technical structures that constitute practices (199).

3.1.5 Research on space and time insights

Human choices are dependent upon the conditions under which the choice is made; these choices have temporal and spatial dimensions (146). This was identified early in the SPT literature by Schatzki, stating that practices are both anchored in and dispersed across space and time (79). We posit that insights from behaviour and practice theories have different roles based on the temporal and spatial dimensions they are being employed in. Practice insights can result in almost immediate changes in the way that a practice is performed (for instance, if adopting a new technology), while behaviour insights often entail a longer-term cultural and societal shift (as it requires a shift in values and social norms) and can target the meaning element of a practice.

Scale is an important consideration in the study of practices and behaviours. Practices depend upon individual performances for their continued survival and it is individuals who carry and integrate the necessary skills and knowledge that make each performance possible (80,150). Practices are often nested in each other and have complex relations in the SOP. Practices are dynamic and mobile through their reproduction as performances and as such, exist in varied temporal and spatial locations. This has also been termed time-space whereby space is simply a place to carry out particular activities or practices at a certain time (200). By focusing on the actions of individuals rather than the individuals themselves, SPT brings aspects of space and time to the forefront of the decisions of everyday life (201). SPTs have been critiqued for focusing more on the performances of practices rather than the mental or emotional state or events. Socio-psychology approaches can fill this gap by directing attention to the values, norms and mind frame of individuals when they are engaging in the performance of an action (98,202).

In the SPT literature, practices are referred to in two different states; a practice-as-entity is a practice that endures over space and time and is composed of the three elements (*i.e.* meaning, technology and skill); while a practice-as-performance is when the elements are brought together and are different each time because of the context (203). Practice-as-performance can be used to collect data on activities and resource consumption for analysis while practice-as-entity is used to sketch patterns of historical development and understand the context (139). Behaviour change insights may be suitable for influencing practice-as-entity, whereas the practice-as-performance may be more targeted through SPT insights such as changes to the technology or skills used to perform the practice.

Practice insights should also consider the context in which they are being performed, this relates back to the chalk and cheese debate and the role of the C in the ABC method: context or choice. Context is vital in understanding why a practice may be performed the way it is: people may choose to cycle to work because driving takes too long due to traffic congestion, not because of environmental concerns (199). SPT provides this insight through considerations of meaning, while socio-psychology insights may miss this reasoning altogether if the context is not considered, although in some research it is (199). Recent work has examined the material (or technology) element separately from the practice and discussed how the materials used in a practice influence the space and time that the practice, and other practices, are performed (204). Engaging in one practice rules out an engagement in another at the same time and can then influence what practices are performed when and in what space (84). It has been suggested by multiple researchers that to instigate change, the focus needs to be placed on the junctions in space and time that constitute opportunities for change and innovation (51,89,99,175,176,205). This may occur at times such as moving house, targeting new technology being installed or new communities that can influence social norms (Publication II, III & V).

Research on the different spatial aspects of practices has included those of travel, eating and recreation (168,206). Due to changes in technology, the daily commute now involves many different practices that previously would have been performed at home or work. These include reading, writing, making phone calls, homework, self-care, drinking and eating (207). Socio-psychologists have studied the habitual routine of travel choices and how to influence these through choice option, information and situational cues (208). Those who have a strong habitual routine in their travel practices are less influenced by information and cues, however, habits can be broken through manipulating accountability demands or the level of attention paid to the actions of the behaviour. The physical infrastructure used for mobility can influence what choices people make in how to perform a practice. For instance, a high degree of car road networks and poor public transport options can influence the frequency of which travel practices are performed in a car (209).

The timing of the performance of behaviours and practices is a pertinent topic in relation to resource consumption, particularly in the home (99). Recent work in the SPT literature has brought the temporal aspect of practices under analysis. Time is socially constructed, meaning that the distinction between weekday and weekend is entirely attributable to the framework of time as designed by the society in which we are living in (89). The key concept is that some practices demand a fixed location within daily schedules and/or temporal organisation (84). The temporal placement of the actions and the associated network of relations that surround it, as investigated in socio-psychological theories, influences individuals actions (205).

Peak loads of resource consumption in households are associated with different forms of synchronization, or particular behaviours and practices being performed together (84,210), as well as meanings and values associated with convenience and control in daily life (176). For instance, the time patterns of energy consumption in households are closely related to the temporal patterns of the daily practices of the households (89,176). Energy consumption practices performed in the 17:00 to 21:00 evening time-slot contribute to the peak energy demand (114). With the rise of renewable energy, there is now an uneven temporal distribution of domestic energy demand (211). People demand energy at specific times of the day and not necessarily in line with when this is being produced by renewable sources. Residents may also be unwilling to alter particular practices even if it would change their resource consumption (such as having shorter showers (Publication V & VI) or use less energy in the evening (163). Recent studies have examined this further, finding that washing has the greatest time dependence in practices each week, being performed at a regular time by households, while using computers is the least time-dependent (89). These findings can be used to develop interventions into resource consumption of both individuals and households.

3.1.6 The home, community and societal scale applications

Individual behaviours and practices are often studied *in-situ* as this provides an easier contact point for the researcher. However, these actions do not occur in a bubble, devoid of contextual influence or never being performed in different locations (89). Practices and behaviours tend to cluster together in particular places, being performed by many people in similar ways (89). These can be based around the home scale, the community scale and the social scale. Other authors have referred to these scales as the individual, inter-personal networks, community, segments and population (14). Inter-personal networks are close networks of people such as families, households or social groups. Community spaces are where people share values or activities that identify them closely with one another. This can be linked to ideas of a community of practice (150,212) where communities are the site of learning by individuals (12). Interventions are applicable for each level, taking advantage of social connections, temporal elements and domain influences over a behaviour being studied (14).

To create long-lasting change in favour of sustainable consumption, we propose that all levels of society need to be targeted. The schematic in Figure 3.3 outlines how we propose SPT theory and behaviour change theories can best be applied at different scales. Practice insights can be used to achieve quick changes in a specific physical space (*e.g.* the home) while conserving established routines and respecting the HSOP where multiple individuals interact. This can be obtained through the implementation of technology that does not interfere with the timing or order of practices. Behaviour change, on the other hand, requires a shift of societal and cultural norms to be effective. Values and norms driving individual behaviours are usually present at all levels of society and are independent of space and time.

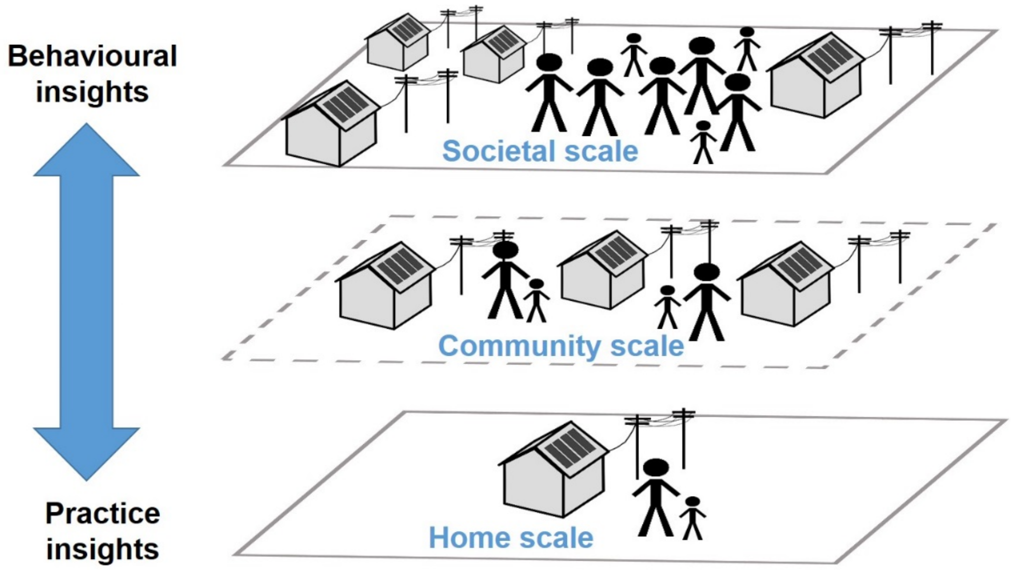

Figure 3-3 The different scales that behavioural and SPT insights can be best targeted.

3.1.7 Conclusion

The significant challenges posed by climate change and overpopulation require an understanding of resource consumption across all scales of society. Policy implications should consider the reach and durability of various interventions targeting the reduction of resource use (*e.g.* energy, water, materials) if they are to be applied effectively (13). Persuasion and enabling methods are usually not aligned in behaviour change studies as they are seen as two distinct methodologies. We argue that they are in fact trying to achieve the same objective, which is to reduce resource consumption in households but approaching it through different angles. On the one hand, socio-psychology uses persuasive methods to address personal energy use from a top-down approach, delivering social norms and providing information; on the other hand, SPT's enabling methods are very focused on the elements of a practice that are utilized in the performance and addresses consumption from a bottom-up approach. Rather than being conflicting methods, the two schools of thought complement each other, filling each other's gaps, informing and modifying attitudes while enabling long-term changes that bring value to the user.

The timing of the action is key because the practice or behaviour is limited by the context and influenced by other concepts such as comfort and convenience. Given the complexity of the home system, this section suggests that rather than disestablishing, realigning and recreating interlocked connections and practices, automated technologies and design changes could enable improved resource efficiency. Automated practices can function at flexible times and operate only in conformity with the house technologies, not the individual. Yet, they are still required to meet occupant needs and skills to be able to work effectively.

Socio-psychology theories have traditionally informed resource reduction in households from a user point of view. Their aim has been to modify behaviour by changing existing attitudes, knowledge and values without necessarily understanding the reasons behind existing behaviours, but rather focusing on the use of persuasion to promote change. Consumers should understand the implications of their actions and adopt a positive attitude towards resource consumption; but changing behaviour may involve perceived lifestyle impacts or change of embodied habits that require high levels of commitment which may, or may not, be feasible in everyday life. Studies testing the long- term effects of socio-psychology interventions suggest that the effects of most persuasive behaviour change methods last only between a few days and a few years, stopping as soon as making changes becomes too difficult, disruptive or loses the novelty effect. SPT offers an alternative approach to close some of the gaps found in persuasive interventions through investigating what drives people's practices and the reason for certain behaviours; that is, what and who is influencing the user in question. As highlighted by SPT researchers, people do not consume resources as such, but resources are used during the performance of a practice. Technologies used to achieve these practices are therefore a key part of the practice and have a direct impact on resource use. These changes can be effectively applied at the scale of the home to drive resource change. Insights from socio-psychological theories can be best applied at the community and society scale where changes to values and social norms, along with information diffusion and education can drive long-term change. Understandings of communities of practice and change agents from the SPT literature can assist in delivering interventions.

Having an understanding of what drives practices and behaviours at the individual, home, community and societal scale allows the focus of policymakers to be on designing and implementing effective interventions that will enable sustainable consumption in society. It also enables designers of new technologies to focus on the material elements and skills that can assist users to make permanent changes rather than just convince them that change is necessary.

3.2 Routines in domestic practices

Knowledge of how residents routines relating to various domestic practices emerge, develop and change provides an insight into sustainable consumption (36). This section will discuss reported research relating to the domestic practices studied in this thesis: personal hygiene, thermal comfort, travel, waste management, purchasing, food, laundry and garden watering practices. These practices are discussed across publications II, III, V, VI, VII and VIII in the thesis.

3.2.1 Personal hygiene practices

The most water-intensive practice indoors in Australian homes is personal showering, accounting for 25% of total water use in the home (45). The practice of personal hygiene has changed routines and elements substantially in the last few centuries (180). Originally reliant on buckets of water and heating over a stove, larger bathing containers and the advent of heated water plumbed to the house changed the skills and meaning related to hygiene practices (180). Changes in building design, technologies and social expectations have resulted in showering being the dominant form of performing this practice in most developed countries, showering may now be performed once or even twice a day (180). In Australia, a seasonal change in the length of a shower has been found to occur, with the average shower in summer being 6 to 6.2 minutes in length, while in winter this increases to 6.6 to 7.2 minutes in length (22). Previous research has shown that there are many reasons for undertaking personal hygiene practices including for refreshment, cleanliness, relaxation, warmth or social expectation (213). Freshness can be viewed as a state of mind that is related to the action of refreshing the body with water or changing clothes, while cleanliness is related to the removal of bodily contamination (82). Other ways to perform personal hygiene practices are through a bath, towel washing or swimming in the ocean or a lake (39). With the inclusion of personal hygiene practices into daily household routines, competing practices such as sleep, gardening, exercise, cooking, school and work can have the most influence on the time taken and allocated to these practices (62,213).

3.2.2 Thermal comfort practices

In Germany, household energy use studies collated by (56) found that for households designed for low-energy use or through passive design, the measured energy use was above the expected output. The highest energy-related practices consist of cooling and heating, using approximately 40% of the total energy use in the house (46) and generating 16% of operational greenhouse gas emissions (31). With the increase in the floor size of the average home, subsequent increases in energy have been found for heating and cooling (16). Some households already practice energy-efficient ways of keeping thermally comfortable through non-auxiliary means such as using blankets, clothing, drinks or opening and closing windows and doors (214). However, some research has found that due to social norms and expectations of comfort, residents will use auxiliary heating and cooling technology when visitors are over (215). Lower-income households have been found to use less energy overall for economic reasons (16). Some previous research has found that thermal comfort practices using air conditioning occurs at particular times (89,176). Energy consumption practices performed in the 17:00 to 21:00 time-slot contribute to the peak energy demand (114). With the rise of renewable energy, there is now an uneven temporal distribution of domestic energy demand whereby the demand for energy is not in line with the time of production. Solar PV and storage systems are required to take advantage of this electricity without exporting it back to the grid (120,211).

3.2.3 Travel practices

Travel practices have been defined as a consumption of distance practice, however there has been a lack of temporal and contextual studies into travel practices (38,216,217). People’s travel practices, and the elements associated with that practice, change. Travel behaviours or practices are largely habitual, embedded within daily routines and dependent on particular structural and locational factors (218). Changes in these practices require subsequent changes in many daily practices that are interlocked with travel such as shopping, work and social interaction (219). For many, the car is the dominant mode of transport for a range of activities, leisure, work and holidays (216). Cars are flexible, immediately on hand, don’t need permission from others for use or need purchasing of tickets (209,216). Travel practices are interlocked with other practices and have powerful space and time-dependent interactions (216). People walk from their home to visit close friends or family or as part of a work journey (216). This encourages social networks to overlap, with quick, casual meetings. People can hold ambiguous and sometimes contradictory views of walking and cycling as an effective means of travel, which results in discrepancies between what they do and what they believe (220). Factors such as being able to have multiple stops in a trip *via* a car, safety whilst walking or being sweaty after cycling influence people's travel mode choices (220,221). People understand the health and environmental benefits of walking and cycling but often find these hard to fit into their daily routines unless they have structures in place such as the end of use facilities and lighting that counter the barriers (220,222). There has been a lack of temporal and contextual studies of mobility practices (38,216).

3.2.4 Waste management practices

Each household in Australia is estimated to produce almost 1.5 tonnes of waste per year producing a total of 12.4 million tonnes. (223). In Western Australia, this is slightly higher at 1.6 tonnes of waste per capita, with state targets to increase recycling rates to 15% by 2020 (224). Household waste consists of organics (46%), paper and cardboard (27%), metals (14%), glass (10%), plastic (2%), and rubber, textiles and other (less than 1% each) (224). Recycling rates are high for households, with 97% recycling paper, cardboard, metal, plastic and glass through curbside collections (223). 23% of Australian households compost food waste, however, the average Australian household throws out approximately (AUD) $616 worth of food each year and over 80% report this as a concern leading to feelings of guilt (223,225). This equates to 15.9Mt of CO_2 emissions annually (225). There are many benefits to composting including extending the lifetime of landfill sites, mitigating greenhouse gases and creating a useable product (226).

Larger scale studies at a neighbourhood or city scale reveal differences in recycling practices at a household level. This is driven by differences in household practices through perceptions and social norms of convenience, disgust, cleanliness and environmental and health concerns; the skills to perform waste management practices include knowing what can be recycled or composted and how; and the technology to do so through indoor and outdoor garbage bins, and associated curbside collections or uses for composted materials (181,227). Both structured recycling systems and recycling efforts by members of one's social or neighbourhood circle have been found to increase recycling rates (228). However, current barriers to greater recycling in Perth include an undeveloped market for recycling organics and a lack of customer awareness on the benefits of recycling organics. Vague goals such as saving the planet, do not engage with relevant social practices or give people a chance to perform new practices, unless they also take account of the practices skills and technology in the performance (13,227). Structured recycling systems and other members of one's social or neighbourhood circle recycling have been found to increase recycling rates in both behaviour and social practice based research (13,228).

3.2.5 Purchasing practices

Purchasing practices can be divided into two segments: purchasing of major household goods and services (automobiles, household appliances) and green consumerism (purchasing practices that consider the environmental impact of the product) (196). It has also been found that low-income households generally use less natural resources in their homes (27). Previous studies have examined purchasing practices through tracking individual items such as light bulbs (229), single-use spoons, reusable water bottles and washing machines (230). These studies have found that consumers with environmental impact or efficiency information available for a product at the time of purchase will have this influence their purchasing decision (230) and that many low-income households will use goods for as long as possible before replacement and will often buy products second-hand, particularly clothing (27). Moving home often coincides with purchasing new modern appliances, influenced by the size of the home, spatial layout and beliefs around moving home being a fresh start with a preference for new items (231–233).

3.2.6 Food practices

Food consumption is responsible for significant environmental impacts and a greater understanding of the meaning around food practices is needed (187). One's relationship with food can change due to having a new kitchen, resulting in new skills, technology or meaning being applied for cooking and eating. This influences the practices and can increase their frequency if this is positive, or decrease if people are not satisfied with the kitchen or dislike some appliances (231). The food practices based in the home also influence how often, where and why people eat out, which can be spontaneous or conscious decisions to streamline their daily lives and for convenience or reward (234). The food practices of bulk shopping and cooking are popular household food practices but depend on many other factors such as time, money, transport options, other events and the technology and skills to do so. Bulk shopping is popular with households with highly interlocked practices and where the households have other time-competing practices requiring their attention such as work, children or social events (186). Bulk cooking is popular with residents at weekends to minimise the time spent on food preparation during the week (235). However, households that only have small fridges or freezers to store food are restricted in their food practices and when a change occurs in a practice element, such as purchasing a larger fridge to store more food in it, this can free up time for other practices during the day and week (236).

3.2.7 Laundry practices

After water use in the bathroom, laundry practices use the largest amount of water in household practices across Australia (48). Laundry practices are made up of a series of dispersed actions throughout the day: from gathering laundry that needs washing, allowing this to run a cycle in the washing machine, to dry on the clothesline or tumble drier, to collecting and storing the laundry (237). This makes laundry practices similar to travel practices in that they are linked together and coordinated with other activities but are also highly energy and water intensive practices, strongly influenced by changes in technology over the decades (207). Laundry practices are time and effort consuming as well as water, chemical and energy-consuming (36). There are many influences on the performance of laundry practices: the weather, availability of clothes or linen that can be washed together, and the available time to undertake the practice (238).

Over the past few decades, there has been an increase in the number of washing loads households perform each week due to the types of clothes people wear, the number of, and the type of, fabrics of which they are made (167,214). There are also a number of studies of household laundry practices in the social practice theory literature as it was one of the first practices to be examined in the household by theorists. Laundry is now seen as a process of clothing care to meet societal expectations of personal hygiene and dress standards (128). There is a strong reliance on the domestic washing machine to clean clothes as opposed to hand washing in the past (167). The change in technology has made it easier to wash sheets and towels more frequently for hygiene reasons while wanting to wear fresh clothes every day has been found to be positively associated with the number of wash and dry cycles that occur (179). There is a need to understand why people wash their clothes before policies or technologies that influence laundry water or energy use should be implemented (239). If people are washing clothes for hygiene reasons or presentation reasons, there may be other ways that these results can be achieved without the traditional washing machine approach to laundry (239). One study in the UK found that most residents do not use a tumble dryer as they perceived it to be wasteful, however when they moved into a passive house, they were not able to dry their clothes on clothes racks inside because it influenced the relative humidity of the house and they instead had to purchase a tumble drier (231). As the equality of work participation for women and men in society rise, laundry practices have moved from being performed on weekdays to mostly being performed at weekends (211). There has also been an increase in laundry being performed in the early morning due to the demand for other practices such as children's sporting activities, shopping or visiting friends during the day (211). Laundry practices were traditionally tightly interlocked (240), however, there has been some loosening in the time an individual actually performs the laundry practice due to technology. We are no longer required to hand scrub and rinse clothes for hours each week, instead we place them in the machine and can engage in other practices while the clothes are being cleaned. The same applies to drying, both on a clothesline and in a tumble drier (176). Using automatic timers can assist in displacing these practices in time even further (176).

3.2.8 Garden watering practices

The most water-intensive practice in Australian homes is garden irrigation representing 39% of the total water use in the home (45). In some Perth areas, this can be as high as 56% (19). Home gardens are an important feature in the home and represent an extension of the living, entertaining and recreational space for family members (19,241). Increases in the size of urban house blocks have also influenced the amount of lawn or garden that requires regular watering (19). There has been minimal research investigating garden watering social practices in the literature, however, some research has found that during English and Australian droughts in the 2000s, water restrictions on watering days or sprinkler restrictions had some success in reducing the performance of these practices and subsequent water consumption (241). The amount of time spent in the garden and watering is influenced by the demand of other daily practices and can be seen as a burden by some people who are happy to reduce these practices when cultural norms or regulations influence water consumption (241). Renters or those living in a strata complex may have limited say over their garden watering practices if they are not part of the owners corporations or the landlord has stringent requirements for garden maintenance (16).

3.3 The meaning of home

This thesis also contains research related to the meaning or emotional landscape attributed to home by the case study residents. There are different perspectives of the home advocated through the literature that has provided succinct overviews of the research undertaken and it is not the intention here to repeat this work, what follows is a condensed summary (124,242–246). A selection of these aspects has been compiled in Table 3.1 to highlight the recent literature. A home is a feeling, a sense of comfort, of belonging and not necessarily a location, one can live in a house and not feel at home (246,247). The physical attributes a home provides (security, a place to raise a family, a place to perform activities, and one of ownership) were the primary attributes of a home in the literature pre-2000. Inclusion of other aspects in the meaning of home to reflect the social and personal space it provides has been undertaken by multiple authors since (244,248,249). The literature has concluded that housing that provides both material security and an emotionally stable environment are key desires for people, but particularly those who have faced homelessness and involuntary housing stability.

Table 3-1 A selection of aspects of the meaning of home from reviewed literature and the elements that relate to social practice theory (Publication VIII)

Aspects of home	**References**
Security and safety	(243,248–255)
A place to raise children and have relationships over generations	(124,178,256,257,243,244,248,250–252,254,255)
An asset, a place to own	(249–252,254)
A place to spend time and undertake activities	(124,251,254–258)
A place for privacy, a haven and being away from the world	(243,244,248,250–252,257,259)
A place to do what you like in, a sense of control	(124,178,258,259,243,248,250–254,256)
A reflection of one's ideas, values, identity and emotional landscape	(124,178,258–260,243,244,248,249,251,253,254,256)
A site of consistency and permanence	(124,243,244,249,251,252,254,255,258)
A site of engagement with community/neighbours	(244,248,253,255)

Chapter 4 Results summary

This chapter provides a summary of the results from publications II, III, V, VI, VII and VIII, addressing the research questions for this thesis. The full publications can be found in the appendices following this exegesis. Section 4.1 posits the home as a system of practice (Publication II) and discusses the implication of this for influencing energy consumption in the home (Publication III). Section 4.2 investigates the HSOP of the resident's pre-occupancy in WGV and comments on the degree of interlocking of domestic practices influencing resource flows (Publication V). Section 4.3 analyses the energy and water consumption of household's pre and post-occupancy in WGV and investigates the domestic practices related to these (thermal comfort and personal hygiene) and how they have changed (Publication VI). Section 4.4 analyses the changes that have occurred (or not) to resident's other domestic practices and the HSOP once they have moved into WGV and comments on the influences of these on household routines (Publication VII). Finally, section

4.5 discusses the resident's motivations, perceptions, expectations and experiences of establishing a home in the WGV development (Publication VIII).

4.1 The home as a System of Practice and its influence on domestic energy and water use

This section aims to answer the following research questions:

Is there a home system of practice (HSOP) and if so, can it be influenced to enable the reduction of resource consumption in domestic practices?

To answer this question, an extensive literature review was conducted, as outlined in Chapter 3.1. Subsequently, the results of a Living Laboratory case study conducted by a research colleague were analysed to see how domestic practices form a system and how they may be influenced (Publication II and III). The case study involved eight households located in Fremantle, Western Australia, each with a NatHERs rating of 6-Stars or above, classifying them as low energy or high-performance houses (109). The resident's energy and water data were tracked for two years over 15-minute intervals, combined with two semi-structured interviews of residents to discuss the influence of their routines and practices on resource use (109). In the second year of data collection, a persuasive behavioural change program was implemented in an attempt to alter the resident's practices. This took the form of an electronic dashboard containing household energy and water consumption levels, monthly reports on usage and seasonal behavioural tips to encourage change to less resource-intensive practices (183). A selection of the results relevant to this thesis is discussed below. Firstly, the practices of personal showering and thermal comfort were investigated to determine the way the practices are performed in each household. Secondly, these practices are discussed in relation to the HSOP. Finally, there is a discussion on how to influence practices in the HSOP to create long-lasting change.

4.1.1 Everyday practice

4.1.1.1 Personal showering

To assess the practice of personal showering, histograms representing the distribution of personal shower lengths were created and frequency curves fitted to represent the individual shower events (Figure 4.1). These results show that personal showers follow a routine pattern for the length of time during weekends and a similar pattern at weekends. The right skewness of the lognormal curve suggests that personal showers do not or cannot become significantly shorter than they are currently. The interviews with residents uncovered that the showers are taken for different reasons or meaning during the week compared to the weekend. Early morning showers are usually shorter than later showers because there are other demanding practices requiring attention in the morning for residents, while at the end of the day they have more time for a shower. This supports the literature stance that different meanings will result in different lengths of showers being undertaken (180,213), however, the longitudinal study format highlights the routine nature of this practice in daily lives. Accordingly, significantly shorter showers are unlikely to occur unless the skill or technology elements of the practice are modified.

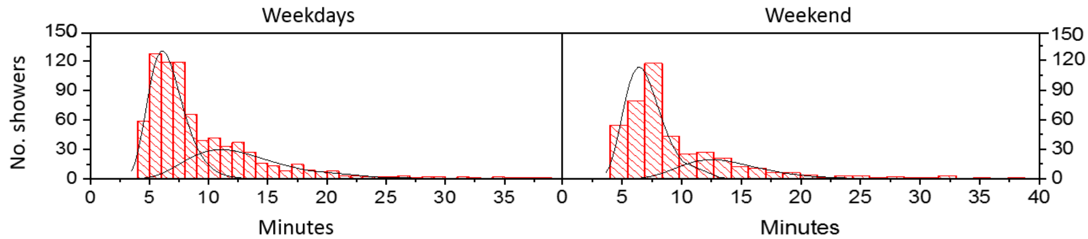

Figure 4-1Example of lognormal shower length distributions for weekdays and the weekend. The multimodal histograms represent the showering practice of different occupants (Publication II)

Histograms depicting the distribution of personal shower times follow Gaussian curves, which means that the practices occur at a similar time, each day, according to the individual’s routine (Figure 4.2). During weekdays, shower times occur during defined intervals from 6:00 to 9:00. There is a less defined but still identifiable pattern in the evening after 16:00, although this stretches over a number of hours as evening routines vary. During the weekend, showering times were significantly different, with weekend showers occurring much later and occurring over various timeslots that do not follow a strict pattern. This shows how contextual factors such as work and school routines can influence the temporal performance of personal hygiene practices.

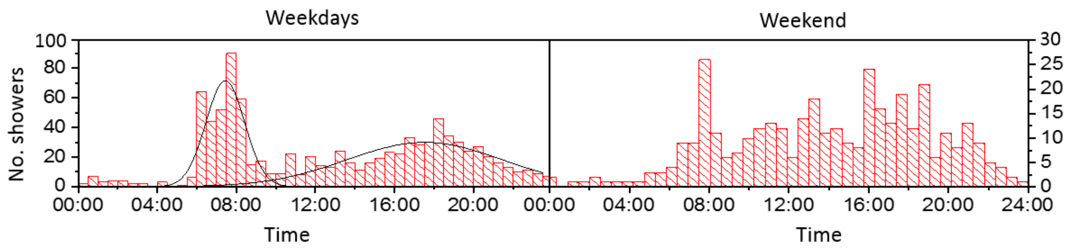

Figure 4-2Example of distribution of shower times for weekdays and weekend in the same home. Weekday showers are more defined than weekend showers, which in this case, are multimodal (Publication III)

4.1.1.2 Thermal comfort

The practice of staying thermally comfortable in winter through the use of heating has become increasingly resource intensive with the broad uptake of reverse cycle air-conditioning and heating units in homes in Perth (261) and in the studied homes. The practice of heating can also be carried out for different purposes, including warmth, comfort or as a habit (262). The use of the heater is not necessarily related to the internal house temperature, but to individual needs and daily routines. In three of the homes studied, a distinct routine to the use of the heater was observed. The residents in home 1 used the heater for two hours in the morning whilst undertaking their morning routines before going to work for the day. It was then used again in the evening when the occupants were home and watching television to stay comfortable. The occupants of the 2nd home only used the heater in the late morning around 10:00 when their solar panels are generating electricity, despite their house recording lower temperatures than others studied. This indicates that the resident's practices may have been driven more by a habitual routine and economic motivators than directly related to thermal comfort (88). A third heating practice routine was identified in the 3rd home, whereby the heater was only used during the evenings after the residents arrived home from work. This occurred consistently throughout the winter months regardless of the actual indoor temperature, indicating a high degree of habitual performance of this practice.

4.1.2 The HSOP

In a home occupied by multiple individuals, each individual possesses a unique SOP. These SOPs interlock with each other as some practices are shared between individuals (e.g. eating a meal), occur sequentially (e.g. showering), or take place because of another set of household activities (e.g. cleaning up after children). These SOPs interlock together to form the HSOP that is part of the social system of the home as shown in Figure 1.1. This HSOP influences when practices can be performed based on the availability of technology, the meaning associated with performing the practice with others and the skills required. For instance, a young child may not be able to take a bath (personal hygiene practice) without an adult assisting them, so the time when this can occur is dependent upon the adult's routine. When a new practice is introduced or modified, interlocked practices in the system need to be adjusted. For instance, when an individual has a shift in work start times, the practice of personal showering needs to also adjust. As showering is interlocked with other practices of those in the household, the other residents may have to review their practices too.

4.1.3 Enabling change in the HSOP

To enable change to consumption patterns in the home, one of three scenarios needs to take place (175):

- A new practice needs to be incorporated in the HSOP leading to a new home equilibrium; or
- One of the elements of the targeted practice needs to be modified; or
- A practice needs to be dis-interlocked or disconnected from the HSOP in order to act independently of the other occupants.

Individual's SOPs interlock with one another in the home in an equilibrium (Figure 4.3a). Intervening in the HSOP to influence a practice will shift the HSOP out of equilibrium (Figure 4.3b) until the individual SOPs are able to accommodate that practice easily into their routines to shift the equilibrium (Figure 4.3c). Unless a realignment of everyday practices occur, new practices cannot become embedded in the HSOP and fulfil a specific role. This tends to be the case with persuasive approaches, such as the use of feedback systems. While residents usually value information about their energy use, the practice of accessing the feedback system platform fails to become integrated into the HSOP and does not have significant lasting effects. The reasons for failure to embed a persuaded change can vary from lack of time and being busy, to forgetting about it (183). Research has shown that when used correctly, automated systems can operate independently of the user, dis-interlocking the practice from the individual's SOP (183). This can be though timers on irrigation systems, dishwashers, washing machines and air-conditioners.

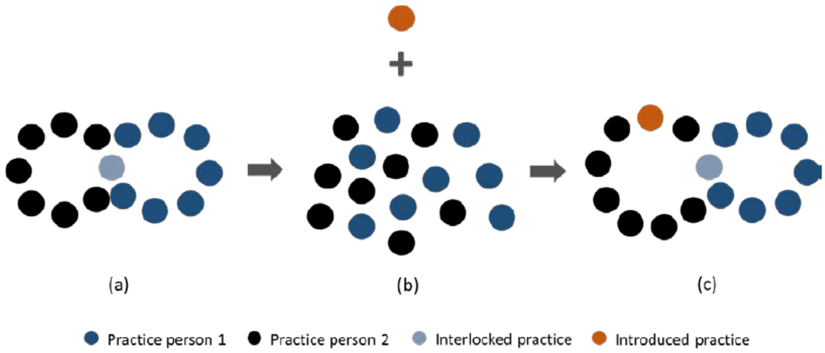

Figure 4-3Equilibrium of practices in the home. (a) Original home equilibrium; (b) Destabilisation of the home equilibrium through the introduction of a new practice; (c) Realignment of practices and establishment of a new home equilibrium (Publication III)

4.1.4 Conclusions

The detailed monitoring of household energy and water consumption patterns over two years allowed for evidence of the routine nature of practices to emerge. This highlights the individual and home SOPs that are present in many households. Informative persuasive approaches to influencing resource consumption often fail, as they do not consider the home system as a whole. Approaches need to address interlocked practices and interlocked routines as well as the three practice elements that influence the performance of a practice. Dis-interlocking practices from an established routine through automation may be more efficient to enable lasting reductions in energy, water and resource use in the home. The effective modification of occupant behaviours and everyday practices requires a holistic understanding of the HSOP, which includes resident's practices, routines, and their interconnections.

4.2 Interlocking practices and their influence in the home

The section responds to the following research question:

What are the daily domestic practices and HSOP of residents pre-occupancy in WGV and what impact does the degree of interlocking have on their performances?

This section is based on Publication V that examines the individual domestic practices and the HSOP of 14 residents who will be moving to a low carbon development. This focuses on the social system of residents and how this is influenced by specific technologies. The personal hygiene, thermal comfort, waste and travel practices of the 14 households were examined. The degree of interlocking of this system is then discussed.

When people move into sustainable houses, they bring practices with them that have temporally evolved along with their daily lives. A common misconception is that change to individuals' resource use can be persuaded without consideration of previous practices (34). However, it has been observed that energy efficient or smart buildings do not always perform as expected due to a lack of resident's skills, time or motivations (76). The successful adoption of technology is dependent on the understanding of these underlying practices, which should be considered at the building planning stage.

4.2.1 Everyday practices of residents

4.2.1.1 Personal hygiene practices

The meaning element of a practice refers to the symbolic meanings, ideas, values, understandings, assumptions and aspirations of a practice (75,183). This can differ between people for the same practice, influencing the subsequent resource use. Publication II showed that the meaning of a shower defines its temporal duration. These results have also been identified in this study as shown in Figure 4.4. Showers or baths for relaxation or personal hygiene were the longest, being on average 12 minutes in length. When the practice is interlocked with other practices and restricted in time, they are quicker. This occurred where the practice meaning was either cleanliness or freshness. Freshening up *via* a shower between activities may also be used to take a break, similar to relaxing, which can explain the increased length.

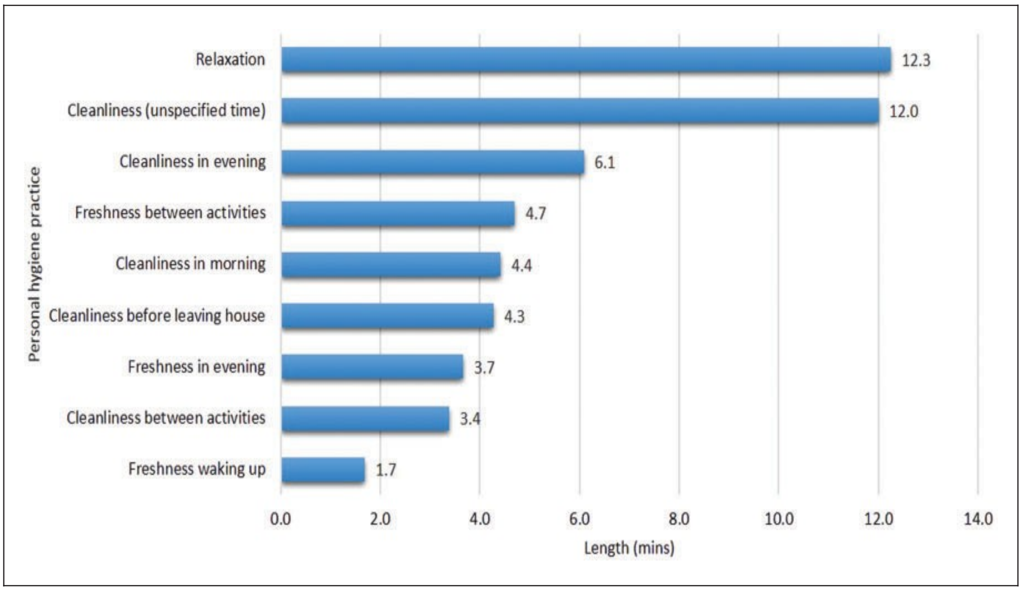

Figure 4-4 The average length of personal hygiene practices based on meaning. Data from 12 residents, two left out due to incomplete data (house B male and house N) (Publication V)

4.2.1.2 Thermal comfort practices

Thermal comfort practices of households were mostly similar, whereby resident's tried to reduce the use of auxiliary heating or cooling through other means first. Common approaches to keeping warm included the use of blankets, clothing, opening and closing doors and windows and using hot water bottles. These practices indicate that most households are already aware of and practice energy-efficient ways of keeping thermally comfortable as outlined in (214). Eight households utilised reverse cycle air-conditioning, gas or electric heaters to keep comfortable. These households often reported the children using these forms of heating more than the adult residents use them. Houses B, D and F reported comfort when the oven was on for cooking during winter, which would simultaneously heat the living areas of their house. This particular use of technology was only effective in houses that have a small living area.

However, resident's thermal comfort practices changed when they had visitors, with all households reporting that they switched to using mechanical heating or cooling when people visited. This may be linked to perceived societal norms, which were assessed through the Low Carbon Readiness Index developed (133), as illustrated in Figure 4.5. These results show that all residents have friends and family who support them in reducing GHG emissions, even if they do not believe that most of society want or attempt to reduce their own impact. Most residents also have a goal of living in a comfortable house. It could be posited that when hosting visitors, the residents want to blend in with the rest of society and use mechanical heating or cooling. Despite the fact that they may personally be concerned about the emissions, the social norm of being perceived as living in a comfortable home may hold a stronger meaning for them. This seems to suggest that many of these householders see themselves, their own households and their close social circle as a haven or avant-garde of low carbon living. Most households also generally have a high enough income to justify the occasional use of auxiliary heating and cooling.

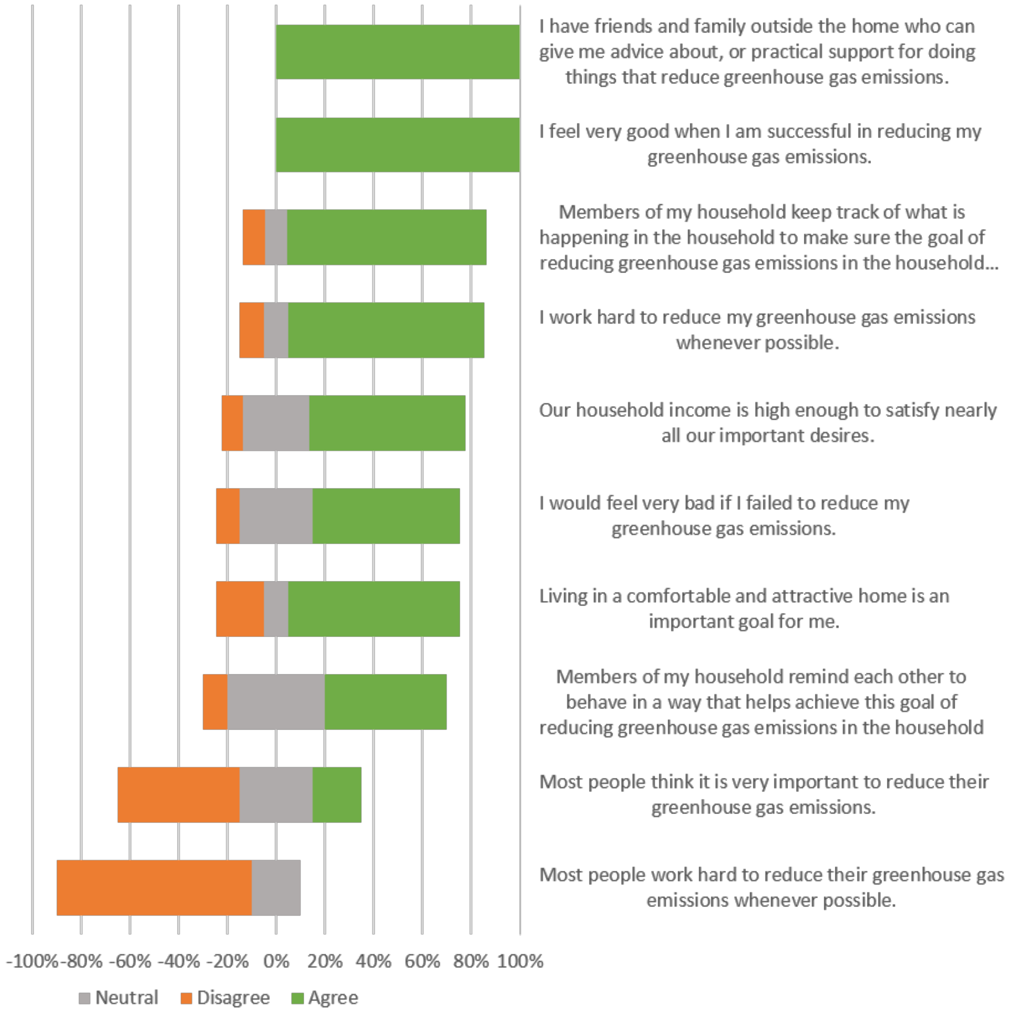

Figure 4-5 Residents' answers to questions from the Low Carbon Readiness Index. Data from Houses D, G, H, J, L and N left out due to incomplete data (Publication V)

4.2.1.3 Waste management practices

The final element of a practice is that of skill (39,183). This refers to the expertise, technique and competence needed for executing the practice in the desired manner.

Once a skill has been learnt, often at a young age, they can become habitual and largely automatic. When technologies are changed, the skill required to perform the practice may also change, as well as the meaning. The practice of waste management pre-occupancy in WGV was assessed to see if residents were executing this practice. Figure 4.6 shows that most residents separate plastics, cans, cartons and cardboard from the rest of their waste for recycling, indicating that they have the skills to do this. However, only 60% of the resident's compost garden or kitchen waste, even though some have expressed a desire to do so. This indicates that they lack the technology or skills required to perform these practices.

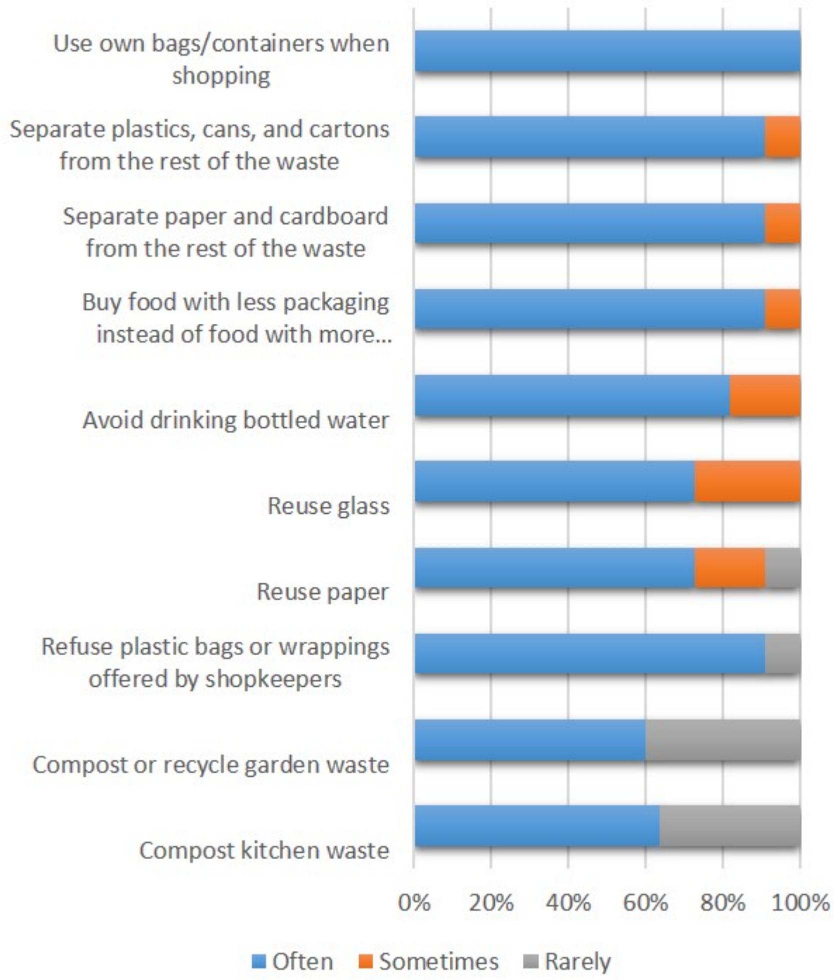

Figure 4-6 Waste practices of 12 residents, two left out due to incomplete data, house B male and house N (Publication V)

4.2.1.4 Contextual influences on practices

Along with requiring the technology, skills and desire to perform a practice, contextual factors can have a large influence on resident's practices. This was observed when discussing residents travel practices. Most households attempted to combine their errands into the same car trip, often before or after work. This made their SOPs more streamlined and convenient, allowing them to perform more practices in a day. Households that were frequent users of public transport, and/or cycling, and/or walking reported being car-dependent for large shopping trips. This indicated that it was not convenient for them to perform shopping practices whilst also travelling in particular ways.

4.2.2 Interlocking of practices in the HSOP

The HSOP can have different degrees of interlocking. A household of full-time workers, for instance, is likely to have a HSOP with a higher degree of interlocking compared to a household of retirees. The implication of a highly interlocked HSOP is that practices are less likely to be influenced as they are constrained by a very rigid routine with a high degree of habitual performance. Lightly interlocked HSOPs, on the other hand, may lack a regular routine. They are more flexible and adaptable to change. A summary of the studied HSOPs is outlined in Table 4.1.

Table 4-1HSOP for each house with comments on the interlocked practices (publication V)

House	HSOP	Comments
A	Highly interlocked	The resident works full-time, has structured personal hygiene, travel, shopping, cooking and work routines. Weekends flexible with socialising but retains the same travel practices (car).
B	Highly interlocked	Male adult works full-time and has a very structured routine of personal hygiene, cooking, eating and travel. Female adult works part-time and her days off feature shopping, housework, cooking and laundry. Weekends are structured around shopping, leisure and travel, with various modes of transport being used (car, bike, walking)
C	Highly interlocked	Works four days a week, structured travel, exercise, cooking and personal hygiene on those days. Days off always feature exercise, shopping, housework and socialising. Retains same travel practices (car).
D	Lightly interlocked	Full-time artist, travels frequently for long periods of time around the county for work. Unstructured days when in Perth feature shopping, working, socialising and housework. Frequent car use practices.
E	Highly interlocked	Works four-days, structured travel, personal hygiene, cooking and shopping practices. Travel practices include car, bike and walking.
F	Highly interlocked	Two full-time adult workers, very structured routines focused on personal hygiene, exercise, travel, work and socialising during the week. Weekends feature shopping and leisure. Consistent travel routines to work *via* car and car share, use bikes and public transport for local travel to shops and socialise.
G	Lightly interlocked	Shift worker with various shift times, interlocked practices of shopping, work and walking the dog. Consistent car use practices.
H	Lightly interlocked	A highly unstructured lifestyle based on daily activities. Regular personal hygiene practices, all others vary. Travels *via* car or walks locally.
I	Lightly interlocked	A retiree who showers and eats at regular times but other activities are lightly interlocked. Consistent car use practices.
J	Lightly interlocked	Artist and part-time tutor. Practices vary depending on daily activities. Regular personal hygiene practices. Consistent car use practice but walks locally.
K	Highly interlocked	Fly-in, fly-out professional on a regular schedule. Set activities each day and times (personal hygiene, eating, shopping, transport). No car uses a bike and public transport locally, plane and bus to work.
L	Lightly interlocked	Part-time artist and mother, some days structured around work and son's day-care. Travel, shopping, cooking and personal hygiene vary depending on the day's activities. Consistent car use practices.
M	Lightly interlocked	A full-time academic who has been living in two houses for many years travels frequently for work meetings in various locations and days do not follow a regular pattern. Consistent car use practices.
N	Lightly interlocked	Very unstructured practices depending on daily activities across all hours. No car uses public transport and walks locally.

Figure 4.7 provides an example of a highly interlocked HSOP, illustrating their daily practices on a Friday, a workday for both adults. The female wakes up earlier than the male, goes to yoga and then returns home to eat breakfast and shower at similar

times to the male, requiring co-ordination between them to use the same technology for these practices (shower, bathroom, kitchen, cooking appliances). They then both leave the house at a similar time to go to work taking different routes, the male alone in the car while the female is picked up by a neighbouring colleague as they car-share to work together. The house is then empty until the residents return that evening after having gone to the beach together with friends. Finally, they cook dinner and eat together. The female resident waters the garden while the male washes the dishes, both utilising the same resource (water) but in different practices, with different technology, skills and meanings.

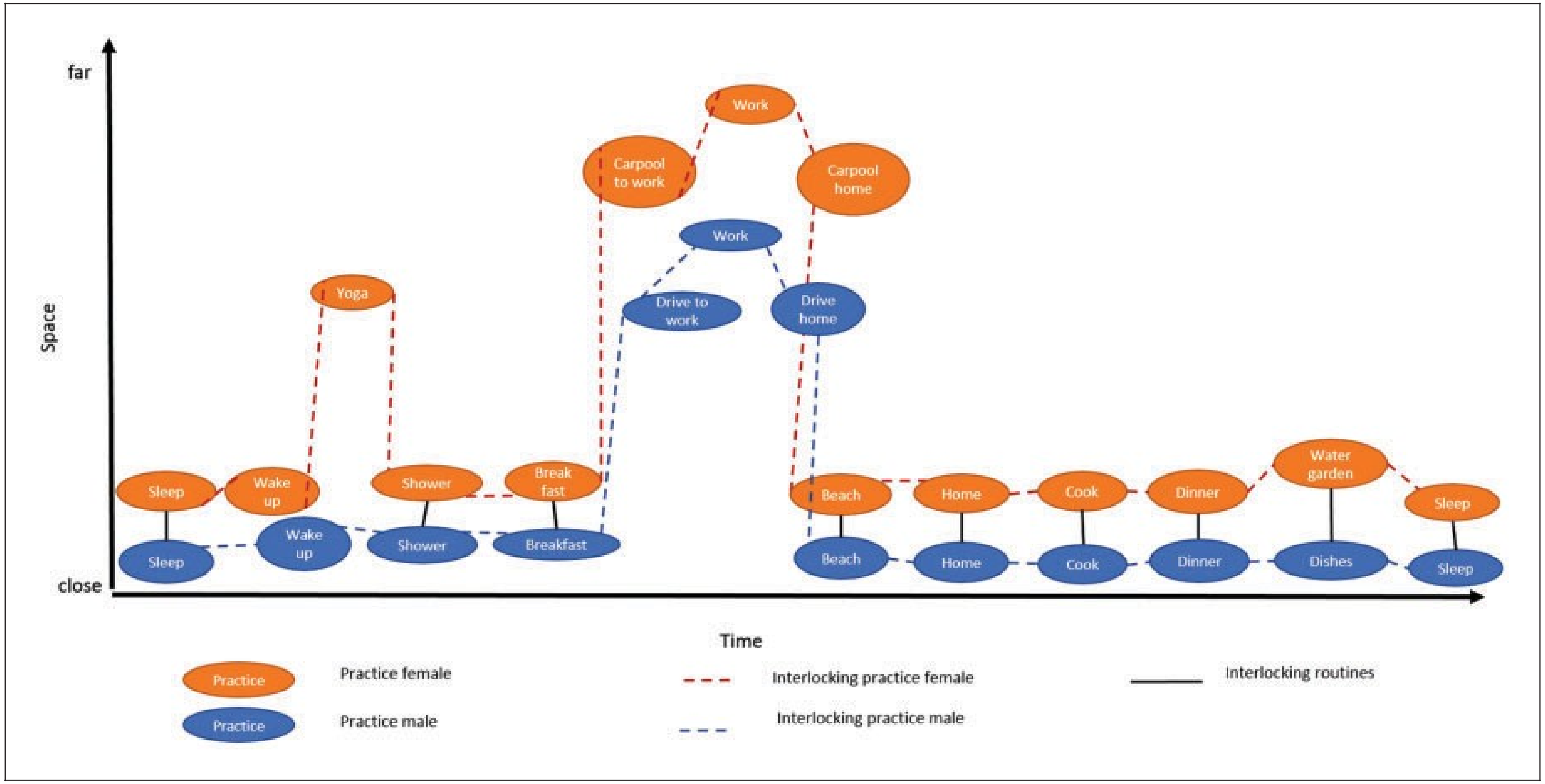

Figure 4-7 Example of the daily practices of two adults (Household F) during one day (a Friday) and showing the distance from the space of the household that these practices occur (Publication V)

4.2.3 Conclusions

This section focused on identifying and providing insight into the existing practices and HSOP of the residents prior to them moving into WGV. Personal hygiene, thermal comfort and waste management practices were discussed in relation to the meaning, technology and skill elements of the practices. The contextual influences on travel practices and their HSOP were also highlighted as important to understand why people perform practices the way they do. This is relevant given that resource-efficient or smart buildings do not always perform as expected, for instance, due to occupants' lack of skills, time or motivations. Influencing already established practices, especially highly interlocked practices, may be difficult to sustain in the long-term.

4.3 Household energy and water practices change post-occupancy in an Australian Low-Carbon Development

This section responds to the following research question:

What changes occur to pre-occupancy energy and water domestic consumption practices post-occupancy in a Low Carbon Development?

This section is based on Publication VI that compares and contrasts the pre-and post-occupancy energy and water practices of 13 residents and 14 households and the influences on these. Household energy and water consumption levels are measured and normalised to the metropolitan average to discuss the influence of design and technology on use. The normalised equation used (Equation 4.1) is as follows:

$$Normalised\ change = \frac{Pre\ occupancy\ value}{Metropolitan\ average} - \frac{Post\ occupancy\ value}{Metropolitan\ average}$$

Equation 4-1Normalised equation for determining the pre- and post-occupancy values of energy and water in households compared to the Perth Metropolitan household average

Heating, cooling and showering practices consume the largest proportion of household energy and water use and so the changes to thermal comfort and personal hygiene practices are examined along with a consideration of the influence of lifestyle and family composition on cooling practices.

4.3.1 Overall change in energy and water use at the household level

4.3.1.1 Energy use

The average Perth metropolitan energy use is 20 kWh/household/day for households with electricity and gas. At pre-occupancy, almost all households were below this average (Table 4.2). The households that were above the average (households C, and N) had either a high number of occupants, particularly young adults who were reported as being less conscious of their energy use (households C) or had a number of old and inefficient appliances (e.g. refrigerator, freezer, tumble dryer and air-conditioner). The change in pre-and post-occupancy energy use has been normalised to 1 against the metropolitan average (equation 4.1). This allows a comparison between changes in each household. Post-occupancy all households are under the average metropolitan energy use however; over half of all households actually increased their energy usage from pre-occupancy levels. This can be attributed to two residents reporting more time spent at home working (SHAC residents) and the other two coming from extremely low consuming households previously (household B and O). These changes in energy use can be partly attributed to design features, particularly for household B, who is located on the 2nd and 3rd floor of the apartment block, and report difficulties in naturally ventilating their home. Household O also has a student who is at home using energy most of the day. The SHAC households H and J undertake energy-intensive art practices, featuring photography, sewing and painting, which have high lighting requirements, accounting for the high energy usage.

Table 4-2 Household energy use pre- and post-occupancy and normalised to the Perth metropolitan average use (20 kWh/day). NA values are due to no or inadequate energy bill data provided by the resident (Publication VI)

WGV Development	House	Pre-occupancy energy/ household/day (kWh)	Post-occupancy energy/ household/day (kWh)	Change normalised to the metro average
Evermore Apartments	A	NA	4.44	NA
	B	5.54	6.61	-0.05
	C	29.25	7.02	1.11
	I	NA	5.90	NA
	O	5.54	5.88	-0.02
SHAC Apartments	D	NA	14.08	0.45
	H	7.37	9.46	-0.10
	J	7.21	8.52	-0.07
	L	NA	6.79	NA
	N	21.16	5.67	0.77
Semi-Detached House	F	11.93	6.72	0.26
House	G	NA	12.30	NA
Semi-Detached House	M	NA	4.88	NA

4.3.1.2 Water use

The average Perth metropolitan water use/household/day is 622L, based on 2010 data (45). Four households were above this average pre-occupancy (Table 4.3). This is due to having large gardens, or 2 or more residents that had frequent showers or baths and multiple loads of washing each week. Post-occupancy, all the households are now below the metropolitan average, except one. This reduction is attributed to design features, namely low flow fixtures, no baths and reduced garden space post-occupancy that requires watering. Household J was the only household to remain above the average water use. This is surprising since the female resident reports being environmentally conscious of her water use although the high level could be attributed to watering a large pot plant collection on her balcony and inside. Two households increased their water use from pre- to post-occupancy. Household B's increase may be attributed to not having rainwater data pre-occupancy, which was used in some inside fixtures and in the garden, where usually mains water is used. Household F's WGV dwelling features an extensive fruit and vegetable garden. This required a large amount of water to establish, even though some of this was over the winter rainy season; rain can be unreliable in Perth, even in winter. This was supplied through the shared community bore, however, as opposed to the mains water system.

Table 4-3 Household water use pre- and post-occupancy and normalised to the Perth metropolitan average use (622L/household/day). NA= no values due to no or inadequate water bill data provided by the resident (Publication VI)

WGV Development	House	Pre-occupancy water use/household /day (L)	Post-occupancy water/household/ day (L)	Change normalised to the metro average
Evermore Apartments	A	NA	13 1.40	NA
	B	210.01	233.48	-0.04
	C	409.65	133.35	0.44
	I	NA	114.78	NA
	O	210.01	109.51	0.16
SHAC Apartments	D	2186.44	371.90	2.92
	H	817.21	516.00	0.48
	J	NA	657.39	NA
	L	1873.26	110.14	2.83
	N	508.47	230.59	0.45
Semi-Detached House	F	295.85	359.53	-0.10
House	G	959.39	511.95	0.72
Semi-Detached House	M	NA	359.53	NA

4.3.2 Changes to Individual Practices and the Home System of Practice

4.3.2.1 Personal hygiene practices

Water for personal hygiene practices using showers is the largest water use inside the household in Perth (45). Personal hygiene practices by residents pre- and post-occupancy were usually performed by showering, with a few residents also continuing to have infrequent towel washes. Figure 4.7 compares the meaning of personal hygiene practices pre- and post-occupancy in WGV, highlighting how the meaning of the practice affects its performance. The average practice duration pre-occupancy was 6 minutes, while the average practice duration post-occupancy is 4.4 minutes. This can be compared to previous results for shower duration by Australian residents with an average between 6 minutes to 8 minutes (22). The duration for each meaning decreased pre-occupancy, except for cleanliness before leaving the home. This may be due to some residents not leaving their home as frequently in WGV due to working from home and therefore spending more time cleaning themselves when they do. The interlocking of practices is highlighted through an almost negligible change in duration for inter-activity cleanliness and morning cleanliness practices. The practice remains interlocked with other practices and is, therefore, less connected to the practice itself.

Unexpectedly, the relaxation meaning was not reported by the resident's post-occupancy. This may be related to the change in technology, as most of the relaxation practices were undertaken *via* a bath pre-occupancy and bathtubs were not present post-occupancy or choosing other ways to relax, such as swimming in the ocean instead. The cleanliness meaning was categorised into either evening or morning for all resident's post-occupancy due to more detailed completion of the personal hygiene diary by residents.

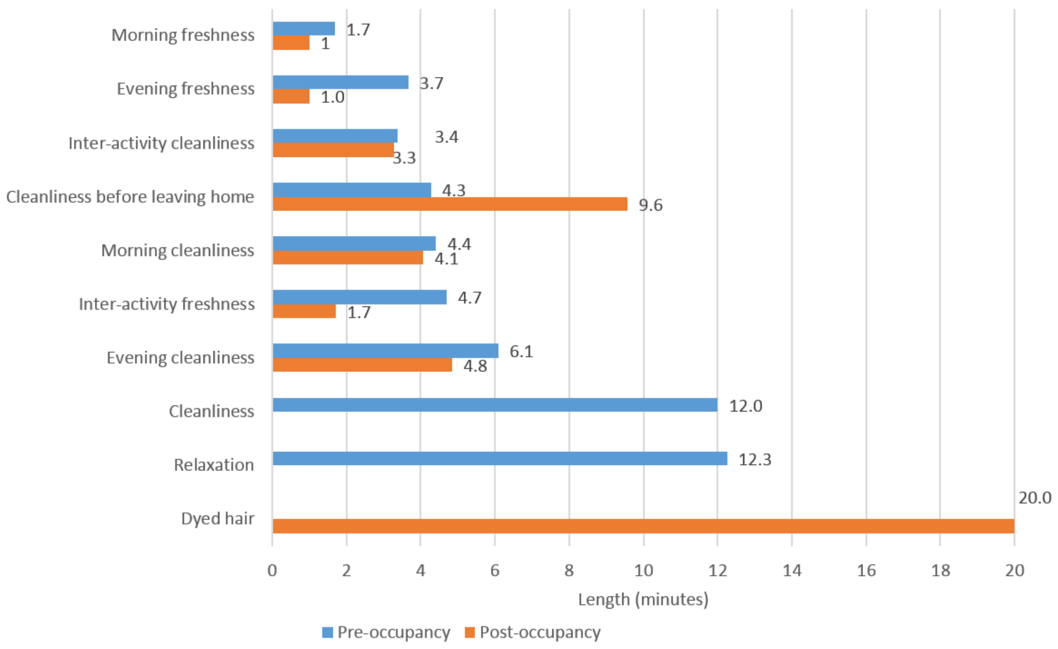

Figure 4-8Average length of personal hygiene practices pre- and post-occupancy based on meaning (Publication VI)

4.3.2.2 Ambient heating and cooling practices

Heating and cooling practices demand the largest amount of energy in household practices (44). The self-reported frequency of the use of heating and cooling systems by the household's post-occupancy showed similar practices compared to pre-occupancy. Individual resident's report being more thermally comfortable in their WGV dwelling. The use of ceiling or standing fans, along with opening and closing windows and doors is the most common way of staying comfortable. SHAC residents do not have air-conditioning in their apartments and so for some residents, this required a change in practices to adapt to this, particularly in winter when they found the apartments cold. Evermore residents do have air-conditioning installed but only one resident reported using this. This resident is retired and spends most of her time in the apartment and finds it more comfortable to use the reverse cycle air-conditioning as needed. The residents in the detached and semi-detached houses reported using their heating and cooling systems to stay comfortable but only after trying non-auxiliary methods first. Households who pre-occupancy reported the use of auxiliary heating or cooling with visitors in their home (Publication V) now report that this is unnecessary because the thermal comfort of the dwelling is considered suitable, except for those who would normally use it for their own comfort.

When residents were asked how often they felt thermally uncomfortable in their WGV dwellings, 75% or above answered that for less than once a month they feel too hot or too cold. This indicates that their adaptive thermal comfort practices, auxiliary technological use as needed and the design of the dwellings are mostly adequate for their perceived comfort, supporting the range of temperatures recorded. Figure 4.8 shows the measured range of temperatures in the households living areas over a 3-month period from December 2018 to February 2019. The thermal comfort range for living rooms in dwellings is considered to be between 20°C and 25°C by the Australian National Construction Code (263). It should be noted however that these temperatures were recorded during the Perth summer. The largest range of temperatures experienced in a dwelling was 22.3°C in household B during the monitoring period from December to February. This may be because this apartment is located on the 2nd and 3rd storey of the Evermore apartment complex and the 3rd floor does not have any adjoining apartments to assist in temperature regulation. It is also believed that the residents may have moved the sensor from its original position on the 2nd floor during monitoring. However, the range of temperatures in a similarly designed apartment, household C, indicates that these apartments, possibly due to their design and location on the 2nd and 3rd floor, feature a large range of temperatures. The dwelling with the smallest range of temperatures recorded was household O in the Evermore apartment complex. This apartment is located on the ground floor with a ground-coupled slab which aides in thermal stability. It is also located between other apartments so is protected from extreme morning and afternoon sun by the neighbouring buildings. In relation to household practices, the occupants of households B and O pre-occupancy shared the same dwelling pre-occupancy and reported similar thermal comfort practices. This highlights the influence that design has on the temperatures of a home, regardless of occupant practices.

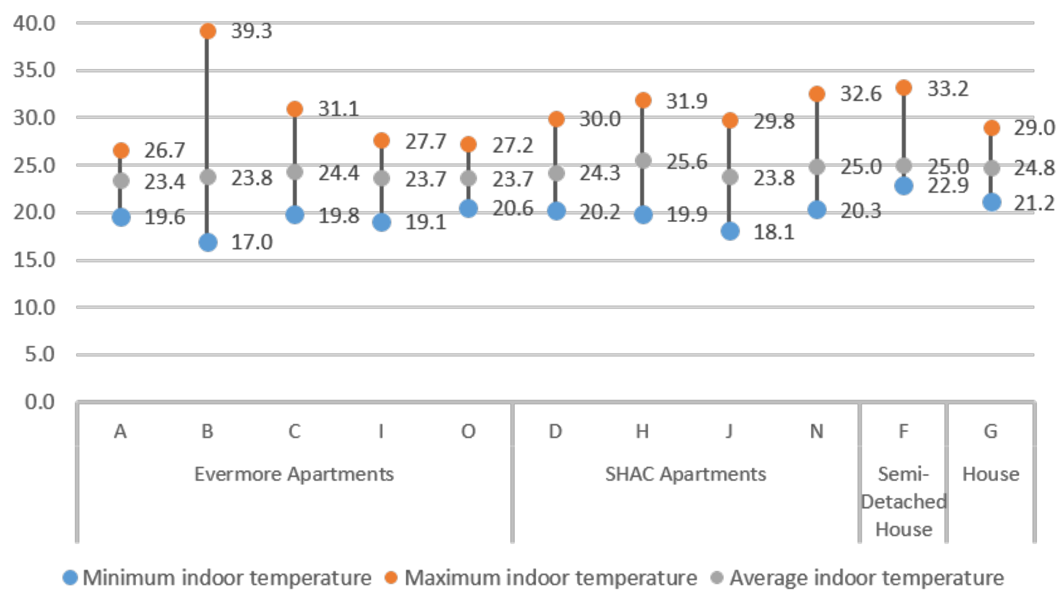

Figure 4-9Minimum, maximum and average indoor temperatures in each dwelling's living area. House L in SHAC Apartment excluded due to residents moving out of the dwelling during the data collection period. House M in a semi-detached house excluded due to equipment

4.3.2.3 Influence of lifestyle and the Home System of Practice on cooling practices

This section will examine the cooling practices of the 3 houses in the low-carbon development to highlight the influence of household variability in cooling practices in relation to the HSOP. Figures 4.9 and 4.10 show energy usage in households F, G and M during the hottest weekday and weekend day of the year during the monitoring period with complete data. These households were chosen because they are not apartments, which had some incomplete monitoring data. Households F and M are semi-detached houses and household G is a detached house. Sunday 20th January had an outside minimum of 21.8°C and a maximum of 37.7°C, while Thursday 7th February had an outside minimum of 21°C and a maximum of 36°C. Saturday 22nd December 2018 was a hotter day (min 24.3°C, max 39°C), however not all households had complete monitoring data for that day.

On Sunday 20th, the energy use shows that all the households are using energy through the day. In all the households, there are peaks in the morning when the residents wake up, between 11:00 and 13:00, when they would be preparing lunch and completing household chores, and then again in the evening around 17:00 – 19:00 when preparing dinner. Household G has the air-conditioning on during the day, resulting in high-energy use from 09:00 to 18:00. This is supported by the indoor temperature sensor which records the temperature to be between 23.5 °C and 24.5°C during this time and 25°C or above outside of these times.

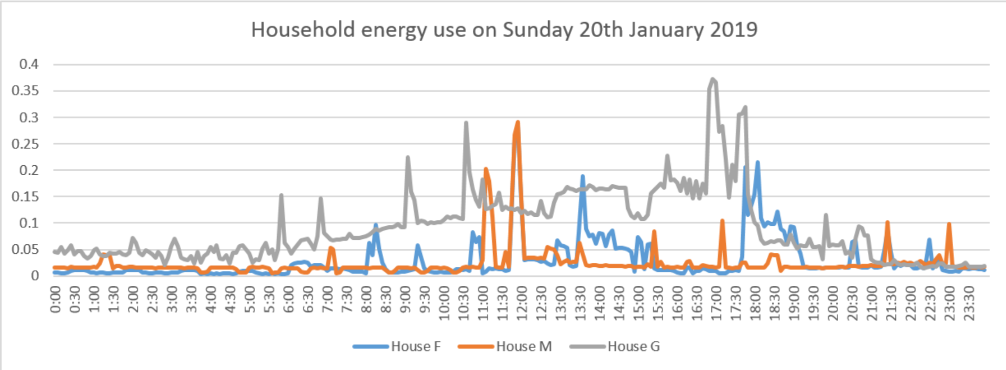

Figure 4-10 Household energy use (kWh) on Sunday 20th January 2019, the hottest weekend day during monitoring (Publication VI)

The energy use profile during a weekday, Thursday 7th February 2019 is markedly different for households F and M, which consist of full-time, off-site (Monday to Friday) workers. There are small peaks in the morning between 05:00 – 07:00 when the residents wake up and prepare ready for work, then low energy use until the evening between 18:00 – 21:00 when the residents are returning home, preparing dinner and going to bed. In contrast, household G, which consists of a shift-worker and full-time student/part-time casual worker was home during the day and use energy throughout. There were similar peaks between 06:30 – 08:30 and 10:00 – 13:00 and then the air-conditioner is switched on from 13:30 – 19:00. There is then an evening peak until 22:00 at night when the residents go to bed. The temperature in household G increases steadily from 25°C to 29°C during the morning before the air-conditioner is turned on between 13:30 and 22:00, at 25°C, when the temperature begins to rise again.

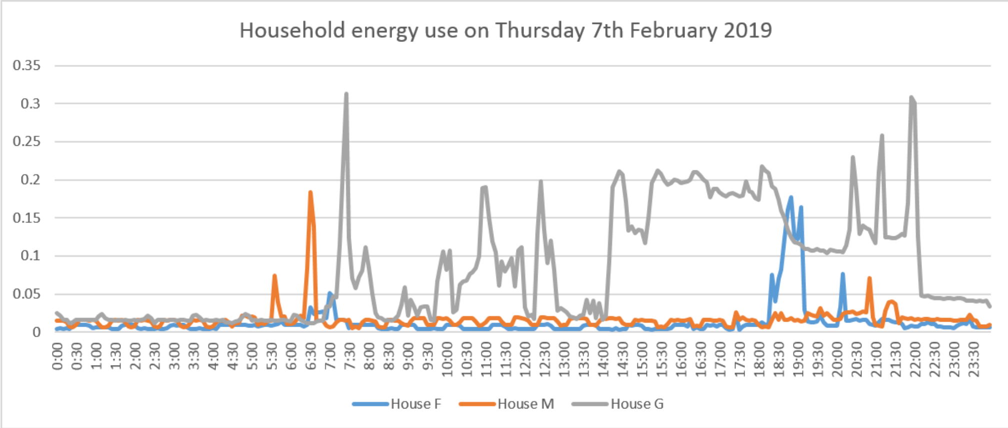

Figure 4-11 Household energy use (kWh) on Thursday 7th February 2019, the hottest weekday during monitoring (Publication VI)

This data shows the relationship between time of day, the HSOP and energy use. The HSOP recognizes the interlocking of individual resident's practices in the space of the home influencing the practices of others and resource consumption (Publication II and V). In this example, the households where residents are out of the house on weekdays have low energy use, with higher levels of consumption during the early morning and evening when the residents are home. This contrasts to the household with a resident home during the day due to different work conditions, who are utilising energy through their practice of staying thermally comfortable. On a weekday where all the residents of the households are home and practices such as cleaning and washing are being undertaken, the energy use profiles of the households feature more peaks throughout the day.

4.3.3 Conclusions

This section provides insight from a pre-and post-occupancy longitudinal study of LCD residents. There were distinct changes in practice occurring when technology changes in households. Lower household water consumption levels are primarily due to low flow fixtures and a smaller garden to water. Energy efficient lights were also installed to reduce the operational running costs of the home. The changes in the technology used to heat and cool the home also influence household energy use. Along with a change in technology used in the practice, a change in the skills of the resident performing the practice is also required. This was highlighted through the personal hygiene practices of residents. The HSOP understanding of domestic practices reflects the routines of households in resource consumption.

4.4 Changes to Household Practices Pre-and Post-Occupancy in an Australian Low-Carbon Development

The section responds to the following research question:

What changes occur to individual domestic practices and the Home System of Practice when residents' move into WGV?

This section, based on Publication VII, continues the longitudinal study of resident's domestic practices and the HSOP, focusing on practices other than thermal comfort and personal hygiene, which have been discussed in Publication VI. This section discusses 13 household's practices of waste management, shopping and purchasing and laundry practices and examines the state of interlocking of the resident's home system of practice pre- and post-occupancy in WGV.

4.4.1 Travel practices

Residents across the entire cohort pre-occupancy expected a change in their travel practices, with 9 out of 14 residents intending to alter the transport technology used in their practice of getting to work, socialising or running errands. However, the use of transport did not change with the exception of one resident who walks to work now instead of driving:

"Living here made it easy for me to not use my car and my work has moved to Fremantle in late last year. So instead of commuting 40 kilometres one way, twice a week…I walk or ride my bike" (Resident D)

Some residents have replaced some local trips to shops with walking or biking instead but otherwise shopping and work practices have remained the same. Those who reported using public transport (bus or train) in WGV are only those who were already using these forms of transport before they moved in.

The hills around WGV are a deterrent to the older residents who are more car dependent, especially for shopping trips, as Resident I and A stated:
Resident I: "Well, I'm 73 and I do have a few physical problems that kind of make it hard to walk long distances."

Resident A: "I just haven't got around to it and the hills here are actually quite steep. I've been a bit put off about "will I make it?"

The two apartment complexes, SHAC and Evermore have dedicated bicycle racks for residents to store their bicycles in. In Evermore, these are behind the gates to the complex, along with a bicycle repair station with tools, which is regularly used by residents who already own bicycles and with the inclusion of two communal bicycles, are now encouraging other residents to change their travel practises as highlighted by Resident C:

"I'm not a big bike rider, but…the complex has now got two communal bikes so I did actually have a bit of a trial run the other day…I can ride a bike, it's just that I haven't really done it very much – or certainly not in the recent years, so I am trying to build my confidence that I will use it to go in and out of Fremantle."

In SHAC however, the communal bicycle space is open to the public and there have been reports of some theft of bicycles. This has deterred members from storing their bicycles outside, which results in them being moved inside the apartment or into the small storage shed adjacent to the carpark.

4.4.2 Waste Management Practices

Pre-occupancy, all households recycled their waste through the roadside recycling bins (managed by the local council) with either weekly or fortnight collections. This practice has continued post-occupancy in WGV. In regards to the recycling of soft plastics, which should not be placed in the roadside recycling bins, no household's pre-occupancy reported recycling these. Post-occupancy, SHAC and Evermore residents independently implemented a soft plastics recycling system for each development that is then taken to a local drop off point by a volunteer. This resulted in all apartment households now recycling soft plastics. All apartments and semi-detached households also compost through a shared compost system in each apartment complex and shared between the two semi-detached houses. The remaining detached house resident had not implemented a compost system at the time of interview but was planning to in the future. Those who composted pre-occupancy are continuing this practice but appreciate the scheme set up, as highlighted by Resident I from Evermore who said that:

"It's been really great to have somewhere to put it and to know what to do with it."

Having a recycling system implemented by other residents who were more invested and motivated to do so has allowed residents who would not normally pursue this practice to participate, as Resident C reports:

"I'm not, you know, to be honest, I'm not as actively engaged with that [recycling] as a lot of the other people are, but I'm very happy to abide by…they know what they're doing, and as long as I know what to do, I'm happy to do it, you know?"

These results highlight that residents are willing to change their waste management practices if there is community support and adequate facilities in place for them to do so.

4.4.3 Food shopping practices

Pre and post-occupancy changes occurred for shopping frequency and location, as discovered through the interview and survey questions on these practices. The frequency of shopping increased for most household's post-occupancy. This is due to the households either decreasing in size with children not moving into WGV, therefore reducing the food required each week or by residents making a conscious effort to only buy what they need for a few days at each shopping trip. This change in practice has been supported by an increase in the use of local stores and markets post-occupancy.

Resident O from Evermore was also involved in bringing a local business into WGV to sell some speciality produce to the residents:

"…twice now, [we] have sold some goat's milk products from [a local] goat farm. And that's growing out of the fact that those products used to be sold at the farmer's market… [so we] contacted him and this arrangement was made. And it's happened twice so, it's involved contacting people throughout the whole eco village [WGV] and they could come in and buy things."

Residents in Households F and M are using the shared garden produce extensively and enjoy the seasonality of the produce. This has also reduced the amount of food they need to buy at the shops weekly. When they have excess, they are sharing it with others they know in the WGV precinct. The residents in Evermore have also started a produce garden with new plants and existing plants moved in pots to WGV. This allows residents to pick produce at their own leisure and have access to specialty plants that they did not have before in their gardens, as Residents B and O highlight:

Resident O: “Residents [of Evermore] have got a vegetable garden going and they just call everybody to harvest at will. And we've harvested lots of greens and zucchinis cucumbers and kale”

Resident B: “People giving grapes and we get mangoes”

4.4.4 Practice of purchasing household items

The practice of purchasing household items was also tracked in this research. Post-occupancy practices of buying recycled toilet paper and donating clothes to charity decreased. The other practices all saw an increase in reported performance post-occupancy. This includes an increase of over 50% for repairing products instead of buying a new one, as well as buying recycled paper when needed. An increase in purchasing energy efficient appliances and purchasing clothes from charity stores was also noted. Finally, all residents reported that they have avoided purchasing drinking water in plastic bottles post-occupancy.

The purchase of new furniture and appliances did not occur for most households. Some report purchasing a particular item such as a table or sofa because their previous one would not fit in the dwelling space in WGV or to match the other new appliances in the apartment. Two families that pre-occupancy lived in the same house moved into separate dwellings in WGV as the adult children moved into their own apartment. This resulted in them having to purchase additional appliances for the second apartment such as a dishwasher, fridge and washing machine. Resident C was unsure in the pre-occupancy move what to do with her worm farm but found a solution before the move to WGV, while Resident N has sourced all of his furniture second-hand:

“Interviewer: What happened to your worm farm?

Resident C: I bequeathed it to my neighbour.”

Resident N “A friend gave me a table. I got a second-hand fridge…everything is either given or second-hand or found at [WGV]. So I [have been] recycling furniture.

The influence of various factors on purchasing practices was also studied pre and post-occupancy in the survey through a 5- point Likert scale. These results are summarised in Figure 4.11 and show that pre-occupancy, the cost and energy and water efficiency of an item were the main influencing factors on the item purchased. The manufacturer and aesthetics were of least influence, while recommendations from friends and family were of moderate influence. Post-occupancy, these influences remained in that order, however, recommendations from friends and family increased from pre-occupancy, as did the aesthetics of the item. The efficiency of an item remained at a similar level of influence; however, it overtook cost as the driving factor of item purchase.

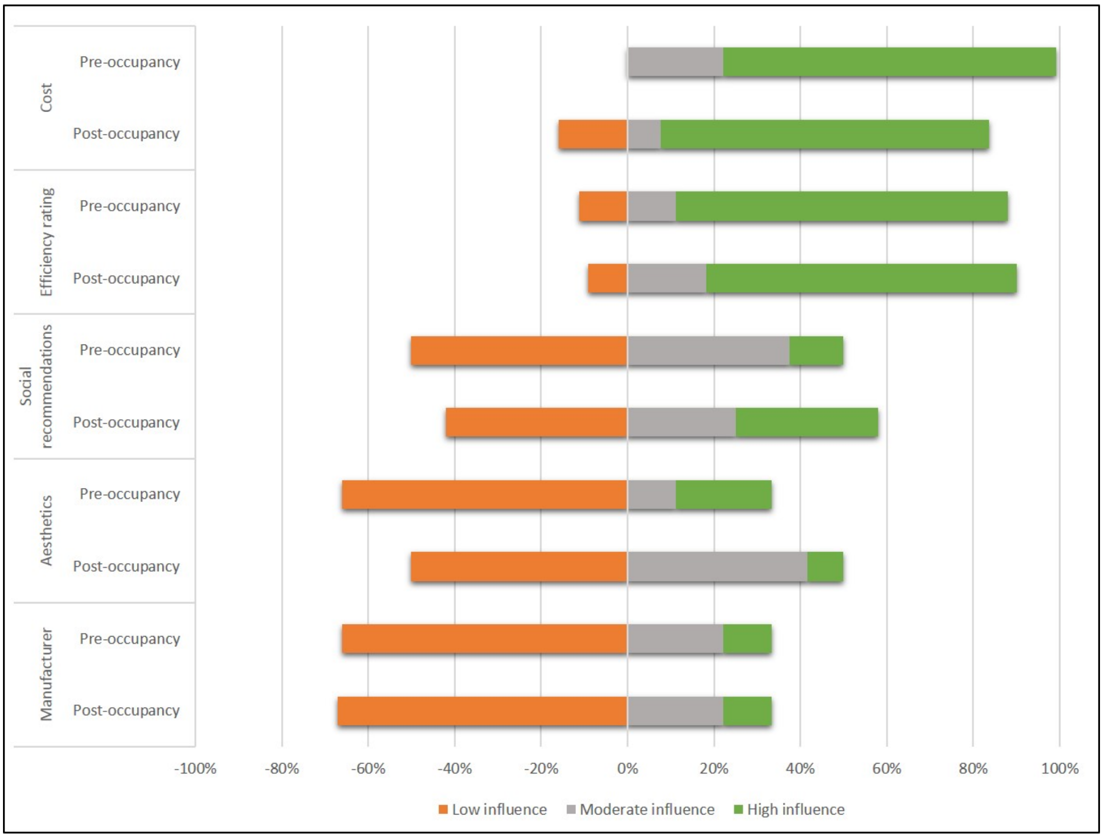

Figure 4-12 Graph showing the influence of various factors on resident purchasing practices (Pre-occupancy: 9 responses out of 9, post-occupancy, 13 out of 14). (Publication VII)

4.4.5 Laundry practices

There were no changes to the meaning element of the practice, with residents reporting similar reasons for washing clothes as pre-occupancy, mostly around cleaning dirty clothes, the social expectation of having clean clothes and the comfort that comes with that, as highlighted by Resident J:

“I feel better about myself out in the world with clean clothes.”

There were unexpected changes to resident’s laundry practices in both the volume of laundry washed and the way the practice is performed that were not anticipated in the pre-occupancy interview. Most residents performed a similar number of loads of washing and drying as they had in their previous dwelling, with changes occurring only in households that had changes in the number of residents in the house, decreasing the volume of washing. The majority of residents pre-occupancy (12 out of 14) did not use a tumble drier to dry their clothes due to environmental or energy conscious preferences. Post-occupancy, some residents have begun to use a tumble drier due to the reduction in clothesline space in WGV and for convenience, while others retain their previous practices, such as Resident A:.

“I just don't [use a tumble drier]. I think I like the freshness the air on the clothes and sheets. I like that smell in preference to the hot tumble dry kind of smell. I guess if it was [raining heavily] for days on end and I couldn't dry anything, yes. Then I would use it but it came with the apartment and I prefer not to use it.”

All the residents in Evermore had a tumble drier included in the apartment on purchase due to there being no permanent clothesline in the complex. Residents report only running the tumble drier during the day to make use of the solar energy provided by the solar panels and battery to offset the additional energy usage. Other Evermore apartments have purchased small collapsible clotheslines that are positioned on balconies or inside. The residents have reported difficulty with drying bed linen and towels on these and the parents of children who have moved into other apartments in Evermore (that were residing with them pre-occupancy) have reported the children using their tumble drier for convenience. This is highlighted by Resident I’s comment:

“There is no clothesline here [in Evermore] which would be nice to have a clothesline, but I don’t think they want the visuals of hanging clothes.”

Resident G in the detached house has also changed her drying practice from air dying to using a tumble drier post-occupancy for the convenience, as she does not have a large outdoor clothesline. Resident's in SHAC do not own tumble driers and have a communal clothesline on the side of one of the buildings. This can serve as a social space for residents, with informal social networking when residents are hanging their laundry.

4.4.6 Interlocking of practices

The degree of interlocking of the HSOP of residents was first reported in Publication V. This has been compared to post-occupancy and is shown in Table 4.4. The resident's daily routines in WGV are generally similar, especially when influenced by work, despite the move, as Resident A states:

"It's pretty much the same. I mean, you know, if you're working, you're doing the same stuff, aren't you?"

Some practices though have become influenced by the design and technology of WGV. The presence of solar panels influences when residents put the dishwasher, washing machine and drier on, whether for economic reasons or environmentally conscious reasons. Many residents are conscious of putting these on during the day where they had not previously, shifting or displacing the interlocking of practices with others. Otherwise, the use of automatic systems is minimal, a few houses reported using the timer settings on the washing machine, dishwasher or air-conditioner unit but most will use these only when they are home. This has changed for residents using their washing machine and dishwasher during times they can use the solar power but has not changed for air-conditioner use. These changes in practices have required residents to learn a new skill (the setting of a timer). It has not changed the demand for the practice or the intention of the practice (having clean dishes and clothes).

Residents who had automatic reticulation post-occupancy have now all moved into apartments and now only hand water pot plants. Those in single houses all have reticulation on their gardens, which is set to automatic, different to their post-occupancy dwellings. This has dis-interlocked the performance of watering the garden for some residents who now do not have to actively engage in the performance of the practice each time (Publication 2). This reduces the influence of other practices preventing or altering the practice of watering the garden. For instance, when the irrigation is on a timer, a resident does not have to remember to turn it on, this ensures the reticular will run at the scheduled time regardless of if the resident is home or not.

Only two residents changed their interlocking status from lightly to highly post-occupancy and no residents changed from highly to lightly. This was due to resident L's son starting school with consistent hours that allowed for her work to become more consistent and washing and cooking routines to become interlocked. The other resident who changed was resident M who was moving between a number of different houses pre-occupancy and he now has a stable residence in WGV. This has allowed him to standardise his travel times between work, shopping and leisure times and has then flowed on to interlocking his cooking, washing and showering practices.

An example of a practice that is often highly dependent upon other practices is the times that residents eat meals (264). Table 4.4 also shows the resident's pre- and post-occupancy meal times and the reasons for this. Those residents who are highly interlocked and work full-time have structured meal times. Those who are lightly interlocked eat at different times of the day. Those who live in houses with other occupants are influenced particularly in the evening by the other occupant's movements.

Table 4-4 Relationship between meal times each day and WGV HSOP interlocking and occupation of households, pre and post-occupancy in WGV (Publication VII)

Dwelling	House	Pre-occupancy meal time same each day?	Pre-occupancy reason	Pre-occupancy HSOP interlocking status	Post-occupancy meal time same each day?	Post-occupancy reason	Post-occupancy HSOP interlocked status
Evermore Apartments	A	Yes	Work, eat simply	Highly	Yes	Work	Highly
	B	Mostly	Work, partner's movements	Highly	No	Work, evening activities, partner's movements	Highly
	C	Yes	Work and other household members	Highly	Yes	Work	Highly
	I	Yes	Hunger and convenience	Lightly	Yes	Hunger and habit	Lightly
	O	Yes	Work, evening activities and health	Highly	Yes	Work and evening activities	Highly
SHAC Apartments	D	Mostly	Work and other household members	Lightly	No	Work and other household members	Lightly
	H	No	Evening activities and hunger	Lightly	No	Depends on many factors	Lightly
	J	No	Depends on many factors	Lightly	No	Depends on many factors	Lightly
	L	No	Tries to have regular times with child when home	Lightly	Yes	Child	Highly
	N	No	Depends on many factors	Lightly	No	Depends on many factors	Lightly
Semi-Detached House	F	Mostly	Work and evening activities	Highly	Mostly	Work and evening activities	Highly
Semi-Detached House	M	Yes	Healthy to eat regularly	Lightly	Yes	Healthy to eat regularly	Highly
Detached House	G	No	Shift worker	Lightly	No	Shift worker	Lightly

4.4.7 Conclusions

With the move into WGV, it was found that the overall interlocking of a resident's system of practice did not change. This was due to resident's lifestyles not altering drastically post-occupancy, with household composition remaining the same for most residents. Residents still work the same each week and undertake household chores and socialise at similar times and places compared to pre-occupancy in the LCD. These factors influence practices and their timing. This aligns with the literature that states that when practices that are interlocked shift, they force a reconfiguration of the system (62). These results show that because there was not a major shift in residents transport practices, along with no shift in work practices, the interlocking of their HSOP has not changed. Significantly, the timing of preparation and eating meals each day is influenced by resident's system of practice and how this practice interlocks with others in their home. Those who have highly interlocked HSOP are more likely to eat meals at the same time each day and do so due to work times, other household member's practices and habit. Those who have lightly interlocked practices are more likely to eat when hungrier or depending on fluctuating work times. Post-occupancy design features have affected laundry practices but not the timing of them being performed. The location of the LCD close to food shops has resulted in local shops and markets being used more. Homegrown fruit, vegetables and herbs are being used more in the LCD also. The community has influenced recycling rates and increased self-reporting of other's recommendations influencing purchasing practices. This highlights the influence that community members have on resident practices, through providing the skills, technology or motivation (meaning) to change practices.

4.5 Pre and post-occupancy evaluation of resident motivations for and experiences of establishing a home in a Low-Carbon Development

There is some understanding of how an individual's daily practices consume resources in the home, but the home as a space itself and peoples' relationships to it remain an interesting research area. This section responds to the following research question that is addressed in Publication VIII:

What are the resident's motivations, perceptions, expectations and experiences of establishing a home in WGV?

4.5.1 Resident awareness of the possibility to move to a low-carbon development

There are multiple ways that the residents became aware of WGV. Most residents discovered the LCD through their friends, some of whom were from a community group they were in (such as the SHAC artists' community). Others had friends involved in the project or were informed about it by work associates aware of the development. The strong influence of social networks in distributing information throughout the community was shown through the majority of residents discovering the LCD through personal connections.

4.5.2 Motivation to move to a low-carbon development

Residents' motivations for moving to WGV were primarily due to the sustainability features of the homes and the development. This was followed by the attraction of living in a community of medium-density dwellings, as well as being able to interact with neighbours and engage in community events. Residents discussed having more community connection with neighbours because of common
interests, more community events or group projects between the groups (see quote below, Resident G) and more sharing of information (Resident O).

"The new lifestyle. Being part of something… being part of a community" (Resident G)

For half of the studied residents, the LCD provided housing stability for them either by allowing them to purchase their own home or allowing them to lease an apartment belonging to SHAC, and the interviews uncovered a further aspect of this motivator: control over space. The final attractions of the LCD were the location, the design of the LCD and the dwelling design.

4.5.3 Perception of life and home in a low-carbon development

While attraction to the physical attributes of the LCD is important, the reflection of the meaning of home in an LCD is also important to attract people in the future. The most frequent features are a sense of community, social aspects and family interactions. Residents pre-occupancy recognised the sustainability features of the homes and the development and the economic and environmental benefits these provide as preferred features. SHAC residents who had not had stable and secure housing in the past were drawn to the permanent WGV housing opportunities. Resident H stated that the support from the community and the general focus throughout the LCD on sustainability would result in his daily practices changing to become more sustainable. Resident D made the statement that simply being in the LCD with a community of like-minded individuals would motivate her to change her practices take environmental choices into consideration. She also stated that:

"Moving to a low carbon precinct I believe will improve my quality of life and motivate me to make better consumer and environmental choices." (Resident D)

Comfort through design and aesthetic features in the home were important for 5 out of 14 residents. These results are similar to those outlining the motivations for residents moving to the LCD, possibly indicating that they will feel satisfied with their move to WGV (265).

4.5.4 Expectations of living in a low-carbon development

Many residents who had not previously lived in houses with sustainability features mentioned that they expected to be able to live more sustainability when they moved into WGV. Residents used terms such as easier, normal and being supported when discussing the expectation that their daily practices would become more sustainable in their use of resources, including energy, water and transport. Those residents who have already lived in a home with sustainability features did not expect many aspects of their life to change. They had expectations of travel practices changing, but discussions primarily revolved around the sense of community and opportunities to interact with their neighbours instead.

Some concerns that are evident through interviews with residents have come from those who had not lived in a medium-density or LCD dwelling before. Individual residents were concerned with aspects outside of the dwelling design that they lacked influence over. This included neighbours' actions that may disturb them, the green space located within the LCD and how to incorporate it into their daily lives and the landscaping and management of the common garden areas. These concerns highlight the importance of communicating the benefits of living in an LCD effectively with residents and clearly outlining policies and regulations before people decide to move in. Housing policies that are viewed as bureaucratic, or development regulations that are not well understood, may lead to conflict and produce a negative perception of the LCD as an attractive place to live.

4.5.5 Post-occupancy evaluation of living in a low-carbon development

In terms of control over space, residents reported enjoying making their homes the way they wanted, and felt a sense of pride and ownership in their homes, with hope for future housing stability. This was particularly evident for the SHAC residents, who were motivated by this for the move. A design aspect of Evermore that was criticized by all WGV residents was the extra lighting at night around the buildings and car park. While this is intended for security reasons and has been dimmed slightly in response to resident complaints, many WGV residents had to shut their curtains at night to be able to sleep, preventing them from having windows open to passively cool their homes. The lighting and security gates and fencing around the Evermore entrance meant that residents reported feeling uncomfortable entering the development, associating it with a jail, a medical institution or a sporting field, not a home. On the other hand, residents did appreciate the security aspect that this gating and lighting provides.

Before moving into the LCD, the important features of home included community aspects, sustainability features, design, security and comfort, and these aspects are compared to the post-occupancy responses in Figure 4.12. These features were mostly still expressed post-occupancy. The most common features post-occupancy are the home as a haven, family and social aspects and comfort aspects. The safe and secure housing aspects were reported at 36% post-occupancy, the same as pre-occupancy. A new feature mentioned after the move was the ability for a home to be a place where the residents can be creative and express themselves. One resident in each of the SHAC and Evermore developments reported this. The garden and pets' aspects of the home both remained important features. Noticeably, the sustainability aspects of the home were not mentioned after residents had moved to WGV, despite their importance before the move. This may be due to residents being satisfied with their sustainability practices post-occupancy.

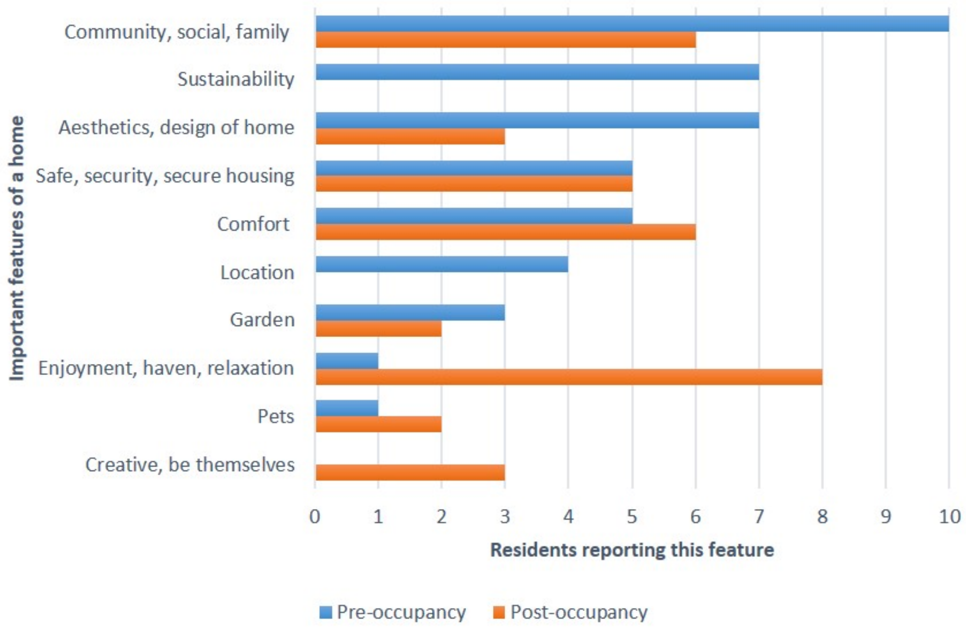

Figure 4-13 Important features of and associations with a home as reported by 14 residents pre- and post-occupancy in the LCD (Publication VIII)

The community focus was a driving force for many residents wanting to move into the LCD, with 57% of residents reporting it as being a motivating factor. Since moving in, all the residents reported enjoying the community atmosphere of the LCD. This included both those in the apartment buildings (SHAC and Evermore) and those in the semi-detached and stand-alone houses. Those in the apartments enjoyed the informal interactions with their neighbours as they walk about their development, while those in the houses enjoyed being in their garden and interacting with residents walking past as well as the more formal gatherings organized within the LCD.

Whilst the community aspects were highly praised by the residents, there were some aspects raised by residents relating to areas that had influenced their experience of community in the LCD. The SHAC residents were some of the first to move into the LCD, and some reported feeling that they had a responsibility to present a profile of a good community to the surrounding community outside of the LCD, even when their pets or kids did something that others did not believe to be socially acceptable.

SHAC holds regular community events and workshops and encourages the broader WGV community and residents of surrounding areas to attend these.

4.5.6 Conclusions

This section highlighted that home is associated with being a place of community, sustainability, safety and comfort, as well as a place that incorporates aesthetically pleasing features. The motivation for residents moving into the WGV LCD was to have housing stability, live the life they want (including performing sustainable practices) and enjoy the attractive design of the LCD. The user experiences of living in an LCD include unexpected design influences on daily practices and an appreciation of the community atmosphere created. The strong sense of community and the self-reported thermally comfortable homes met residents' expectations post-occupancy.

Chapter 5 Discussion

This chapter brings together the results from the publications discussed in the previous chapter and presents these in relation to the overarching research question:

How are residents' domestic practices influenced by moving to a low-carbon development and what are the user experiences of living in a low-carbon development?

This chapter will discuss domestic practices theoretically at different scales and states of interlocking, followed by assessing how the results of the case study show the influence on domestic practices of residing in a LCD. Finally, a discussion on the user experiences of living in a LCD concludes the chapter.

5.1 Resident's domestic practices

Social practices constitute a useful way of understanding daily actions both within and outside the household (35,51,72–74,266). Within the household, numerous studies have focused on the practices that consume large amounts of energy and water (3). While this is constructive in addressing those particular practices, this thesis has built on these seminal studies through a longitudinal and holistic approach to understanding domestic practices and the context they exist in. With the focus of many developments in the built environment moving towards more sustainable and less consuming forms of houses in LCD, understanding the residents and their practices, who will reside in these can ensure that innovative designs are utilised to their full extent. With changes in household context for each individual and a move to a more community-focused lifestyle, the results of this thesis provide a detailed understanding of the resident's domestic practices. This section will discuss the implications of this understanding in the context of SPT, the HSOP and review the domestic practice changes that occurred post-occupancy in WGV.

5.1.1 Insights from Socio-Psychological and Social Practice Theory on scale implications

The significant challenges posed by issues such as climate change, overpopulation and resource management require an understanding of actions that involve resource consumption across all scales of society. Policy implications should consider the reach and durability of interventions if they are to be applied effectively (13).

Persuasion and enabling methods are usually not aligned in behaviour change studies as they are seen as two distinct methodologies. This thesis has argued that they are in fact trying to achieve the same objective, which is to reduce resource consumption, but approaching it through different angles. On the one hand, social psychology uses persuasive methods to address personal resource use from a top-down approach, delivering social norms and providing information; on the other hand, SPT's enabling methods are focused on the elements of a practice that are utilised in the performance and addresses consumption from a bottom-up approach. Rather than being conflicting methods, the two schools of thought complement each other, filling each other's gaps, informing and modifying attitudes while enabling long-term changes that bring value to the user.

Figure 5.1 outlines the different scales that insights from the two schools of thought could be applied to. Practice insights can be used to achieve quick changes in a specific physical space (*e.g.* the home) while conserving established routines and respecting the HSOP where multiple individuals interact. While HSOPs can be realigned, they constitute a challenging task without a more fundamental change in context. This can be obtained through the implementation of technology that does not interfere with the timing or order of practices. Behaviour change, on the other hand, requires a shift of societal and cultural norms to be effective. Values and norms driving individual behaviours are usually present at all levels of society and are independent of space and time.

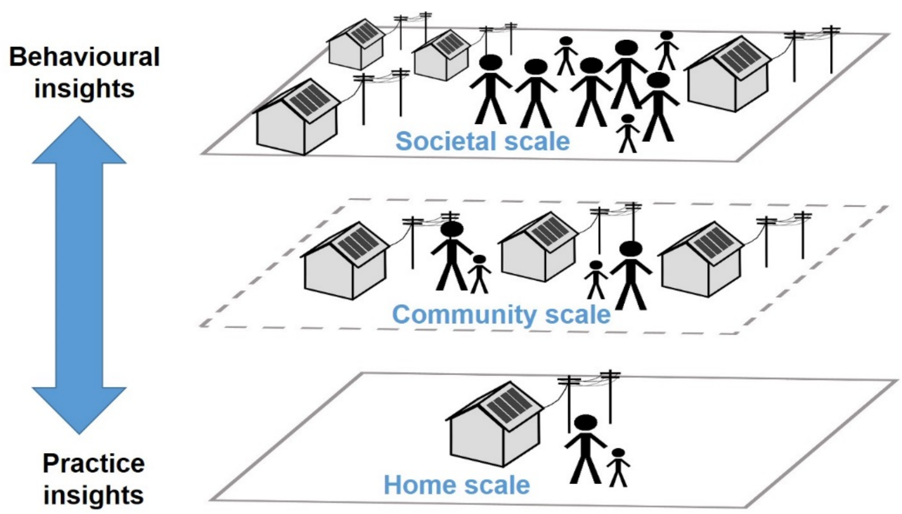

Figure 5-1 The different scales that behavioural and SPT interventions can be best targeted to (Publication I)

5.1.1.1 The home scale

Interventions through socio-psychology methods in the home may only last for a short period of time, while design changes based on SPT insights will last for years, if not decades (87,267). In spite of the limited data, the few existing longitudinal behaviour change studies suggest that some persuasive methods have longer-lasting effects than others in the space of the home (71). Information campaigns, for example, might be effective for a short-term solution, such as saving water in summer (268). IHDs can be a good tool while it is a novelty, but if it does not meet consumer needs, the technology quickly becomes idle and its effectiveness might only last a few months. Other interventions such as teamwork (269) and audits, which demand a higher level of personal engagement, might last a few years. Previous research has shown that behaviours end up reverting to what they originally were after the behaviour change intervention is interrupted (34).

Behaviours are influenced by close relationships as well as the wider society and culture and their insights would be better applied at a community and societal scale (63,77,270).

Design modifications at a household level based on SPT insights result in a change occurring to resource use (203). For instance, changes can be made to the physical building system (*e.g.* the addition of insulation, shading devices or solar panels), resulting in a reduction in resource consumption. Technology can also be used to dis-interlock practices through automation, enabling lasting reductions in energy, water and resource use (Publication II). Automation is a once-off change, allowing a 'set and forget' mentality to drive the practice in future, reducing the need for human intervention and thus failure.

The replacement of current technology with technology that enables change through everyday practice can have a long-term effect on resource reduction. Rather than requesting that households turn off their standby appliances manually, for example, appliances without a standby mode could be provided instead (Publication III). The success of innovative technology is dependent on user knowledge and can be hindered by rebound effects; however, the implementation of practice-based design and co-creation is a contemporary approach which ensures that users not only take part in the design of a technology that is needed in the long-term, but also understand its function (26,86,112,271).

When technology is used to modify a practice (through SPT insights), it targets the specific space where the practice is carried out, without modifying the HSOP or the timing of the practice. This can enable change without requiring persuasion (34).

5.1.1.2 Community scale

Community spaces are where people share values or activities which identify them closely with one another (14). Insights from both SPT and socio-psychological theories can be applicable at this scale, particularly regarding social norms, shared practices and information diffusion. Values and practices are co-constructive, where a person's beliefs, ethics and worldviews simultaneously shape and are shaped by their performance of practices (272). Practices and behaviours that these insights have been applied to previously include the practices of mobility or food shopping (112,209,273,274). Applications from the temporal studies of practices and behaviour can be applied at this scale through targeting when people are utilising the space if there are peak times that they are there and using resources that would be more effective to target them than others.

The ideas of both socio-psychological theories and shared practices have been discussed in the literature as a community of practice (150,212) where communities are the site of learning by individuals. Interventions in practices and behaviours that consider communities of practice have been shown to be effective in research targeting changes in driving cars within small villages, cooking for large groups of people once a week, shared community gardens and shared compost systems (41,275). Creating a sense of community helps to increase the visible impact of the practice or behaviour, normalising what is being done and creating a sense of authority to the need to change practices for sustainable practices (99). These insights can be effective in changing practices and community perceptions of sustainable consumption (276) (Publications VI &VIII).

Changing the skill of practices performed is also a way to target interventions on a community scale and can be achieved formally through education or social learning, such as through demonstration workshops or discussions amongst friends (183). These groups can be communities of practice and be used as a targeted place to initiate practice and behaviour changes. Changes in skills, however, can be assumed to take longer to generate desired outcomes, as it is necessary for the skill to be learned and implemented (39).

5.1.1.3 Societal scale

As previously discussed, the meaning relating to a practice is closely connected to the context of where the practice is carried out and of what is socially acceptable. For instance, if the use of an electric heater is the norm to achieve warmth in the home, then the use of blankets, for example, is not considered a viable solution. This has been discussed in previous research, where residents who would usually not use auxiliary heating to keep themselves warm at home, will use it when friends or family visit because they believe it is the social norm (Publication V).

Modifying the meaning of practices requires a societal shift, which is where socio-psychology theories can be used to best effect (Publication VI). Social and structural changes (205), if perpetrated by government and organisations, or communities of practitioners, can affect cultural and social norms, along with the diffusion of knowledge (205). Research has found that individuals perceive the solutions to climate change to be at the national or organisation level (205). This highlights the expectation that individuals have that these changes will be disseminated from a societal scale. This can be through policy changes, information and education campaigns, and long-term changes to cultural and social norms that may take generations to take effect. An example of this is the importance of change agents in the energy sector. These individuals can champion certain ways to perform practices that use fewer resources or shift the timing of the performance of energy-intensive practices through education or social norm campaigns (277).

Socio-psychology behaviour change programs have previously been applied at a societal scale to effectively encourage the use of seat belts in cars. Results from multiple decades show that effective and well-planned media and enforcement campaigns can have a positive impact on seat belt usage rates (278,279). Other research shows how an SPT understanding can be applied to enable change in specific places. Through providing people with belt-positioning booster seats (technology), education on its use and benefits (skills) and a social marketing campaign to emphasise social norms (meaning), effective behaviour change was achieved (280). These examples show how at a societal scale, both socio-psychological and SPT insights can lead to enabling people to change effectively.

5.1.2 Insights applying to the Home System of Practice

The timing of the intervention in the HSOP is key because the practice or behaviour will be limited by the context and influenced by other concepts such as comfort and convenience. Given the complexity of the home system, the results presented in this thesis suggest that rather than disestablishing, realigning and recreating interlocked connections and practices in the HSOP, automated technologies could enable improved resource efficiency through acting completely independently of the HSOP. Manual practices are bound in space and time in a rigid routine, while automated practices are bound only in space in the sense that they can function at flexible times and operate only in conformity with house technologies. Yet, they are still required to meet occupant needs and skills to be able to work effectively.

Influencing the routine use of resources has the largest benefit due to the long-lasting nature of the change. Technological improvements also play a role, allowing practices to be performed easier or with less interlocking compared with other practices, or automatically negating the need for human interaction or decision making which may not be the more sustainable option (Publication II) (175,281). Automation influences highly interlocked practices as it reduces the influence of other practices and contextual factors on the timing and elements of the practice. For lightly interlocked practices, changing an individual element, technology, skill or meaning, is potentially more beneficial. In the absence of technology changes, cost-saving consumption choices are subject to rebound effects when liberated income is used for additional consumption (282).

Rigid and habitual routines that are highly interlocked have smaller standard variation related to the time that practices are performed in comparison to more flexible routines (Publication II). These rigid routines may prove harder to influence. Routines, however, are re-aligned when there is a change in context (e.g. at the weekend). Personal showers follow a similar pattern every time they are accomplished (Publication II). For instance, individuals tend to have personal showers of the same length every day, but longer showers that have meanings other than freshening up or getting clean also occur. The lognormal distribution shape of personal showers indicates that shorter showers are unlikely to happen which is counterintuitive to the common belief that public Waterwise information campaigns can influence the length of a shower. Similarly, the use of the heating system is not only directly related to the temperature, but also to other interlocked practices and personal expectations (Publication VI). Given the complexity of everyday practices and their interconnectivity in the home system, affecting them is challenging and unlikely to occur without taking a holistic perspective (34). Traditional behaviour change approaches that attempt to persuade change through the provision of information and feedback displays assumes that individuals are driven mostly by reason (159). This often ignores that practices are bound in space and time and reproduced sequentially as part of an established routine. Modifying them requires either a change in the practice elements, including meaning, or a complete re-alignment of the HSOP. Another solution is to separate, or dis-interlock, practices from the HSOP, for instance, through their automation. Therefore, a solid understanding of the HSOP and daily routines that residents' exist in is necessary to foster targeted alterations in practice and subsequent resource consumption.

This understanding could take the form of Figure 4.7, where a household of two adult's daily practices was mapped out in Publication V. As this example showed, there are only a few places where changes could be made to the resident's practices and subsequent resource use. Dis-interlocking these bundles of practices could occur through automating the garden watering or using a dishwasher to wash the dishes, but otherwise, there is minimal change that could occur. These results concur with those found in other studies focusing on temporal aspects of household practices where there are clear set times for certain activities, dictated by the time and location of others, forming bundles of practices (89,176,283). However, in contrast to previous studies, this research focused on individual home systems, allowing for an in-depth understanding of household dynamics and the HSOP. This allowed lightly interlocked HSOP to also be studied, whereby there were more opportunities for change to occur in the timing of the performance of resource-intensive practices such as garden watering, washing of dishes or cleaning the house and utilising renewable energy generated from the solar panels in the LCD.

5.1.3 Pre-occupancy domestic practices

The results from Publication V focused on identifying and providing insight into the existing practices and HSOP of Australian residents prior to moving into a LCD.

Understanding resident practices is important to be able to design buildings and spaces that are functional and meet user needs, whilst reducing the energy and water consumption of these households, as was the aspiration of the WGV development (Publication IV). This is relevant given that smart technology or low-carbon housing does not always perform as expected, mostly due to residents' lack of skills, time or motivations in understanding how to utilise it as designed in their own SOPs (284).

Influencing already established practices, especially highly interlocked practices, may be difficult if not impossible without consideration of the context and routines they are enmeshed in. Through an in-depth analysis of the elements of meaning, technology and skill, the personal hygiene, thermal comfort, clothes drying, garden watering and waste practices of 14 families and homes were studied pre-occupancy in the LCD. This provided a holistic understanding of the resident's usual practices and their performance before the change in context and housing in WGV occurred. This longitudinal study of a developing LCD allowed the collection of real-time data thereby providing a more accurate representation of behaviours and practices (112).

Households were identified as either lightly or highly interlocked dependent upon the residents' HSOP. This is a classification that was developed for Publication V based on findings from previous studies calling for a more holistic classification system than basing it on resource consumption levels of the household alone (175,285). Households with working residents or children have a regular routine that they must adhere to that interlocks with their showering, travel, shopping and socialising practices, forming bundles of practices. Households that comprise of the self-employed or retired have less structure driving their daily practices, resulting in them being performed at various times of the day. This supports the findings found in a previous study whereby those who live alone (as it the case in household I) prefer to eat at similar meal times (286) However, the duration of the practice concurrent with the meaning remains within a similar range. The Low Carbon Readiness Index results also show that while individuals and households believe it is meaningful to reduce their carbon emissions; this meaning is altered when visitors are over. This highlights the strong influence that societal norms and values have on individual actions in the HSOP and the need to consider the long-term influences on these when addressing resource consumption.

5.1.4 Changes in domestic practices post-occupancy in a Low-Carbon Development

Having studied the pre-occupancy practices of residents in WGV, the post-occupancy aspect of this research enabled a comparison of domestic practices to occur.

Consumption of energy and water is reduced mostly by virtue of the design and appliances installed in the home. There were distinct changes in practice occurring when technology changes in households. Lower household water consumption levels are primarily due to low flow fixtures and a smaller garden to water. Energy efficient lights were also installed to reduce the operational running costs of the home. The changes in the technology used to heat and cool the home also influence household energy use. Reverse cycle air-conditioners have less energy demand when running on the heating setting than gas or electric oil heaters when used to heat a large space (44). Along with a change in technology used in the practice, a change in the skills of the resident performing the practice is also required. This was highlighted through the personal hygiene practices of residents. Those who had previously had access to a bath and used this for cleanliness and relaxation, post-occupancy had to rely on a shower to perform this task instead. Some residents then changed their practice for relaxation to a visit to the beach.

Although the design and the technology of the LCD dwellings provide an improvement, personal practice history influenced the resident's practices that involved energy and water consumption. Publication II & V & VI showed that the meaning of a shower defines its temporal duration which supported the previous literature findings (180,213). The influence of personal practices of thermal comfort remains, though the routine use of auxiliary heating and cooling systems based on work routines and entrenched habits of use (Publication II and VI).

Post-occupancy design features have affected laundry practices but not the timing of performance. The increase use of a clothes drier by some residents, as compared to air drying pre-occupancy, will increase the energy used in the performance of the entire laundry practice. This may be offset somewhat if the practice is performed during the day when there is sufficient energy provided by the solar PV panels on the dwelling or through energy stored in the communal battery. Where the household size has changed post-occupancy, residents are performing less loads of laundry than pre-occupancy. This will influence the overall consumption of energy and water in the household as a whole.

The location of WGV close to food shops has resulted in local shops and markets being used more. Homegrown fruit, vegetables and herbs are being used more in WGV also. The community has influenced recycling rates and increased self-reporting of other's recommendations influencing purchasing practices. This highlights the influence that community members have on resident practices, through providing the skills, technology or motivation (meaning) to change practices. The increased influence of family and friend recommendations on purchases post-occupancy could also be attributed to the sense of community developed in WGV. A decrease in the donation of clothes to charity may have been due to residents already donating enough before the move, or wanting to purchase new items to fit the feel of a new house, or if they had additional money. The motivating factors influencing the meaning behind the practice of purchasing, influenced product purchase and disposal should be explored further in future research, especially relating to a circular economy approach and the value that waste has in society (281). Pre-occupancy, residents expected their travel practices to change quite significantly, especially an increase in the use of bicycles, the electric vehicle (a car share provided in WGV), and walking. However, the use of transport post-occupancy did not change for the majority of residents with the exception of one resident who walks to work now instead of driving.

For travel practices, policies that promote and enable non-car travel options to assist in promoting these and overcoming barriers to non-car travel options could be considered (219). For recycling practices, creating supportive structures that can easily be incorporated into current practices will have more likelihood of creating lasting change (221). There is also a need to consider the other practices that are interlocked with each other such as bulk shopping trips, travelling with different ages and abilities of children and adults, location of schools, health care and entertainment centres to understand why and how people perform practices before they can be influenced (221).

5.1.5 Post-occupancy Home System of Practice

The overall interlocking of a resident's HSOP has not changed for the majority of household's post-occupancy due to resident's lifestyles not being significantly altered, with household composition remaining the same for most residents. Residents still work the same each week and undertake household chores and socialise at similar times and places compared to pre-occupancy in WGV. These are the factors in this real-life study that influenced practices and their timing. This aligns with the literature that states that when practices that are interlocked shift, they force a reconfiguration of the system (62). These results show that because there was not a major shift in residents transport practices, along with no shift in work practices, the interlocking of their HSOP did not change. The timing of preparing and eating meals each day is influenced by resident's system of practice and how this interlocks with others in their home. Those who have highly interlocked HSOP are more likely to eat meals at the same time each day and do so due to work times, other household member's practices and habit. Those who are lightly interlocked are more likely to eat when hungry or with fluctuating work times.

The HSOP influence on household energy consumption patterns was outlined over two of the hottest weekdays and weekends of the monitoring period for 3 households with different routines. The marked difference in energy use based on time of day and the practices being performed. The HSOP and energy consumption patterns will often remain the same, regardless of where the energy is sourced from (grid sourced or solar PV), which should be a consideration for builders and designers of low-carbon development and energy-efficient homes and technology. The timing of meals was also discussed in relation to the HSOP in Publication VII, whereby households that are highly interlocked have routine meal times compared to lightly interlocked households that usually eat at varying times depending on their daily actions.

5.2 User experiences of a Low-Carbon Development

The second aim of this thesis emerged after the pre-occupancy data collection, where the themes of home, community and user experiences in a LCD emerged. Publication VIII explored residents' motivations and expectations for how their life would change when they moved into an LCD, and the post-occupancy evaluation of this.

The concept of home in the literature revolves around technical perspectives (technology features), social perspectives (comfort, social place, physical use) and sustainable practice (sustainable housing) perspectives of home (245). The aspect of comfort in social housing policy generally relates to thermal or physical comfort, something that can be measured, predicted and changed through design adaptations (246). Previous research has found that the future of comfort remains fluid and controversial (83) and that the user experiences of LCDs are highly personal, strongly linked to their health, wellbeing and social experiences instead of those with the technology and environmental outcomes (11).

Some of the results from this research support this view, where the traditional notions of home design only focus on thermal comfort. In taking a social view of home perceptions and expectations of a move to an LCD, however, this research highlights the varying results that occur when non-technical aspects of an LCD are considered (245). Home in this research has been outlined to be primarily a place for community, sustainability, aesthetic features, safety and comfort, although the sustainability aspect reduced in importance once residents moved into the LCD. This could be due to residents easily integrating their practices and technology in the new environment and focusing more on the community aspects of their lifestyles. The different meanings of the home revealed through this research point to various opportunities and obstacles for reducing resource consumption in homes (114). Future research should focus on how the meaning of home influences individual and household resource consumption, and investigate how living in a LCD affects these. This could then inform more appropriate policy-making related to homes and resource use that does not solely focus on the built environment.

In the literature, a primary aspect of the meaning of home is the importance of control over space, whether in relation to personal identity, security, comfort, privacy or activities (124,253,254,259). These results are the same even for households with sustainability features (287,288). This is supported in this research, as residents were particularly motivated by housing stability and having control over their own space (248,249). Other motivation results also reflect the conclusions made by previous research (248), that the external environment of the community is important to people in a home along with housing stability. Location and design are common factors in purchasing a home anywhere, let alone in an LCD, and are replicated in this study as common features people look for in a potential home (265).

Previous studies have shown a strong desire by residents to adopt sustainability features in their homes, and the WGV precinct provides them with this opportunity (289). The sustainability features of the LCD in this research were rated as a strong motivator for residents, followed by the community aspects being fostered at WGV. Residents believed that living in the LCD would enable them to develop practices that require fewer resources, increase their interaction with the community and change their travel practices. Residents of the LCD primarily found out about the opportunity to move into the LCD through their social networks of friends and workmates. Social networks are a trusted and familiar source of information for people in society (23), and hence might be used by real estate agents to increase awareness of, and interest in, LCDs. LCDs feature design aspects and technology that require resident interaction to ensure their optimal performance. These can be of concern for prospective residents, as shown previously (290), although the residents in this study were not concerned about these features pre-occupancy. Designers, planners, real estate agents and strata managers need to explain these clearly to prospective residents to ensure the technology is maintained in good working order to achieve the sustainability outcomes of the development.

The expectation of a strong sense of community pre-occupancy concurs with the findings from many studies on the important features of a home including the community aspects (248,249,255). The strong sense of community and the self-reported thermally comfortable homes met residents' expectations post-occupancy, and are a positive selling point for future LCDs. Some design and community aspects were met with surprise in this research, as has been highlighted in other studies (11). The lighting and security aspects of the Evermore development received mostly negative views from the residents, particularly how the security gates influence the ease with which they could move about the LCD precinct and interact with other residents, and the lighting disrupting their internal comfort in the evening. The communal barbecues also had mixed reactions, engaging some residents but not all. Other options for community interaction and meeting places should be explored to accommodate other preferences.

Research focusing on questions of the home often examines only the physical and techno-economic aspects of the built environment of the dwelling that people reside in. Those studies that focus on the home tend to include social and emotional connotations along with the built environment (290). If policy is only focused on the built environment, then human social and emotional connections with their home may be neglected (9). As these are important elements of social practices, any programs designed to influence resource use in the home are unlikely to result in long-term change. The emotional landscape of a home is increasingly being recognized as significant to residents, including in this study, and its relevance should be advocated for in housing policy, along with the physical structure of the dwelling (8,247,251).

For housing policy to lead to attractive homes in the future, it is important to understand which elements of the design of a home are desired by residents post-occupancy, and how these features influence daily practices. In terms of a policy approach towards housing, the WA Department of Communities acknowledges the desire for residents to have a safe, secure, stable house, and provide various dwelling types to meet residents' needs (287). It is clear from this review that the term home is a complex system of physical and emotional elements (288), and the various ways of categorizing it provide opportunities to change resource consumption in related practices. It is with this open policy direction in mind that this thesis has explored how residents perceive their homes and what they expect from the move into a LCD.

Chapter 6 Conclusions and recommendations for future research

This thesis has combined concepts from socio-psychology and SPT to assess domestic practices at scale in a longitudinal study. These theories have been established in the literature as the basis for influencing individual practices and understanding some aspects of individual resource consumption however, there has been a call for a more holistic understanding of the influences on domestic practices in light of the evolving built environment of the home and calls for more sustainable consumption practices in society in general (11,13,35,290).

The study of the scale of policy and interventions into domestic consumption actions and daily routines was discussed in Publication I. This furthered the chalk and cheese debate (63,148,149) in the literature around the different applications of socio-psychology and SPT approaches. This thesis argues that both schools of thought have merit in understanding practices and behaviours and the focus should instead be on the scale of application the research insights contain: the individual, the home, the community or at a societal scale. Publications II and III highlight the power of automation in dis-interlocking the practices within the HSOP to enable residents to act in a more sustainable manner, instead of having to persuade them to do so (34).

The remaining results and discussion in this thesis were based on a longitudinal study of resident's domestic practices pre- and post-occupancy in an Australian LCD. The WGV development was introduced in Publication IV, highlighting the innovative solar PV and battery technology, water-efficient design, mixed residential dwellings and strong community-focused vision of the LCD. A mixed methodology approach utilising detailed monitoring and in-depth interviews, cultural probes, survey's and workbooks containing travel and personal hygiene diaries and social network questions were employed to understand the influence on domestic practices and the HSOP of living in WGV. This covered the practices of thermal comfort, personal hygiene, garden watering, waste management, food shopping, item purchasing, travel and laundry practices. The user experiences of life in WGV was also investigated as a strong community focus and support for sustainable domestic practices was expected.

The results presented demonstrate that by establishing a baseline of domestic practices and the HSOP, the influence of context and building design can be assessed. The pre-occupancy study highlighted the importance of daily routines in influencing the temporal and spatial performance of practices and subsequent consumption of resources. The residents have a strong association with comfort and convenience in motivating their practices and their personal practice history influences the performance of practices even in the changed context. Household's water and energy use decrease due to technology and design influences post-occupancy, with all households now falling under the Perth metropolitan average for water and all but one below the average energy consumption (Publication VI). Changes to the meaning element of personal hygiene practices show how these are interlocked, and unlikely to change in their duration when there are other demanding practices to be undertaken (Publication VI). In relation to the lesser-studied domestic practices, the results show that post-occupancy, the presence of solar panels influenced when residents turned the washing machine and tumble drier on (Publication VII). Many residents are conscious of turning these on during the day or use timers where they had not previously. Changes to resident's travel practices were not as broad as expected while recycling rates increased, influenced by a supportive community and shopping practices became more localised through the use of smaller food retailers (Publication VII).

Finally, these results conclude that resident's resource use is heavily influenced by their work and socialising routines, these must be taken into consideration when designing low-carbon houses and influencing resource use in the home. While individual consumption changes do not necessarily reduce the resource intensity of modern lifestyles (291), the results of this research show the power that design and technology have on household resource consumption. Through strict design guidelines, the houses built in WGV were at a 7-start NatHERs rating, included energy and water saving technologies and were orientated according to passive design principles. Ensuring these guidelines are in place for all new build houses in countries, along with sufficient education of builders and verification methods, would reduce household resource use without the need for environmental awareness, behavioural or practice change intervention campaigns. In addition to the design of houses, recommendations of standard appliances such as dishwashers, washing machines, air-conditioners, clothes driers, fridges and freezers that assist households in reducing their energy and water consumption would also assist this transition.

Rebates on these appliances could also be offered as incentives. This one-time change to the technology element of the practice should be supported by ensuring the residents of households with these appliances, as well as other technologies such as solar PVs, batteries, water tanks and timers, have the appropriate skills to operate them in an effective manner to ensure continued sustainable resource use.

Design guidelines and architectures should also consider the influence their decisions have on other resource consuming practices in households including laundry practices, waste management, thermal comfort and personal hygiene practices. For laundry practices, providing space for and acceptance of outside clotheslines in apartments reduces the use of clothes driers. For waste management, ensuring there is space in both the dwelling and the outside area dedicated to waste storage in bins, for the separation of waste into different streams would allow these practices to be performed easily. Currently, residents in both the SHAC and Evermore apartments have multiple areas for compost waste which complicates the performance of the practice. There is also little additional space inside the bin storage area for division of waste into various streams, such as soft plastics, cardboard, metals and other recyclable material. This increases the confusion of where to place waste items, the possibility of contamination and the time taken to sort waste. These may influence the performance of the practice by residents of a long time.

The value that community networks have in supporting daily household practices changing has also been highlighted in this research. The need to engage with the consumer and their daily actions has been acknowledged in the policy sphere (292). A SPT approach acknowledges that humans have certain contexts in which they consume resources and their power to change these actions depends on the resources being used for the practice, the meaning of the practice which is being undertaken and the skills they have to alter the practice (78,285,292). This also allows for the refocusing of decision-makers attention to different routes into these practices and practice bundles to explore other options to reframing them (293). These include the reach and durability of existing practices and their elements and identifying what changes might have the greatest effect over space and time (13).

The user experiences of LCD are vital in designing and managing successful developments that achieve not only their technological and emission reduction targets but ensure the well-being of the individuals, households and the community which are considered. This research has contributed to the literature emerging from Australia on low-carbon households in terms of energy, water and resource consumption (11,43,93,290,294). It was found that the desire to reduce individual and household GHG emissions and resource consumption was a strong motivating factor in deciding to move to a LCD, along with having housing stability and being located in a desirable location. The attractive design of the dwellings and the community focus of the LCD were highly influential. The post-occupancy evaluation results show that the strong sense of community and the thermally comfortable homes met residents' expectations. The association with home was as a haven, where the residents' can be creative, relax with their pets, friends and family and be safe, reaffirming the literature on what the home is associated with and validating the design of the LCD in providing this.

6.1 Recommendations for future research

This thesis echoes the call for further study into adaptive comfort (43), where the focus is on the interactions of the user with technology in their daily practices instead of an isolated focus on the technology or user themselves. Although this was a small cohort study of LCD residents, the detailed investigation of household practices has led to a richer understanding of their performance motivations and influences. This should continue to be scaled up to include more residents to broaden the understandings into various contexts (150). Alternatively, a research design that allowed for more focus on the depth of the practice may have uncovered additional insights into the performance of household practices. In attempting to study a range of household practices, this thesis has had to make concessions to the extent that each element of practices has been studied. As one of the first longitudinal studies of low-carbon household residents with a social practice theory lenses, the methodological design was limited to information and insights available in the literature at the time. Future research may be able to spend more time on data collection periods or in more in depth interviews, text probes or workbooks to add greater insight into both the depth of practices and their performance over time in the context of the home.

Inclusion of households of different socio-economic backgrounds, in different locations, particularly outside of a western urban context would also broaden the results (295). Different locations would also present different built environment and technologically innovative approaches to reducing resource use and GHG emissions dependent upon their climate, policy and culture (296). As climate change will have varying influences on locations and climates around the world, studies on different climatic zones would be interesting. This would assist in strengthening the local resilience knowledge and capacity of cities and residents to climate change impacts (297). Inclusion of different home ownership households would also allow for comments to be made on how this influences household practices and resilience to climate change. While some comments have been made around the importance of having a safe and secure house contributing to the association and feeling of home, this was not explored further in this thesis. Further investigation of how home ownership, or the changing status from renter to homeowner or vice versa, influences household practices, resource use and feelings of home would be a valuable insight to the literature.

In addition to studying geographical changes, studying the influence of culture and historical context on practices would also be a valuable addition to the literature. This thesis did not comment on the cultural context of the participants; however, some comments were made during interviews regarding the historical influence on the performances of practices such as personal hygiene or thermal comfort. These were not investigated further to allow for a wide range of practices to be studied, however there has been other studies highlighting the historical and cultural influences on household practices (238) that further research could build upon. The Low Carbon Readiness Index used in Publication V could also be altered to include cultural variations and considerations relating to household and individual practices. Additional interview questions, survey questions or text probes could be used to gather data regarding how cultural contexts influence practices as well as a focus on historical practices, particularly in childhood or other houses the participant has lived in, not restricted to the immediate household pre-occupancy to the low carbon development.

Along similar lines, the study of how household practices differ according to age groups or stage of life would also add a valuable contribute to the literature. While this study included households that contained children, teenagers and young adults, the voices of these residents was excluded from this thesis due to uncertainties around their living arrangements post-occupancy in WGV. Comments have only been made on their practices and influence on the HSOP by their parents. Additionally, this study did not include any households who were excepting or had recently introduced young children. This unique life stage may have resulted in resource changes. Other periods of life changes that could be studied include households with recently retired or re-entry to the workforce residents.

Further research could also be undertaken on waste practice, investigating what people dispose of in the compost, recycle and general waste bins (275,298) to understand more about why people are disposing of these items to inform policy on how to reduce this (299). Other research could also examine some of the household practices in more detail, such as the temperature or water level of washing loads to see if residents are using the technology in the most efficient way.

In relation to the interlocking of practices into the home system of practice, there are a number of areas that could be investigated further. One is to investigate the relationship between time restrictions and interlocked practices with regards to the performance of unsustainable practices. This is in relation to the performance of food practices and how this can be related to the interlocking of the HSOP. However, other areas to be investigated include the performance of shopping, laundry, and hygiene practices. Another area focuses on incorporating behaviour or practice change interventions and assessing how they influence the HSOP both pre and post-occupancy. This thesis purposely did not incorporate any interventions, such as those undertaken in other research (183), to enable a greater understanding of how practice theory insights and methods can be applied across a longitudinal study. With the insights provided in this thesis, interventions could be applied at an individual, household, or community level to investigate their effectiveness.

A similar post-occupancy, longitudinal study could also be undertaken once residents have resided in the LCD for a longer period. This would provide insights into the long-term influence of the design, technology and community. This would allow for a greater understanding of how practices are performed over time and if changes that have occurred during the first year of residence, when the research for this thesis was undertaken, remain. Alternatively, the data collection period could have been extended both pre and post-occupancy. This could take the form of extending the workbook data collection from two weeks to a month or more to track longer term practices around travel and hygiene. Additionally, interviews and/or the text probes could be undertaken seasonally to assess the changes in thermal comfort, travel, food, laundry, waste and purchasing practices.

In terms of the methodology used, future research should consider the use of technology and the way residents interact with it before deciding upon the approach. The use of the hard-copy of the workbooks and diaries was a deliberate decision to not discriminate on technological ownership or ability. The text cultural probes, while having a higher response rate than the postcard questions, required the participants to own a mobile phone and be prepared to spend the money on responding to the text messages. For this reason, one of the participants asked for the questions to be emailed instead to not place undue financial pressure on him. Consideration of the socio-economic position of research participants is vital to ensure they are not unduly impacted by participation in this research.

6.2 Final remarks

The opportunity to study resident's pre-and post-occupancy in a LCD has been a unique situation to examine how design, technology and community influences household practices. The development of the HSOP and further understanding of the interlocking nature of practices and their temporal and spatial implications has contributed to the next steps in SPT research.

While there are many more avenues of research to be undertaken on these topics, the results from this thesis should help to inform the development of inclusive, sustainable and community-focused LCDs and the understanding of how to influence individual and household level domestic practices.

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Publications

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Publication I

Breadsell, J.K., Eon, C., & Morrison, G. M (2019). Understanding Resource Consumption in the Home, Community and Society through Behaviour and Social Practice Theories. *Sustainability*. 11(22) 6513; https://doi.org/10.3390/su11226513

Status: published (peer-reviewed)

sustainability

MDPI

Review

Understanding Resource Consumption in the Home, Community and Society through Behaviour and Social Practice Theories

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Received: 14 October 2019; Accepted: 15 November 2019; Published: 19 November 2019

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Abstract: The practices and behaviours of individuals influences resource consumption at many scales and are shaped by a multitude of psychological, social, and technical factors. This conceptual paper examines the differences between socio-psychological and social practice theories, building on the Chalk and Cheese debate in the literature. Insight is provided into their potential value in understanding resource consumption studies at different scales: the individual, the home, community, and societal. Each theory has its own qualitative and quantitative methods which allude to different conclusions and recommendations for resource consumption initiatives. We review the debate surrounding the application of both theories, adding our voice to the potential for both theories to be used at different scales and for different time periods, along with comments on the interlocking nature of practices. Design and technology changes can lead to quicker changes in behaviour and practices, whereby socio-psychological theories offer insights into changes in mind frame, values, and social norms.

Keywords: social practice theory; behaviour change; resource consumption; scale; home; community; society

1. Introduction

This publication reviews socio-psychology theories and social practice theory (SPT) as well as methods commonly employed to influence occupants in their use of resources. The objective of this article is to discuss how these different theories can be successful to promote sustainable consumption at various scales. The term sustainable consumption refers to the consumption of more efficiently or ethically produced goods where consumers consider environmental and social aspects before purchase [1]. Reducing resource consumption to more sustainable levels has been identified as a vital path to address the pressing issues of climate change, over-exploitation of dwindling resources, and subsequent environmental impacts [2].

Sustainable consumption may be encouraged through changes multiple practices including housing, food, waste or mobility practices or individual actions involving energy and water consumption. The reduction of resource use in households is considered by many as a cost-effective step toward urban sustainability [3]. Improved building envelope design and technology are known to significantly reduce energy and other resource demand in households. However, they are not the only influencing factors [4,5]. Individuals are a key player in making everyday decisions and influencing usage through their behaviours and practices, which, in turn, are influenced by place, technologies, interpersonal relationships, society and information [6]. The implementation of strategies based on behaviour change has been a key approach to promoting resource efficiency in residential buildings.

Finding optimal behaviour change methods, in particular, targeting energy conservation has been the focus of research since the 1970s [7]. However, traditional socio-psychological approaches to enforcing sustainable consumption have failed to drive society-wide changes necessary to limit catastrophic environmental impacts [8,9].

The ideas behind changed behaviour for environmental sustainability in the home have generally been based on social theories [10–12]. Typically, socio-psychology approaches consider cognitive dissonance, social norms, information provision, and feedback to instigate change [13]. Since human-computer interactions became accessible, scientists have started deploying them on a regular basis for the delivery of eco-feedback and information. This can be referred to as persuasive sustainability [14]. This model has been sustained by economists and psychologists and has permeated its way into both the UK and the Australian policy context [15,16]. Human-computer interactions are now being deployed in smart technology and homes around the world in an effort to persuade residents to alter their behaviours and practices, and subsequent resource consumption. Change in policy and societal resource use is difficult as policymakers insist that any alternative approaches are translated into the language and terminology that they are already familiar with through behaviour change programs [17,18].

SPT is an alternative theory to socio-psychology and has been prominent in sustainable consumption debates recently. SPT originates in social theory [19] but offers an alternative approach to promoting a reduction in resources consumed. SPT scholars argue that resource consumption depends largely on the practice used to carry out activities [20]. A practice is a routinised action that is composed of a number of interconnected elements: meaning, skill, and technology [6,21]. In SPT, the practice is the unit of analysis, and change can be made to practice through the alteration of one or more of the elements. The innovation of a product or procedure can, therefore, act as an enabler of sustainability, especially when designed in conjunction with users. This is referred to as non-persuasive sustainability [14], although we prefer the term enabling sustainability.

Socio-psychology theories view resource consumption as something that an individual uses depending on their personal values as well as norms, which are influenced by society. SPT approaches focus on the practices and bundles of practices that resources are involved in when these practices are performed [20]. There has been a provocative debate in the literature around the merging of socio-psychology theories with SPT for use in resource consumption studies and policy contexts, termed the Chalk and Cheese Debate [15,22,23]. Each theory has its own qualitative and quantitative methods which allude to different conclusions and recommendations [24]. In this conceptual paper, we argue that rather than being antagonising theories, both theories have a place when applied within the home space. SPT provides a valuable addition along with socio-psychology theories in understanding the complex dynamics between resource consumption and human actions [25–29].

This paper starts with a narrative literature review of SPT and socio-psychology theories that consider domestic resource use and consumption. A narrative literature review is an established approach to exploring the literature surrounding a topic in both the socio-psychology and SPT domains, allowing in-depth insights to be obtained [30]. The search terms used include: Social practice theory, practice theory, socio-psychology theory, psychology theory, theory of planned behaviour, cognitive dissonance, social norms, habitual behaviour, habits in the home, and timing of routines. However, the topics have been explored mostly through starting with seminal papers and exploring the references as needed. This review is followed by a discussion of the Chalk and Cheese debate, a review of the state of the literature surrounding the influence of scale and time on the performance of behaviours and practices and finally, comments on how the two theories insights can be applied at the scale of the home, the community and society.

2. Social Theories

SPT and traditional socio-psychology theories are described in this section through a narrative literature review. The main point of difference between them is the unit of analysis: socio-psychology theories focus on the individual while SPT focuses on practice as the unit of interest. This review does not comment on the political influences and ideologies of the two theories as it is outside the scope of this research.

2.1. Socio-Psychology Theories

Socio-psychology is the study of people's interactions with the wider society and examines how individual behaviours, thoughts and attitudes are influenced by others, either consciously or subconsciously through social and cultural norms. Several socio-psychology theories have been developed since the 1920s and are still employed today to explain individual behaviour. These theories are frequently used for the development of pro-environmental behaviour change programs and include the theories of planned behaviour, cognitive dissonance, social norms and habitual behaviour. There is often an assumed linear relationship between information/awareness, attitudes and respective behaviours [18]. It is assumed in socio-psychological literature that individual change will result in social and resource use change [31].

The theory of planned behaviour predicts that behaviour is preceded by the attitude towards the behaviour (i.e., beliefs and evaluation of the outcomes), subjective norms (i.e., the perception of the behaviour by others) and perceived behaviour control [10]. This means that an individual who is concerned about carbon emissions, for example, might not act to reduce these due to a lack of perceived personal impacts. On the other hand, the likelihood of engagement leading to behaviour change may increase if an individual is consciously supportive of the cause or if the individual simply agrees to take action [32]. This is in accordance with the theory of cognitive dissonance which posits that people are uncomfortable to find themselves in a situation in which their attitude and behaviour are inconsistent and will, therefore, make changes towards correcting this discrepancy [11]. These adjustments can be made through changing behaviour, changing beliefs or creating new cognitive elements aligned with the behaviour [11]. This need for consistency is recognized as an opportunity to encourage behaviour change through triggering individuals' values and self-concepts, effectively making them aware of potential dissonances [33]. This can be employed through the use of nudging or prompts [34].

Whilst personal values and beliefs affect people's behaviours, individual conduct is also influenced by the behaviours and judgment of the wider society. These unspoken social rules are referred to as social norms, which are of two kinds: descriptive and injunctive [12]. Descriptive norms define what the customary behaviour is in a given situation. Injunctive norms, on the other hand, prescribe how one should behave either by approving or disapproving of the behaviour. For example, a study on littering showed that people are more inclined to drop litter in littered locations. In contrast, clean environments tend to remain unlittered for longer periods of time [12]. Social norms are even more effective when encouraged by a peer in the form of a social intervention [35].

The theories of planned behaviour and cognitive dissonance consider individuals as purely rational, evaluating outcomes as well as the costs and benefits of certain decisions, however, daily habits can prevent long-lasting change [36]. Habits are prompted to meet a specific goal and if the goal is met in a satisfactory manner, the tendency is for individuals to repeat the same behaviour on the following occasion when the same goal is being sought [37]. Repetition requires less mental effort, which can lead to unintentional habits forming and once habits are established, future actions are likely to be guided by them, regardless of values, attitudes or norms. Due to the unconscious nature of habits, habitual behaviours are only reviewed when provoked (or nudged) or in the event of a change in context [34,36]. This change in context for modifying behaviours is also what SPT advocates as a way to influence resource consumption.

Most interventions from socio-psychology theories fall into three categories, referred to here as social, technological and knowledge-based interventions. Social interventions involve some form of social interaction, such as face-to-face meetings, audits or workshops. Unilateral impersonal communication such as letters, emails, bills or marketing campaigns has been categorized as knowledge-based interventions. Technological interventions are methods that rely on technology and do not involve any kind of social interaction. That is, in-home displays (IHDs), websites and automatic messages deliver feedback, norms, prompts, nudges and goal setting. IHDs can break down energy usage by appliance and show energy consumption in different formats, catering to different audiences while providing real-time and long-term feedback. Some researchers argue that this method enables the interaction of households with the data and therefore higher engagement [38] and appliance control [39], leading to a significant reduction of electricity consumption [40,41]. However, arguments against the deployment of IHD's focus on the fact that displays are designed by researchers and do not necessarily correspond to what the user wants to see, reverting to the background situation after a novelty period [14]. Brynjarsdottir and colleagues argue that this technology is trying to persuade the user to change rather than providing solutions to change [14]. In addition, the deployment of IHDs to influence behaviour assumes that the user has previous knowledge of interaction with this technology and that the user makes this part of everyday practice. Ongoing research is occurring on how to improve IHDs. However, there are marked differences in individual use even within households so a one-size-fits-all approach seems hard to design [41–43]. There appears to be a level that residents reach in their behaviour changes influenced by the IHDs after which more change is resisted because it disrupts routinised practices in a way which is uncomfortable or unworkable [42,44].

2.2. Social Practice Theory

SPT was proposed in the early 2000s as an alternative to socio-psychology theories [6,19,45–53]. SPT posits that the world is populated by social practices and their interconnected elements [16]. Human behaviour is not the result of rational choice but of the many half-conscious and highly routinised actions people take in their everyday life [54].

Individuals do not use resources such as water or energy directly, but rather with the objective of achieving a desired social outcome, an everyday practice such as cleaning, shopping or dining. In order to understand domestic resource consumption, it is therefore important to comprehend the practices involved in achieving daily objectives [25]. SPT views practices as the unit of analysis, being the mundane activities that make up most of our daily lives such as cooking, cleaning, laundering, personal hygiene and keeping thermally comfortable [55]. Practices are formed by three interconnected elements: technology, skills and meaning [21,56]. Technology is the artefacts that are used in the performance of the practice, skills are the know-how or competencies necessary to execute the practice and meaning is the understanding, assumptions, values and symbolic meanings associated with the practice, including the attitudes and feelings [57]. A change in practice can be achieved by altering one or more of these elements. The three-element model has been praised for its effectiveness in examining all the elements of practice, including non-human, material elements, different forms of intellectual and embodied knowledge, and cultural differences [58]. This allows for objects to be studied at the same ontological level as individuals, without the individual being the principal unit of analysis as it is in socio-psychology theories. Practices are social in the sense that they can be shared by many different individuals, through connected elements of meanings, technology and skill even if they are in different locations or across different time spans. It is through the repetition of practices that they become embedded in everyday life [59,60]. SPT moves beyond the single behaviour analysis of socio-psychology and examines the relationships between practices and their existence across space and time [20,21,61]. Practices can interlock with others to form bundles of practice or systems of practice (SOP) that can have socially shared knowledge, meaning, skills or technology [52,62,63]. This occurs when there are multiple practices taking place at the same time or in a similar order, such as a morning routine of having a shower, making breakfast and driving to work in the same way each workday. When multiple SOPs exist in the space of the home, this can be termed a Home System of Practice (HSOP) [21,56,61,64].

Everyday practices have a dynamic nature because as technologies, infrastructures and meanings change over time, existing social practices become obsolete and new practices become embedded in new routines [65]. Modern technology may influence the way a practice is performed. For example, capsule-based coffee machines imply that consumers buy the manufactured coffee capsules for the coffee making practice [24]. Consumption is interwoven in practices as a by-product of undertaking the practice and can be hard to change due to their habitual and interlocking nature [17,52,66]. SPT argues that change in practice should occur through three main ways: a change in an element of the practice, disconnecting a practice from its interlocking counterparts or bundles, or inserting a new practice entirely to replace the old one [67].

A change in an element of a practice could be through changing the meaning (altering the need that an individual aims to fulfil and how this relates to their perception of their lifestyle, comfort and wellbeing), changing a skill (through education and training) or changing the technology used to carried out the practice (through the introduction of new technologies). This also applies to sustainable consumption practices [8,67]. Skills or meanings may be learnt or influenced through changes in context (e.g., visiting a local farmers market instead of a supermarket to purchase food).and technology can be modified to reduce the use of resources (e.g., low-flow showerheads instead of regular ones) [64]. It is in the realm of changing the meaning element that socio-psychological theories have an opportunity to share insights.

In the context of the home, changes in resource consumption have often been studied for individual practices [21,57,68–77]. However, individual practices form part of the HSOP and should not be targeted in isolation. The HSOP is a network of the practices performed by home occupants on a daily basis forming part of a routine [21]. Routines, composed of practices which are reproduced in a sequential manner (e.g., shower, breakfast, drive to work, etc.), overlap and interlock with one another [21,56], creating a home equilibrium (Figure 1a). These practices have specific temporal and spatial characteristics [78], which means that when performing practice in a specific location such as the home, occupants must consider other occupants' own practices and routines so as to coordinate them from a time and space perspective. For instance, the practice of showering is dependent on the shower being unoccupied at a particular moment in time.

Intervening in the HSOP to alter resource consumption can be done through changing an element of the practice as previously discussed. However, this requires all occupants to adopt the change. The introduction of new practices (e.g., checking an IHD) require established routines to become destabilised (Figure 1b) and realign, finding a new equilibrium (Figure 1c). Unless a realignment of everyday practices occur, new practices cannot become embedded in the HSOP and fulfil a specific role. Consequently, they might not be adopted by the home occupant.

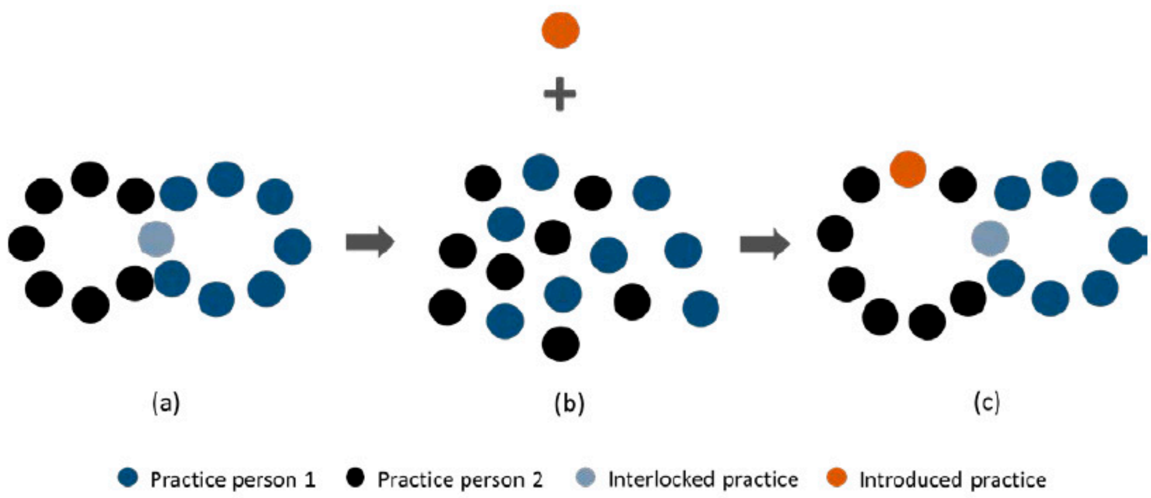

Figure 1. Equilibrium of practices in the home. (**a**) Original home equilibrium, (**b**) Destabilisation of the home equilibrium through the introduction of a new practice, (**c**) Realignment of practices and establishment of a new home equilibrium [56].

Encouraging resource reduction and efficiency can help to promote sustainable consumption, but this encouragement assumes that behaviours are static over time and are the result of conscious customer decisions and available technology [20]. It also ignores the often surprising links between seemingly unrelated practices [25]. SPT is useful for targeting inconspicuous practices and those that are deeply rooted in the normal living behaviour of individuals [25,79]. Practices are dependent upon the institutional arrangements, household context, economic influences and cultural traditions of the environment that the practice exists in [49]. Hence, the scale implications of practices and behaviours need to be considered when discussing their influence over resource consumption. The reproduction of practices and their proximity in space and/or time influences their degree of interlocking [21,61,67]. Consecutive practices that are part of a daily sequential personal routine are highly interlocked. For instance, morning weekday personal showers are highly interlocked with the practice of breakfast, which is in turn highly interlocked with the practice of transport to work. It is posited [21,61,64,67] that practices are highly interlocked when they occur at a similar time and at the same place (Figure 2). For instance, person 1 (P1) having a personal shower in bathroom 1 will influence person 2 (P2)'s shower in bathroom 1 if it is carried out at a similar time because P1 and P2's showers are limited by P1 and P2's own interlocked routines. Practices that occur at different times and in different places may not show the same degree of interlocking. Practices may be lightly or indirectly interlocked if they occur at the same time but in different places. For instance, the water heating technology may not work if P1 and P2 have personal showers at the same time but in two separate bathrooms, indirectly interlocking the two showering practices. Conversely, practices that occur at the same place but at different times may also indirectly affect each other.

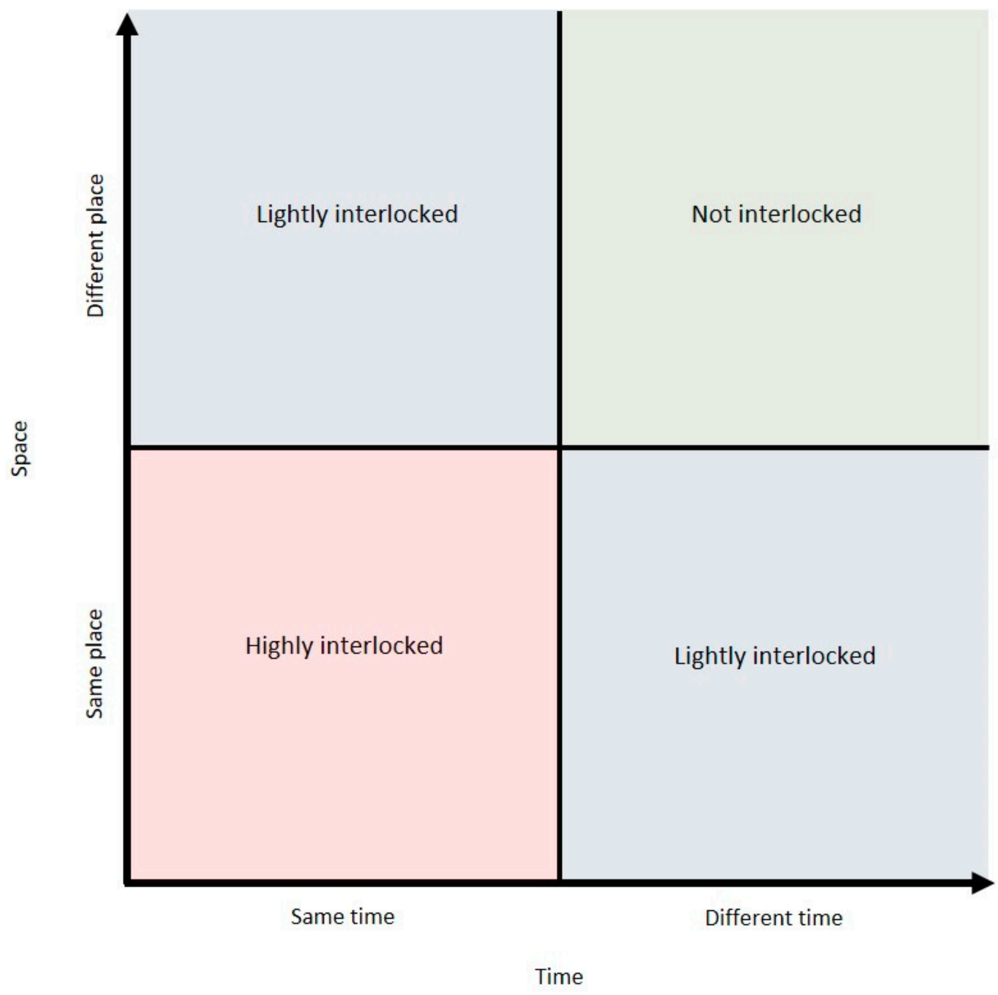

Figure 2. Interlocking degree of practices according to their reproduction in space and time.

3. Chalk and Cheese Debate

The merge of SPT with other theories has been previously attempted [80–83], these attempts focus on the individual and use SPT to deliver unique insights into daily practices. For instance, researchers have sought to merge theories of governmentality and SPT [84] to produce complementary insights bridging some of the weaknesses found in each of the theories. However, the latter approach has been either top-down or too focused on mundane daily practices to result in workable policy insights. Social practices have also been examined alongside transition theory, utilising the multi-level perspective (MLP) understanding to place practices at different socio-technical levels [85–87]. Building end users are examined through facility management and SPT in [88]. Some of the founders of contemporary SPT including Foulds and Macrorie utilise sociotechnical systems to understanding everyday practices [89,90]. However, the merge of socio-psychology theories and SPT has been a focus of disagreement termed the Chalk and Cheese debate.

Shove in her original (2010) article argues that psychological or behaviour change models have received too much engagement by policymakers and this has resulted in ineffective resource consumption policies being implemented [15]. The argument is made that psychological theories are confusing because while they posit that there are many factors influencing behaviours, they also claim that behaviours are deeply embedded in social situations, institutional contexts and cultural norms, locking consumers into particular habits. Shove outlines that the Attitude- Behaviour-Choice (ABC) model of policymaking (based in socio-psychology) has failed because of the value-action gap between individuals' reported environmental values and their behaviours. Shove argues that the ABC approach fails to take into consideration the practices of everyday life that affect the resources used by consumers [15]. According to her, behaviour change theories are based around the incorrect assumption that social change is to be dependent upon values and attitudes which drive the behaviour that individuals choose to adopt [17].

In rebuttal, Whitmarsh and colleagues argued that the dismissal of psychological models is ill-conceived [23]. They also note that other authors [91] refer to the C in the ABC as context rather than choice. Context considers the broader situation that the individual is situated in while choice focuses on the individual state of mind and actions. Considering context is vital in understanding social practices as it influences the elements of practice and how technology is used [41].

Whitmarsh and colleagues argue that if a pure SPT approach was to be incorporated into policy, individuals would run the risk of being excluded from societal decision making and participation, due to the focus of analysis moving to the practice itself, instead of the individual and their state of mind [23].

In response, Shove [22] argues that the two schools of thought have fundamentally different ontologies. The SPT ontology is that the world is populated by social practices and their interconnected elements, while socio-psychology theories are focused on individuals and their behaviours [16]. While we acknowledge this to be true, we do not discount the usefulness of both theories in providing insight into resource consumption patterns and practices of individuals, homes, communities and societies [92]. In fact, researchers are beginning to incorporate these theories into new models. Nevertheless, they require more empirical evidence to determine their success in reducing domestic resource consumption [31,93]. The theoretical differences between the two schools of thought are less relevant when considering interventions and policy recommendations [94].

The next section examines the different scales for application of these theories, whereby socio-psychological theories can offer useful insights for influencing the meaning of practices and SPT can offer insights on the material and technical structures that constitute practices [94].

4. Research on Space and Time Insights

Human choices are dependent upon the conditions under which the choice is made: these choices have temporal and spatial dimensions [17]. This was identified early on in the SPT literature by Schatzki, stating that practices are both anchored in and dispersed across space and time [19]. We posit that insights from behaviour and practice theories have different roles based on the temporal and spatial dimensions they are being employed in. Practice insights can result in almost immediate changes in the way that practice is performed (for instance, if adopting a new technology), while behaviour insights often entail a longer-term cultural and societal shift (as it requires a shift in values and social norms) and can target the meaning element of practice.

The scale is an important consideration in the study of practices and behaviours. Practices depend upon individual performances for their continued survival and it is individuals who carry and integrate the necessary skills and knowledge that make each performance possible [25,46]. Practices are often nested in each other and have complex relations in the SOP. Practices are dynamic and mobile through their reproduction as performances and as such, exist in various temporal and spatial locations. This has also been termed time-space whereby space is simply a place to carry out particular activities or practices at a certain time [95]. By focusing on the actions of individuals rather than the individuals themselves, SPT brings aspects of space and time to the forefront of the decisions of everyday life [34]. SPTs have been critiqued for focusing more on the performances of practices rather than the mental or emotional state or events. Socio-psychology theories can fill this gap by directing attention to the values, norms and mind frame of individuals when they are engaging in the performance of an action [24,96].

In the SPT literature, practices are referred to in two different states, a practice-as-entity is a practice that endures over space and time and is composed of the three elements (i.e., meaning, technology and skill), while a practice-as-performance is when the elements are brought together and are different each time because of the context [97]. The practice-as-performances can be used to collect data on activities and resource consumption for analysis while practice-as-entities are used to sketch patterns of historical development and understand context [18]. Behaviour change insights may be suitable for influencing practice-as-entities, whereas the practices-as-performance may be more targeted through SPT insights such as changes to the technology or skills used to perform the practice.

Practice insights should also consider the context in which they are being performed, this harks back to the Chalk and Cheese debate and the role of the C in the ABC method: context or choice. Context is vital in understanding why a practice may be performed the way it is: people may choose to cycle to work because driving takes too long due to traffic congestion, not because of environmental concerns [94]. SPT provides this insight through considerations of meaning, while socio-psychology insights may miss this reasoning altogether if the context is not considered, although in some work it is [94]. Recent work has examined the material (or technology) element separately from the practice and discussed how the materials used in a practice influence space and time that the practice, and other practices, are performed [98]. Engaging in one practice rules out engagement in another at the same time and can then influence what practices are performed when and in what space [50]. It has been suggested by multiple researchers that to instigate change, focus needs to be placed on the junctions in space and time that constitute opportunities for change and innovation [67,70,78,99–101]. This may occur at times such as moving house, targeting new technology being installed or new communities that can influence social norms [56,61,64].

Research on the different spatial aspects of practices has included those of travel, snacking and recreation [51,102]. Due to changes in technology, the daily commute now involves many different practices that previously would have been performed at home or work. These include reading, writing, making phone calls, homework, self-care, drinking and eating [103]. Socio-psychologists have studied the habitual routine of travel choices and how to influence these through choice option, information and situational cues [104]. Those who have a strong habitual routine in their travel practices are less influenced by information and cues, however, habits can be broken through manipulating either accountability demands or the level of attention paid to the actions of the behaviour. The physical infrastructure used for mobility can influence what choices people make in how to perform practice. For instance, a high degree of car road networks and poor public transport options can influence the level of care practices performed [105].

The timing of the performance of behaviours and practices is a pertinent topic in relation to resource consumption, particularly in the home [101]. Recent work in the SPT literature has brought the temporal aspect of practices under analysis. This work concludes that time is socially constructed, with clear divisions between practices performed during the weekdays and weekends [78]. Some practices require a fixed location either in time or space to be performed, such as drying of washing can only occur after the clothes have been washed and this occurs with particular technology and skills [50]. The temporal placement of the actions and the associated network of relations that surround it, as investigated in socio-psychological theories, influences individuals actions [99].

Peak loads of resource consumption in households are associated with different forms of synchronizations, or particular behaviours and practices being performed together [50,106], as well as meanings and values associated with convenience and control in daily life [70]. For instance, the performance of energy consumption practices in households is tightly interlocked with the temporal patterns of the daily practices of the residents in the house [70,78]. Peak demand practices are performed during the evening, particularly between 17:00 to 21:00, when residents are preparing dinner, using electronic devices and keeping thermally comfortable with mechanical technology [107]. With the rise of renewable energy, the demand for energy during the peak hours of the morning and evening do not match when the energy is being generated [108]. Residents may be unwilling to alter their energy-intensive practices to match the time when energy is being generated even if it would change their resource carbon footprint (such as having shorter showers [61,64] or use less energy in the evening [41]). Recent studies have examined this further, finding that washing has the greatest time dependence in practices each week, being performed at a regular time by households, while using computers is the least time-dependent [78]. These findings can be used to develop interventions into resource consumption of both individuals and households.

5. The Home, Community and Societal Scale Applications

Individual behaviours and practices are often studied in-situ as this provides an easier contact point for the researcher. However, these actions do not occur in a bubble, devoid of contextual influence or never being performed in different locations [78]. Practices and behaviours tend to cluster together in particular places, being performed by many people in similar ways [78]. These can be based around the home scale, the community scale and the social scale. Other authors have referred to these scales as the individual, inter-personal networks, community, segments and population [109]. Inter-personal networks consisting of families, households or social groups. Community spaces are where people who share values or perform similar activities together clusters, such as at sports centres or religious gatherings. This can be linked to ideas of community of practice [25,110] where communities are the site of learning by individuals. Interventions are applicable for each level, taking advantage of social connections, temporal elements and domain influences over the behaviour [109].

To create long-lasting change in favour of sustainable consumption, we propose that all levels of society need to be targeted. The schematic in Figure 3 outlines how we propose SPT theory and behaviour change theories can best be applied at different scales. Practice insights can be used to achieve quick changes in a specific physical space (e.g., the home) while conserving established routines and respecting the HSOP where multiple individuals interact. This can be obtained through the implementation of technology that does not interfere with the timing or order of practices. Behaviour change, on the other hand, requires a shift of societal and cultural norms to be effective. Values and norms driving individual behaviours are usually present at all levels of society and are independent of space and time.

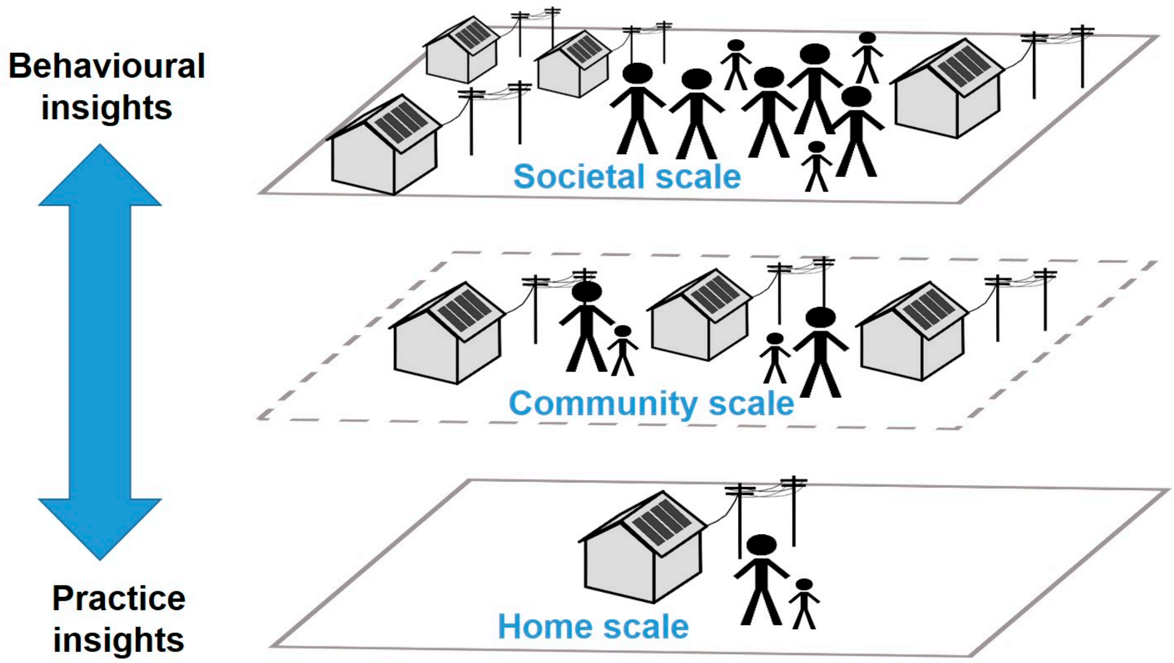

Figure 3. The different scales that behavioural and social practice theory (SPT) insights can be best targeted.

5.1. Home Scale

Interventions through socio-psychology methods in the home may only last for a short period of time, while design changes based on SPT insights will last for years, if not decades [111,112]. In spite of the limited data, the few existing longitudinal behaviour change studies suggest that some persuasive methods have longer-lasting effects than others in the space of the home [13]. Information campaigns, for example, might be effective for a short-term solution, such as saving water in summer [113]. IHDs can be a good tool while it is a novelty, but if it does not meet consumer needs, the technology quickly becomes idle and its effectiveness might only last a few months. Other interventions such as teamwork [114] and audits, which demand a higher level of personal engagement, might last a few years. Previous research has shown that behaviours end up reverting to what they originally were after the behaviour change intervention is interrupted, even if nudges or prompts are utilised [14].

Behaviours are influenced by close relationships as well as the wider society and culture and their insights would be better applied at a community and societal scale [15,65,115].

Design modifications at a household level based on SPT insights result in the change occurring to resource use [97]. For instance, changes can be made to the physical building system (e.g., the addition of such as insulation, shading devices or solar panels), resulting in a reduction in resource consumption. Technology can also be used to dis-interlock practices through automation, enabling lasting reductions in energy, water and resource use [21]. Automation is a once-off change, allowing a 'set and forget' mentality to drive the practice in future, reducing the need for human intervention and thus failure.

The replacement of current technology with technology that enables change through everyday practice can have a long-term effect on resource reduction. Rather than requesting that households turn off their standby appliances manually, for example, appliances without a standby mode could be provided instead [56]. The success of innovative technology is dependent on user knowledge and can be hindered by rebound effects. However, the implementation of practice-based design and co-creation is a contemporary approach which ensures that users not only take part in the design of a technology that is needed in the long-term, but also understand its function [116–119].

When technology is used to modify a practice (through SPT insights), it targets the specific space where the practice is carried out, without modifying the HSOP or the timing of the practice. This can enable change without requiring persuasion [14].

5.2. Community Scale

Community spaces are where people who share similar values or perform similar activities together [109]. Insights from both SPT and socio-psychological theories can be applicable at this scale, particularly regarding social norms, shared practices and information diffusion. Values and practices are co-constructive, where a person's beliefs, ethics and worldviews simultaneously shape and are shaped by their performance of practices [120]. Practices and behaviours that these insights have been applied to previously include the practices of mobility or food shopping [105,119,121,122]. Applications from the temporal studies of practices and behaviour can be applied at this scale through targeting when people are utilising the space if there are peak times that they are there and using resources that would be more effective to target them than others.

The ideas of both socio-psychological theories and shared practices have been discussed in the literature as a "community of practice" [25,110] where communities are the site of learning by individuals. Interventions in practices and behaviours that consider communities of practice have been shown to be effective in research targeting changes in driving cars within small villages, cooking for large groups of people once a week, shared community gardens and shared compost systems [123,124]. Through creating a sense of community between people, the impact that practice or behaviour has through sharing skills and being visible is increased, normalising what is being done and highlighting the actions of a group and the need to change social practices for sustainable impact [101]. These insights can be effective in changing practices and community perceptions of sustainable consumption [64,125,126].

Changing the skill of practices performed is also a way to target interventions on a community scale and can be achieved formally through education or social learning, such as through demonstration workshops or discussions amongst friends [69]. These groups can be communities of practice and be used as a targeted place to initiate practice and behaviour changes. Changes in skills, however, can be assumed to take longer to generate desired outcomes, as it is necessary for the skill to be learned and implemented [127].

5.3. Societal Scale

As previously discussed, the meaning relating to practice is closely connected to the context of where the practice is carried out and of what is socially acceptable. For instance, if the use of an electric heater is the norm to achieve warmth in the home, then the use of blankets, for example, is not considered a viable solution. This has been discussed in previous research, where residents who would usually not use auxiliary heating to keep themselves warm at home, will use it when friends or family visit because they believe it is the social norm [61].

Modifying the meaning of practices requires a societal shift, which is where socio-psychology theories can be used to best effect [64]. Social and structural changes [99], if perpetrated by government and organisations, or communities of practitioners, can affect cultural and social norms, along with the diffusion of knowledge [99]. Research has found that individuals perceive the solutions to climate change to be at the national or organisation level [99]. This highlights the expectation that individuals have that these changes will be disseminated from a societal scale. This can be through policy changes, information and education campaigns, and long term changes to cultural and social norms that may take generations to take effect. An example of this is the importance of change agents in the energy sector. These individuals can champion certain ways to perform practices that use fewer resources or shift the timing of the performance of energy-intensive practices through education or social norm campaigns [128].

Socio-psychology behaviour change programs have previously been applied at a societal scale to effectively encourage the use of seatbelt in cars. Results from multiple decades show that effective and well-planned media and enforcement campaigns can have a positive impact on seat belt usage rates [129,130]. Other research shows how an SPT understanding can be applied to enable change in specific places. Through providing people with belt-positioning booster seats (technology), education on its use and benefits (skills) and a social marketing campaign to emphasise social norms (meaning), effective behaviour change was achieved [131]. These examples show how on a societal scale, both socio-psychological and SPT insights can lead to enabling people to change effectively.

6. Conclusions

The significant challenges posed by climate change and overpopulation require an understanding of resource consumption across all scales of society. Policy implications should consider the reach and durability of various interventions targeting the reduction of resource use (e.g., energy, water, materials) if they are to be applied effectively [68]. Persuasion and enabling methods are usually not aligned in behaviour change studies as they are seen as two distinct methodologies. We argue that they are in fact trying to achieve the same objective, which is to reduce resource consumption in households but approaching it through different angles. On the one hand, socio-psychology uses persuasive methods to address personal energy use from a top-down approach, delivering social norms and providing information. On the other hand, SPT's enabling methods are very focused on the elements of a practice that are utilized in the performance and addresses consumption from a bottom-up approach. Rather than being conflicting methods, the two schools of thought complement each other, filling each other's gaps, informing and modifying attitudes while enabling long-term changes that bring value to the user.

The timing of the action is key because the practice or behaviour is limited by the context and influenced by other concepts such as comfort and convenience. Given the complexity of the home system, this paper suggests that rather than disestablishing, realigning and recreating interlocked connections and practices, automated technologies and design changes could enable improved resource efficiency. Automated practices can be performed at flexible times and in concert with other household technologies, removing the need for the occupants to be directly involved in the performance of the practice. Yet, they are still required to meet occupant needs and skills to be able to work effectively.

Socio-psychology theories have traditionally informed resource reduction in households from a user point of view. Their aim has been to modify behaviour by changing existing attitudes, knowledge and values without necessarily understanding the reasons behind existing behaviours, but rather focusing on the use of persuasion to promote change. It is imperative that consumers understand the implications of their actions and adopt a positive attitude towards resource consumption, but changing behaviour may involve perceived lifestyle impacts or change of embodied habits that require high levels of commitment which may, or may not, be feasible in everyday life. Studies testing the long-term effects of socio-psychology interventions suggest that the effects of most persuasive behaviour change methods last only between a few days and a few years, stopping as soon as making changes becomes too difficult, disruptive or loses the novelty effect. SPT offers a different approach to close some of the gaps found in persuasive interventions through investigating what drives people's practices and the reason for certain behaviours, that is, what and who is influencing the user in question. As highlighted by SPT researchers, people do not consume resources as such, but resources are used during the performance of a practice. Technologies used to achieve these practices are therefore a key part of the practice and have a direct impact on resource use. These changes can be effectively applied at the scale of the home to drive resource change. Insights from socio-psychological theories can be best applied at the community and society scale where changes to values and social norms, along with information diffusion and education can drive long-term change. Understandings of communities of practice and change agents from the SPT literature can assist in delivering interventions.

Having an understanding of what drives practices and behaviours at the individual, home, community and societal scale allows the focus of policymakers to be on designing and implementing effective interventions that will enable sustainable consumption in society. It also enables designers of new technologies to focus on the material elements and skills that can assist users to make permanent changes rather than just convince them that change is necessary.

Author Contributions: Conceptualization, J.K.B., C.E. and G.M.M.; methodology, J.K.B. and C.E.; validation, J.K.B. and C.E.; formal analysis, J.K.B. and C.E.; investigation, J.K.B. and C.E.; resources, J.K.B. and C.E.; data curation, J.K.B. and C.E.; writing—original draft preparation, J.K.B. and C.E.; writing—review and editing, J.K.B., C.E. and G.M.M.; visualization, J.K.B. and C.E.; supervision, G.M.M.; project administration, J.K.B., C.E. and G.M.M.; funding acquisition, G.M.M.

Funding: This research is funded by the CRC for Low Carbon Living Ltd (Project number NP2006) supported by the Cooperative Research Centre's program, an Australian Government initiative.

Conflicts of Interest: The authors declare no conflict of interest

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Publication II

Eon, C., **Breadsell, J**., Morrison, G. M. & Byrne, J. (2018). The home as a system of practice and its implications for energy and water metabolism. *Sustainable Production and Consumption.* 13, pp. 48-59; https://doi.org/10.1016/j.spc.2017.12.001

Status: published (peer-reviewed)

Sustainable Production and Consumption 13 (2018) 48–59

Contents lists available at ScienceDirect

Sustainable Production and Consumption

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

Research article

The home as a system of practice and its implications for energy and water metabolism

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ABSTRACT

Policy and regulations for residential houses often consider the physical system alone and tend to focus on the energy performance of the building. This ignores the effect of occupants' everyday practices and their interaction with the building technologies. This research applies practice theory and the concept of system of practice to eight Australian homes with the objectives of providing a deeper understanding of the complexities of the home system as well as providing approaches to enable (rather than persuade) resource reduction. The homes were investigated through explanatory design mixed methods which combined results of one year of longitudinal quantitative data collection and home occupant interviews. The results revealed that practices are performed in a sequential temporal spectrum as part of a routine and are influenced by interlocked practices as well as interlocking routines from other home occupants. Practices also follow established daily patterns reflected by a frequency distribution curve where the standard deviation reflects the degree of habituality of the practice. Highly interlocked practices with a high degree of habituality are challenging to affect. However, automation could enable resource intensive activities to be dis-interlocked from an established routine and make change within the home system of practice easier and more flexible.

Keywords: Home system; Everyday practice; Energy; Water; Automation; Routines

1. Introduction

The home can be considered a juxtaposition of the physical system including associated energy, water and resource metabolic flows (Harder et al., 2014) with the occupied social system of everyday practice (Guy and Shove, 2000) (Fig. 1). The concept of metabolism is used to describe the flow of materials and energy through an urban system, which similarly to living beings, consumes resources, transforms them internally and generates waste (Girardet, 2010).

The implementation of technologies which lead to more efficient buildings, including energy and water efficient appliances, renewable energy and sealed building envelopes, has been a significant focus for research (Moore, 2012). In contrast, the home itself is not well understood and a theoretical and practical understanding of the complexities of occupant behavior and their interaction with the physical system of the building is an emerging area of investigation (Keyson et al., 2017). Attempts at reducing home resource use through changing attitudes and values and intelligent design features, may be confounded when users resist external control or refuse to change their behavior (Scott et al., 2012). Another approach has been to classify homes into simple typologies with targeted policy or resource criteria but these encounter similar issues of push back from the home residents (Ashton et al., 2016).

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Received 16 June 2017; Received in revised form 13 November 2017; Accepted 4 December 2017; Published online 16 December 2017.

https://doi.org/10.1016/j.spc.2017.12.001
2352-5509/

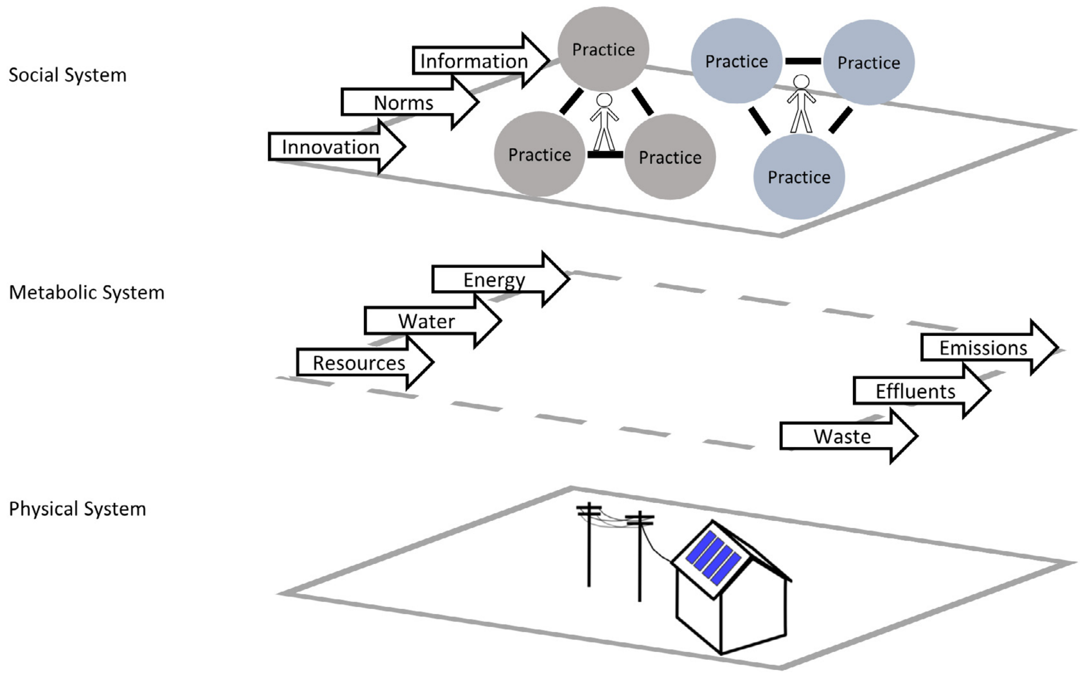

Fig. 1 – The home system, which includes the physical building system, metabolic flows and occupant practices, which are connected in a system of practice (SOP).

Proponents of practice theory argue that innovative user technology cannot be adopted without innovation in practice (Shove et al., 2012; Strengers and Maller, 2014). Smart meters, feedback displays and automation technologies are increasingly deployed to reduce energy and water consumption in residential homes (Faruqui et al., 2010; Fischer, 2008; Jain et al., 2012; Yew et al., 2012). However, these technologies do not necessarily fulfill their objectives if they fail to become embedded in the habits and routines that compose the practices of daily life (Brynjarsdóttir et al., 2012; Strengers, 2011). As a consequence, reducing energy, water and resource use in homes depends on the available infrastructure and technology, but also on occupant's everyday practices (Shove et al., 2007).

Practice theory (Shove et al., 2007), also termed social practice theory (Schatzki, 1996), identifies practice as the preferred unit of analysis rather than the individual (Reckwitz, 2002; Røpke, 2009, 2001; Schatzki, 2002; Schatzki et al., 2001; Shove et al., 2012, 2010, 2009, 2007; Warde, 2005). The advantage is that this approach provides a holistic view to understanding occupant behavior as it recognizes that elements of place and broader societal aspects affect the way practices are carried out in addition to individual values and attitudes (Hargreaves, 2011). Moreover, practice theory posits that individuals do not use resources for the sake of it, but rather as a means to achieve an objective. Therefore, comprehending the external context and occupant needs is crucial to understanding home resource use.

A practice is characterized as a routine behavior composed of several elements which are interconnected (Reckwitz, 2002). As practice theory is still emerging, there is a lack of a unifying model of assessment, however most models feature a number of elements (McMeekin and Southerton, 2012; Schatzki, 1996), the doings and sayings which collectively form the entity of a practice. These previous models can be collated into the three elements of practice defined here as meaning, skill and technology (Fig. 1). Meaning is the aspirations, emotions, ideas, perceptions, symbolic meanings and values associated with the practice (Shove et al., 2012). Skill refers to the know-how, technique, and understandings for accomplishing a practice (Scott et al., 2012), although an important distinction of skill exists between implicit know-how and explicit rule-based or theoretical knowledge (Gram-Hanssen, 2010a). Technology is referred to as the devices used to perform a practice which are the infrastructure, materials and objects (Gram-Hanssen, 2010b). Practice theory should not be confused with the study of cultural practices that is currently being undertaken by cross-cultural psychologists (Kashima, 2014; Kashima et al., 2015; Kashima and Gelfand, 2012).

The implication of applying practice theory to the study of household resource use is that the sources of changed behavior lie in the development of practices (Warde, 2005). The quantitative monitoring of technologies utilized in a home reveals the performance of the products (Foulds et al., 2013), but not necessarily how the resource use fits into the broader systems of the home. Habits and routines co-evolve with practices (Shove, 2004) and the practices relating to the use of resources in the home are manifested in their daily performance (Chappells et al., 2011). Practices exist both in the historical collective reproduction of them as practice-as-entities and in their performance by individuals (Schatzki, 2002), the former being the storage of knowledge and learnings of the elements of the practice (meaning, skills and technology) within a practitioner's mind. Some household members have similar practice-as-entities in that everyone understands practices the same way and thus perform them similarly, resulting in resource use patterns, such as similar shower times. When practice-as-entities vary, we see intra-home and interpersonal variances in resource use and the performance of practices that are related to household habits and routines (Røpke, 2009). Section 3.1.1 outlines in more detail how a change in one part of the practice entity can influence the performance, and as such resource use, of the practice.

This paper builds on the approach that the continual reproduction of habits and routines that compose practices within a home are connected in a system of practice (SOP) (Watson, 2012). The interconnectedness between practices is referred to as interlocking (Fig. 1) (Macrorie et al., 2014a; Spurling et al., 2013; Spurling and McMeekin, 2014) which emphasizes that individual practices are inseparably bound up in the spectrum of everyday practices that are combined in bundles across space and time (Macrorie et al., 2014a, b).

The objective of this research is twofold; firstly, it aims to understand how practices are bound up in the home SOP, especially in a context where houses are becoming more energy efficient; and secondly, it aims at understanding how these practices can be changed to promote resource savings given their layers of complexity. Previous studies of SOPs in the resource use literature have focused on broader societal systems, investigating how these systems influence everyday practices (Macrorie et al., 2014a, b; Watson, 2012). Our research scales down to, and provides interpersonal detail on, the home as a SOP and concentrates on the influence that everyday practices have on energy and water use. This research contributes to understanding how resource reduction can be enabled in the multifaceted system of the home.

This research is based on the longitudinal monitoring of eight Australian energy efficient homes. The analysis of selected practices in the homes was carried out through a mixed methods approach, which combined quantitative and qualitative methods to provide holistic insights into the home SOP and better understand the interaction between occupants and the building technologies. The analysis started with a discussion of the targeted practices in isolation, describing through statistics how they are influenced by meaning, skill and technology. The analysis then focused on the integration of these practices in the home SOP, discussing the influences of interlocked practices and other home occupants. The last section of the analysis discusses automated practices, which unlike other everyday practices, are disinterlocked (i.e. disconnected or isolated) from the SOP and may provide an opportunity to enable resource use change.

2. Materials and methods

Eight homes were established as Living Laboratories (Burbridge et al., 2017; Leminen et al., 2015; Leminen and Westerlund, 2012; Liedtke et al., 2015) to investigate the effect of everyday practices on energy and water use in the home system (Herrena, 2017). The two most water intensive practices in Australian homes are garden irrigation and personal showering, representing 39% and 25% respectively of the total water use in the home (Water Corporation, 2010). The highest energy related practices consist of cooling and heating, using approximately 40% of the total energy use in the house (DEWHA, 2008) and generating 16% of operational greenhouse gas emissions (Lawania and Biswas, 2017). Accordingly, this research is scoped to concentrate mainly on the practices of personal showering, garden irrigation and home heating to represent some of the key practices in the home SOP. The practices of reticulated irrigation, dishwasher use and pool cleaning are also introduced to discuss automated practices.

The homes are located in Fremantle, Western Australia (WA), and possess characteristics that make them more energy efficient than the average WA dwelling. For instance, they all have passive solar design characteristics; that is, they take advantage of afternoon breezes to cool the house in summer as well as direct sunlight and thermal mass to increase thermal comfort in winter. Moreover, seven of the houses possess solar photovoltaic (PV) panels on their roofs (Table 1). Minimum house energy efficiency standards are currently mandated in Australia and internationally and PV panels are increasingly adopted in suburban homes (ABS, 2016; Green and Newman, 2017). The understanding of the home SOP in the context of energy efficient homes is important to ensure that they perform to their full potential.

The eight homes were selected through two distinct methods; response to a media advertisement and contact through a mail drop. Households that submitted an expression of interest were further selected to provide a cross-section of demographic profiles (Table 1).

Empirical analysis was conducted through an explanatory design mixed methods approach (Creswell et al., 2003; Creswell and Plano Clark, 2007). Quantitative data was continuously collected through sensors and convergent qualitative data was collated through semi-structured interviews that focused on the habits and routines of the occupants. This builds on previous research concerning the analysis of daily energy practices through the integration of monitoring data with qualitative interviews to provide insights beyond those of non-integrated approaches (Foulds et al., 2013).

2.1. *Quantitative data collection*

The eight homes had their gas, grid electricity, internal temperature and water use monitored for the full year of 2015. Sensors were connected to existing meters, sending pulses to a data logger (Schneider Electric COM'X 200), which then transmitted the data in csv format to a cloud via a 2G wireless internet connection. Data was collected at 15 min intervals, resulting in a total of 35,040 data points per meter or sensor at the end of the year. The following meters and sensors were employed to gather gas, grid electricity, temperature and water data respectively: Ampy 750 gas meter and pulse counter Elster IN-Z6; Schneider Electric iEM3110; Kimo TM110; Actaris TD8 and Cyble sensor 2W $K = 1$. Home 3 has a rainwater tank designed for use in the outdoor area and a separate water meter was installed in the rainwater tank outlet to measure hand watering of the garden.

2.2. *Data analysis*

The first stage of the data analysis involved the graphic identification of patterns of energy and water use associated with the defined everyday practices. An algorithm was developed to process all the data and identify daily resource use related to ambient heating, garden irrigation and personal showering. The highest summer water peaks (higher than 120 L/interval) were attributed to garden irrigation. Water use for personal showering represents the second highest water peaks of the data. Water volumes used for personal showering were identified in the winter months by an increase in water use concurrently with an increase in gas or electricity use for water heating. The water volume range for personal showering as identified for the winter months was extrapolated to the rest of the year as some of the houses possess solar hot water systems which limit water heating in summer. Previous Australian research has shown that showering volumes between winter and summer can differ by around 8L/person (Rathnayaka et al., 2015), which corresponds to a shower length difference of less than one

Table 1 – House characteristics and occupancies.

Home	No. occupants	Occupation	Efficient technologies
1	2 adults 1 young adult	Retired Full-time worker	Solar hot water
2	2 adults 2 children	Full-timeworker / stay-at-home parent Student / preschool toddler	PV, solar hot water
3	1 adult 2 teenagers 1 young adult	Full-time worker Students Unemployed	PV, solar hot water
4	2 adults	Full-timeworkers	PV, solar hot water
5	2 adults 3 children	Full-timeworker / stay-at-home parent Students	PV
6	2 adults	Full-time workers	PV, solar hot water
7	2 adults 1 young adult	Full-timeworkers Full-time worker	PV
8	2 adults 2 children	Full-timeworker / part-time worker Student / preschool child	PV, solar hot water

minute. These seasonal differences could have impacted on the results; however, it is assumed that the variation is captured by the wide shower volume range of 50 to 120 L per interval that was detected by the algorithm. This attribution correctly excludes the use of the water in the dishwasher (6.15 L to 6.85 L per filling cycle) and washing machine (28.5 L to 43 L per filling cycle) for each home. A similar algorithm was used to identify energy used for ambient heating. A significant increase in energy (electricity or gas according to the heating system of the house) followed by a concomitant increase in the internal temperature during winter was attributed to the practice of manually regulating the heating system. The temperature sensor was placed in the living area to ensure that temperature increase from kitchen practices was not mistaken for ambient heating practice.

Personal shower practice was analyzed separately for weekdays and weekends due to an identified difference in routines. Shower lengths were determined by dividing the volume of water used by the volumetric flow rate of the shower head. This method does not specifically differentiate between water used for showers or baths, the latter being undertaken exclusively by only 5% of the Australian population (Water Corporation, 2010).

Statistical analysis was undertaken through the graphic software OriginLab 2017 which provided a systematic analysis of the data set for the eight houses with a total of 35,040 data points per meter (gas, grid electricity and water) or sensor (temperature) in each home over the year. Distributions of personal shower and irrigation lengths and times were plotted as histograms; those depicting lengths had a specified bin size of 1 min and those depicting time of day had 48 bins (30-minute resolution). Peak analyses generated fitted curves providing coefficient of determination (R^2), coefficient of variation (CV), mean (μ), mode (Mo) and standard deviation (σ). These parameters were used to interpret the elements and interlocking of practices as well as patterns of intra-home practices.

The non-parametric Mann–Whitney U-test (Rosner and Grove, 1999) was conducted to identify statistical differences related to the showering practice during the week and weekend as well as mornings and afternoons over one year. We understand that this test is for unpaired data and was used correctly in this study. Morning and afternoon showers as well as week and weekend showers are independent variables and the samples are not paired, which excluded the use of a non-parametric paired t-test. The reasons that the samples are treated as independent populations are the following:

- The morning and afternoon showers as well as week and weekend showers may be taken by different (or a different number of) occupants of the same house;
- The showering practices may be different in the morning and afternoons as well as during the week and weekend;
- The number of showers (N) in the morning and afternoon differs (as shown in Table 3);
- The population of showers taken during the week over the course of one year is significantly larger than the population of showers taken during the weekend for the same period.

The analysis relating to diurnal energy use in the homes was through line graphs and contour plots.

2.3. *Qualitative data collection*

Semi-structured interviews (Kallio et al., 2016) with household members were conducted at the end of the quantitative data collection period in two stages. Initially the occupants were shown a summary of their monthly energy and water use and asked to identify reasons for any significant change in use between months (Foulds et al., 2013). The second stage of the interview targeted everyday practices in terms of meaning, skill and technology as well as household configuration and lifestyles. This second stage included participant articulation through a home survey with considerations of garden watering, thermal conditioning and washing practices as well as home technology. During this stage occupant routines and possible barriers to changing practices were revealed (Foulds et al., 2013). The explanatory design mixed method approach (Lave and Wenger, 1991) uses qualitative data to provide an in-depth explanation of the measured quantitative data and data from interviews to interpret everyday practices in the home (Foulds et al., 2013).

Care was taken to minimize influence on home occupants as a result of this research as this might lead to practice

Table 2 – Description of the showering length distribution for the eight homes. Statistically valid Gaussian (G) and Lognormal (LN) distributions are identified and numbered in a daily time sequence.

Home	Weekdays				Weekend			
	Shower, n	Mo (min)	σ (min)	R^2	Shower, n	Mo (min)	σ (min)	R^2
1	1 (LN)	6.1	1.6	0.98	1 (LN)	6.4	1.6	0.99
	2 (LN)	11.0	4.3		2 (LN)	12.5	3.5	
2	1 (LN)	4.5	2.0	0.94	1 (LN)	4.3	0.9	0.98
					2 (LN)	9.3	4.5	
3	1 (LN)	4.1	0.8	0.99	1 (LN)	4.0	0.6	0.96
	2 (LN)	8.0	5.0		2 (LN)	6.6	4.5	
4	1 (LN)	4.9	2.9	0.84	1 (LN)	4.4	1.4	0.84
5	1 (LN)	4.4	1.5	0.97	1 (LN)	4.3	0.9	0.95
	2 (LN)	13.9	10.1		2 (LN)	12.5	9.5	
6	1 (LN)	7.0	4.8	0.95	1 (LN)	4.3	5.4	0.93
7	1 (LN)	5.3	2.3	0.97	1 (LN)	4.9	2.2	0.87
8	1 (G)	7.1	1.1	0.97	1 (LN)	6.9	0.9	0.98
	2 (LN)	11.2	1.6		2 (LN)	10.6	3.2	

Mo — Mode; σ — standard deviation; R^2 — coefficient of determination

Table 3 – Comparison between morning and afternoon shower lengths (minutes) in homes with more than one showering practice (multiple modes). The statistical significance (Sig) of the Mann–Whitney *U*-test results are evaluated at a 99% confidence level. For s the difference between the two populations is statistically significantly different and for ns the difference between the two populations is not statistically significantly different. N is the total number of morning or afternoon showers in the year.

Home	N morning	N afternoon	Median (min)		P-value	Sig
			Morning	Afternoon		
1	256	175	6.89	8.55	.000	s
3	415	231	7.11	6.44	.703	ns
5	253	99	6.67	12.56	.000	s
8	168	94	9.11	9.28	.368	ns

and behavior modifications. For instance, the researchers did not maintain contact with participants after equipment installation and until the end of the monitoring period. While the participants were aware of the overall research intentions, the behavioral and practice aspects of the project were not emphasized. The longitudinal nature of this experimental design also reduces the chances of everyday practices being affected in the long term by occupant knowledge of the presence of monitoring equipment (Keyson et al., 2017). While there is still a possibility that practices might have been initially affected despite the measures listed above, the large number of data points (35,040) collected over the year reduces the likelihood of the results being significantly impacted.

3. Results and discussion

Patterns of energy and water use in the home were considered in terms of each individual everyday practice (Section 3.1); interlocking practices and other elements that compose the home SOP (Section 3.2); and automated practices acting independently of the home SOP (Section 3.3). Information and insights gathered from the interviews were used to support the quantitative results (Creswell and Plano Clark, 2011), relating them to other interlocked practices and wider influencing factors outside the home.

3.1. *Everyday practice*

The practices of personal showering, garden hand watering and home heating were chosen for analysis through contemporary practice theory (Macrorie et al., 2014a). The selected practices were discussed in terms of the three influential practice entity elements, which are defined as meaning, skill and technology.

3.1.1. *Personal showering*

Personal showering is the predominant form of bathing for cleanliness, warmth and feeling fresh in many (although by no means all) cultures, and is an established practice that has been performed daily by most home occupants, although not necessarily with the same meaning (Shove, 2003). The length of a shower is a key component of the water metabolism of the house as a system (Kenway et al., 2014).

The histograms representing the frequency distribution of the length of showers ($151 < n < 939$, where n is the number of identified showers in a home) in each home over one year had one or more modes which generally followed a lognormal distribution curve (Fig. 2 and Table 2). It is posited that the lognormal curve reflects the practice elements affecting shower length (e.g. meaning, skill and technology). The implicit

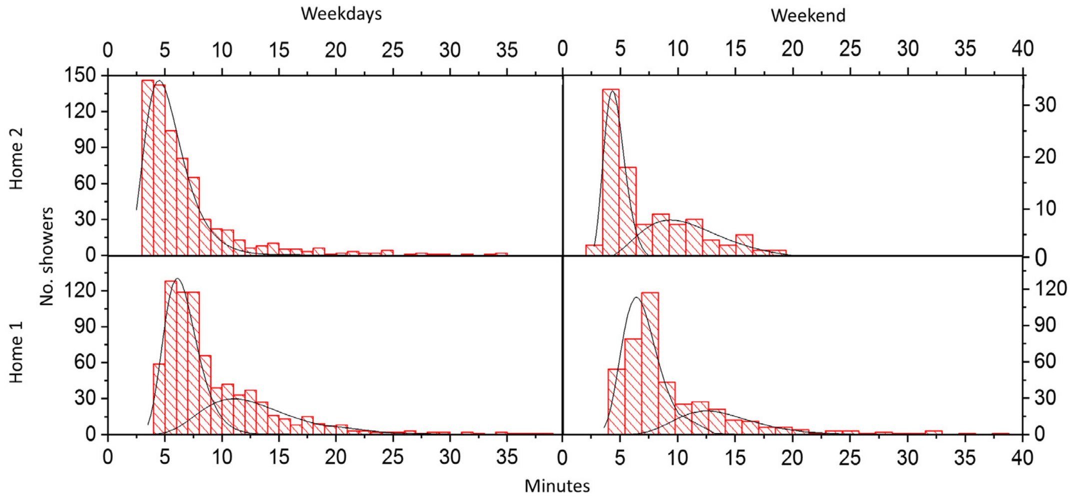

Fig. 2 – Shower length histograms and corresponding fitted (frequency) curves for two homes. During the week the occupants of home 1 have different intra-home showering practices while the occupants of home 2 follow the same practice. The weekend frequency distributions reveal a mix of showers with dispersed meanings. The statistics of the aggregate data for all homes are presented in Table 1.

know-how skills and shower head technology should not fluctuate over time, unlike the meaning for personal showering, which can frequently change and be the influential element for the practice (Shove et al., 2010). Consequently, the distribution curves represent variations in shower length driven by variations in meaning; the mode being the most frequent length and meaning for the showers. The interquartile range of the lognormal distribution (i.e. higher number of showers) represents the main routine for the showering practice, while the upper quartile (i.e. less frequent and longer showers) could indicate alternative meanings for the practice (Fig. 2). Where technology and skills are constant, the meaning of practices can be determined and described by the coefficient of variation (CV) and the standard deviation (σ) of the frequency curve; with a lower CV or σ value indicating a higher degree of habituality (Table 2). Showering length frequency distributions presenting more than one mode could represent the routine of distinct inhabitants with different showering practice-as-entities or different showering meanings for the same occupant.

For instance, during weekdays, in home 1 (a home with three occupants comprising a retired couple and their working granddaughter) the showering length histogram of the household contains two peaks (i.e. two modes) (Fig. 2); the first has a frequency curve with an associated Mo value of 6.1 min (σ value 1.6 min, μ value 6.6 min) and the second has a Mo value of 11 min (σ value 4.3 min, μ value 12.9 min). Interviews with this home revealed that the retired couple share a similar practice-as-entity that differs from their granddaughter. The granddaughter enjoys long showers and weekly baths, articulating a different meaning to showering and bathing than her grandparents. The second curve with associated Mo value of 11 min could therefore be attributed to the granddaughter. Her showering practice (σ value 4.3 min, CV value 0.4) is also less habitual and routine based than her grandparents (σ value 1.6 min, CV value 0.2), which is reflected in the larger standard deviation and coefficient of variation (Table 2).

The occupants of home 2 (one working adult, one stay-at-home parent and two preschool children), on the other hand, all possess the same weekday showering practice with the personal showers following only one single-modal lognormal frequency distribution (Mo value 4.5) (Fig. 2 and Table 2). This indicates that there is a similar meaning or meanings for personal showering between all the occupants.

The local water authority in Perth, Australia, faces serious water shortages for the city and widely promotes for personal showers under 4 min (Water Corporation, 2010), attempting to introduce explicit rule-based knowledge (McMeekin and Southerton, 2012) into the skill of personal showering practice. The Mo values in Table 2 reveal that this is not met for any home. The closest Mo values to 4 min usually occur for the first early morning shower where the meaning is to freshen up before work (weekday) or the day ahead (weekend) (Table 3). This explicit knowledge may not affect the longer showers due to the heterogeneity of meanings associated with the upper quartile of the frequency distribution curve. The later showers are generally longer (Table 3) than the morning showers as they are situated between different routines. They are likely to be more flexible than the morning showers, since they are less constrained by scheduled activities such as work and school. Later showers may also hold meanings other than cleanliness which might include relaxation at the end of a busy day or warmth on a cold winter day, hence the extended length of showering time (Shove, 2003).

The semi-structured interviews confirmed that occupants of the same home can have different meanings for personal showering, affecting the length of shower. Motivations mentioned by the households included showering for relaxation (teenagers in house 3, granddaughter in house 1), showering for the purpose of health (husband in house 4), showering for cleanliness alone (preschool children and stay-at-home mother in house 5) and the social expectation of everyday showering by colleagues in a work place culture (husband in house 5). Those who attribute health or relaxation to their showering practice mentioned enjoying long showers. One of the participants having showers for cleanliness purposes (house 5) also revealed not showering on a daily basis but compensating instead, with long showers when doing so (Mo value 13.9 min, σ value 10 min, Table 2).

Shower lengths between weekdays and weekends were not statistically significantly different for six of the homes at a 99% confidence level (Table 4). The similarity in shower

Table 4 – Comparison between weekday and weekend showers. The statistical significance (Sig) of the Mann–Whitney *U*-test results are evaluated at a 99% confidence level. For s the difference between the two populations is statistically significantly different and for ns the difference between the two populations is not statistically significantly different. *N* is the total number of weekdays or weekend showers in the year.

Home	*N* weekdays	*N* weekend	Time		Length	
			P-value	Sig	P-value	Sig
1	778	423	.002	s	.310	ns
2	697	102	.286	ns	.044	ns
3	939	377	.001	s	.110	ns
4	413	288	.000	s	.124	ns
5	416	155	.000	s	.749	ns
6	479	165	.947	ns	.000	s
7	543	212	.000	s	.709	ns
8	376	167	.751	ns	.285	ns

lengths as well as the positive skewness of the length distribution curve shows that a personal shower routine of a regular length of time is followed each day to achieve a specific meaning and that shorter showers are unlikely to occur, unless the skill or technology elements of the practice are altered (Shove, 2003). The reduction of personal shower length may be particularly challenging for occupants whose degree of habituality for showers is high.

3.1.2. *Garden hand watering*

The other water intensive practice in households is outdoor use (Ashton et al., 2016). The same pattern of habits and routines identified for showering was also found for the practice of hand watering the garden (Table 5), which uses similar volumes of water on each occasion. Hand watering practices depend mostly on technology (garden size) and user skill. A household will not use water for irrigation unless there is a garden, which may be reliant on a household member having the meaning, skill and technology for undertaking the practice of gardening. The volume of water applied to the garden follows a lognormal distribution (Table 5) which indicates that households follow a similar irrigation pattern each time. Homes 1 and 4 both possess gardens (approximately 85 m^2 and 220 m^2 respectively) with lawns as well as decorative and edible plants, requiring larger volumes of water compared to home 3, who only plant in pots located in a paved courtyard. Larger watering volumes (reflected in a greater σ value) especially for homes 1 and 4 could represent meanings other than maintaining plant health. For instance, home 1 occupants revealed that the practice of hand watering is sometimes undertaken twice daily and consists of a pleasurable activity. This is consistent with previous research which identified other meanings for irrigation, including enjoyment (Syme et al., 2004). The σ value for home 3, on the other hand, is only 8 L, indicating that the occupants of this home may only have the one meaning of maintaining plant vitality for garden watering.

3.1.3. *Ambient heating*

Practices to regulate indoor comfort based on temperature have also been performed by people over their lives using various technologies with different meanings and skills. This practice has become increasingly resource intensive with the broad uptake of reverse cycle air-conditioning and heating units in homes in Perth (Strengers, 2010) and in the studied homes. It was observed that households follow different heating practices. Home residents were not strictly motivated by thermal needs when they operated the heating system. Some turn on the heater as part of a routine for the colder months, when arriving home from work, whereas others seek a hedonic experience instead of wearing warmer clothes when the temperature falls (Eon et al., 2017; Shove, 2003).

Fig. 3 provides the example of three homes that operated the heater during weekdays in July 2015, the middle of the Australian winter. In home 1 the heater was switched on for two hours in the morning (07.30 to 09.30) when the internal temperature was on average 18 °C. This occurred when the occupants woke up and was based on their morning routines as well as the experience of feeling cold. As they left the home for their daily activities, the heater was switched off, and this routine was repeated through the winter months. The heater was then switched on again for the rest of the evening, between 17.30 and 23.00, when the occupants were at home and the external temperature had dropped. According to home 1 occupants, they turn the heater on while watching television in the evenings. The occupants of home 5 only switched the heater on during the late morning, at around 10.00, even though their house was on average 2° colder than the other two homes and the heater in this home was not usually used in the evenings. This indicates that the occupant's practice-as-entity could be influenced more by the meaning or the technologies they associate with heating than the internal temperature itself (Shove et al., 2010). Home 5 possesses PV rooftop panels, which according to the occupants, are the main driver for the time when the heater is switched on. Their preference in the evenings and early mornings is to wear warm clothes rather than use the heater. A different heating practice was encountered in home 7, which only uses the heater in the evenings, from around 17.30 to 22.00, after arriving home from work. According to these participants, comfort and convenience are the main reason to use the heater. Our results indicate that regardless of the thermal temperature in the household, the occupants use the heating technology with various meanings and interlocked with their daily routines.

3.2. *Interlocking practices*

While individual practices are influenced by meaning, skill and technology, they are also constrained by other home occupants and interlocked practices inside and outside the

Table 5 – Hand watering irrigation practice in the three homes that practice hand watering; the other five homes possess reticulation systems set on a timer. Modes of time are expressed as times (t) and volumes are expressed in liters (L). Statistically valid Gaussian (G) and lognormal (LN) distributions are identified.

Home		Hand watering, n	Mo (t, L)	σ (min, L)	R^2
1	Time	1 (G) 2–5 (G)	8.57 11.47–20.57	49 22.3–46.6	0.90
	Volume	1 (LN)	125.9	21.2	0.97
3	Time	1 (LN)	6.6	33.0	0.78
	Volume	1 (LN)	21.5	8	0.98
4	Time	1 (LN) 2–3 (G)	6.45 10.31–18.44	30.0 30.0–102.0	0.82
	Volume	1 (LN)	149.2	92.5	0.85

Mo — Mode; σ — standard deviation; R^2 — coefficient of determination.

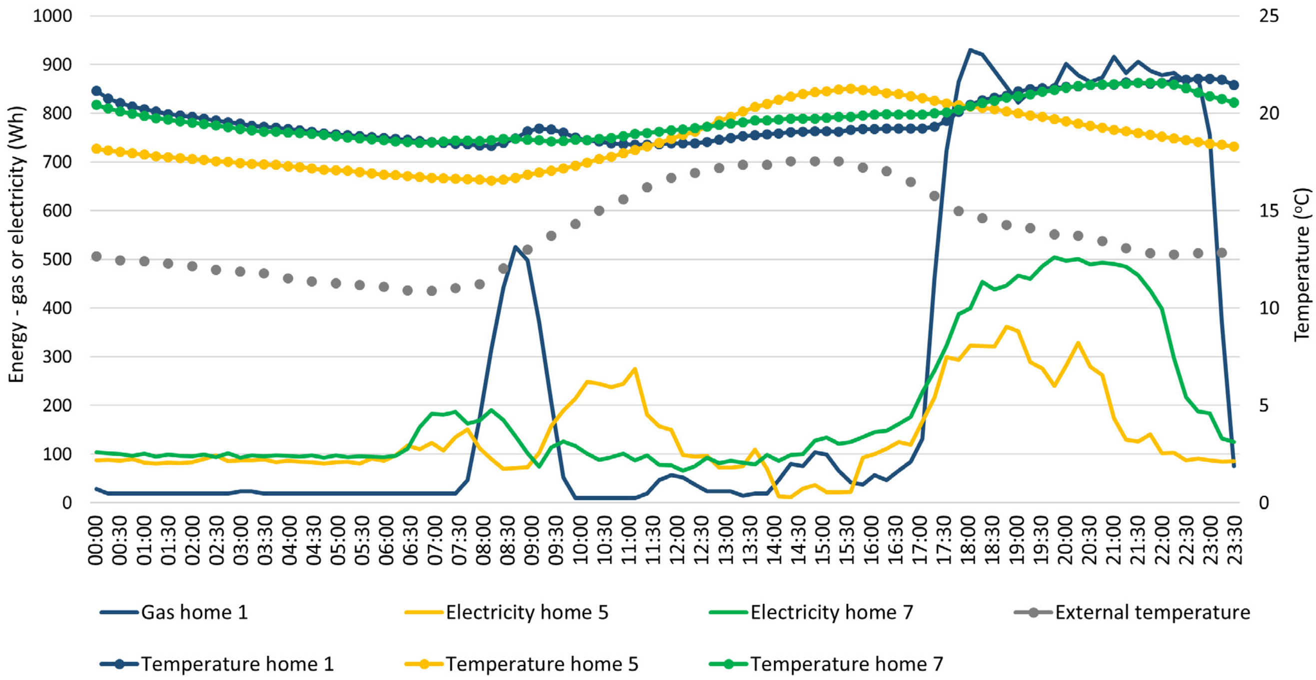

Fig. 3 – Average use of the heating system on weekdays in homes 1, 5 and 7 in July 2015, in the middle of the Australian winter. An increase in internal temperature alongside an increase in energy (gas or electricity depending to the heating system of the home) use is attributed to the practice of heating.

home system. The term interlocking refers to the interconnectedness and interdependence of practices in a routine. For instance, the practice of composting relies on the practice of gardening and/or the practice of cooking and cannot exist without one or the other. These practices are all connected in the home SOP.

Previous research has related the time of practices to occupant lifestyles and socio-economic status (Ashton et al., 2016). For instance, peak water use occurs earlier in houses occupied by early risers who are economically active and therefore bound by the practices of breakfast, transport and work. Late risers, on the other hand, do not have a specific water use pattern (Keyson et al., 2017) and are not interlocked in binding activities constraining the hour of water use. Similar results were observed in this research.

This section will explore interlocking practices in the SOP by discussing the practices of personal showering and garden hand watering.

3.2.1. *Personal showering*

The time of shower and the habituality and routine nature of the practice (reflected in the σ values in Table 6), are influenced by other interlocked practices in the system. Home 3, for instance, comprises a mother and her three teenage sons. The mother works in a full-time job and therefore her time of taking a personal shower is constrained by the practice of work as well as other interlocked practices that form her daily routine, such as waking up in the morning, eating breakfast and transport to work. Her sons, on the other hand, have a flexible schedule and are often at home during the day. The showering time histogram for home 3 (Fig. 4) reveals two weekday peaks, one in the morning (Mo and μ at 07.22), which has a σ value of 55.8 min, and one in the evening (Mo and μ at 17.19), which has a σ value of 225 min (Table 6). The morning shower, which is taken over a shorter time-period may be attributed to the mother, while the afternoon showers, spread over a longer time period (therefore less habitual and routine based), may be attributed to the sons,

Table 6 – Description of the showering time distribution for the eight homes during weekdays and the weekend. Statistically valid Gaussian (G) distributions are identified and numbered in a daily time sequence. Showers that do not have a clear distribution shape were not evaluated.

Home	Weekdays				Weekend			
	Shower, n	Mo (time)	σ (min)	R^2	Shower, n	Mo (time)	σ (min)	R^2
1	1 (G) 2–6 (G)	8.06 8.43–21.32	8.60 26.4–95.2	0.96	1 (G) 2–5 (G)	9.22 11.48–21.13	53.8 19.4–89.5	0.93
2	1 (G) 2–3 (G)	6.29 9.12–18.37	19.20 92.2–147	0.92	NA	–	-	
3	1 (G) 2 (G)	7.22 17.19	55.8 225.0	0.85	NA	–	-	
4	1 (G) 2 (G)	6.49 16.11	25.8 145.2	0.91	1 (G) 2–3 (G)	7.50 9.31–17.38	34.6 103.5–136.0	0.93
5	1 (G) 2 (G)	7.53 18.36	25.8 61.8	0.94	NA	–	-	
6	1 (G) 2–3 (G)	6.53 17.14–21.15	33.6 56.4–63.6	0.89	1 (G) 2–4 (G)	9.50 12.17–21.17	64.9 33.9–156.4	0.85
7	1 (G) 2–4 (G)	6.47 8.50–17.32	14.6 29.6–62.3	0.98	1 (G) 2 (G)	10.17 17.07	73.6 25.6	0.88
8	1 (G) 2 (G)	7.22 19.23	12.6 13.3	0.75	NA	–	-	

Mo — Mode; σ — standard deviation; R^2 — coefficient of determination

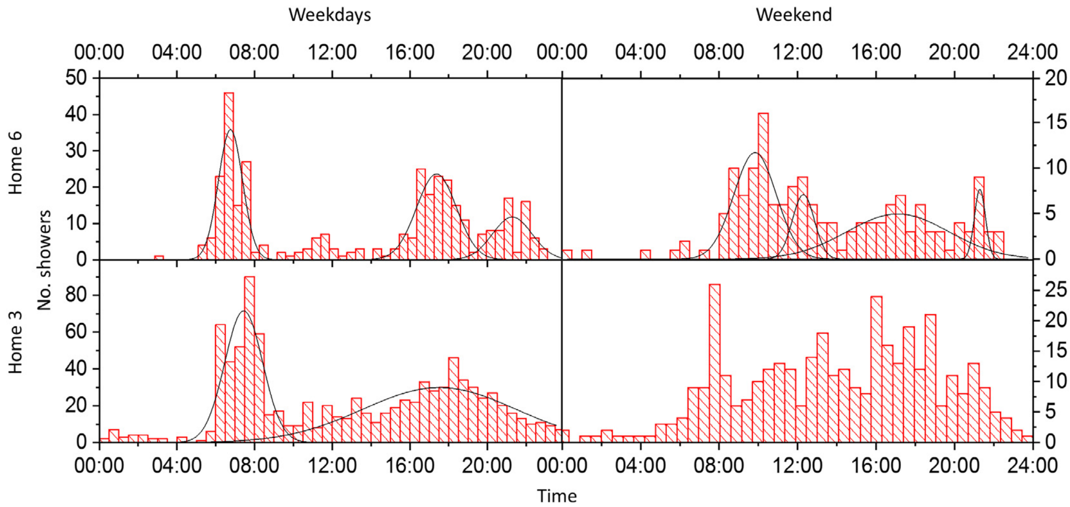

Fig. 4 – Personal showering time histograms and corresponding distribution curves for two homes. Shower times generally follow a Gaussian distribution curve (Table 6).

who are likely to have showers when convenient rather than as part of an interlocked routine.

Home 6 consists of a working couple whose weekday shower times follow the same patterns as the mother of home 3 (Fig. 4). Morning showers have a small σ value (33.6 min), as they are constrained by the interlocked practice of work (Table 6). Evening showers, on the other hand, have higher σ values (56.4 and 63.6 min) as evening routines are more flexible and less interlocked (Table 6).

Showering times were statistically significantly different during weekdays compared to weekends for five of the homes at a 99% confidence level (Table 4). There is also a higher σ value during the weekend for the time that showers are taken than for weekday showering (Table 6 and Fig. 4). Weekend showers are usually taken later in the day and show a greater time distribution for most households compared to weekdays. The weekend shower distributions of homes 2, 3, 5 and 8 are multimodal and cannot be attributed to a specific routine. This demonstrated that although personal shower time is generally tightly interlocked with other practices this may realign in a different context when new home dynamics emerge (e.g. during weekends).

Shower time histograms follow a Gaussian distribution curve (Fig. 4 and Table 6). This could be explained by personal showers occurring at certain times of the day based on routines and interlocked practices. However, once in the shower, meaning and skill combined with the available technology take over and showering practitioners tend to follow certain procedures for achieving cleanliness or comfort. This is demonstrated in Fig. 3 by the length of the shower during the weekend being similar to that of the shower during the weekday. While the shower time varies based on the interlocking practices and routines to be followed that day, the actual process of showering remains the same for these occupants.

3.2.2. *Garden hand watering*

As with personal showering, hand watering takes place during defined periods of the day, when occupants are at home before or after going to work and becomes part of an interlocked daily routine (Table 5). Interviews revealed that garden watering practices are also variable over time and are dependent on skills as well as on the practices of other home occupants. For instance, home 6 revealed that while they did not irrigate their garden in the past, they decided to establish a new lawn, creating the need for a new watering practice to be interlocked into their daily routines. On the other hand, home 2 revealed that they had been trying to grow vegetables but did not have the skill required and decided therefore to cease the watering of their vegetable beds. Home 1 explained that they need to water the lawn daily due to their dog's waste. The local water company also promotes for conservation of water use in the garden (Water Corporation, 2017). However, requesting the occupants of home 1 to reduce external water use may never work simply because their watering practice is interlocked with the practice of the dog relieving itself. Replacing the existing garden water hose for a more efficient fitting or training the dog to go elsewhere would be a more effective solution to influence the water metabolism of the home.

While other research has posited that practices are bound in complex spatial and temporal bundles (Macrorie et al., 2014b), we demonstrate here that distributed, interlocked home practices are reproduced in a sequential temporal spectrum. This sequential spectrum can re-align when social conditions change, as is evidenced through the difference in interlocked practice times between weekdays and weekends (Table 6, Fig. 4).

3.3. *Automated systems*

Given the complexity of everyday practices and their interconnectivity in the home system, affecting them is challenging and unlikely to occur without taking a holistic perspective (Brynjarsdóttir et al., 2012). Traditional behavior change approaches that attempt to persuade change through the provision of information and feedback displays assume that individuals are driven mostly by reason (Steg and Vlek, 2009). This often ignores that practices are bound in space and time and reproduced sequentially as part of an established routine (as discussed in Section 3.2). Modifying them requires therefore either a change in the practice elements, including meaning, or a complete re-alignment of the home SOP. Another solution is to separate, or dis-interlock, practices from the home SOP, for instance, through their automation.

Four of the homes in this research use automatic irrigation to water the garden. The quantitative monitoring data showed that the irrigation volumes were frequently readjusted through the year. According to the research participants, these readjustments were the consequence of other interlocked practices, for instance, the establishment of a new lawn. Local regulations require that reticulated irrigation is only used on allocated days, times and months of the year. However, results revealed that three of the homes programmed the irrigation system incorrectly, watering on the wrong days or times. The innate flexibility of the automated irrigation promptly enables practice modifications. However, skills are still needed to operate the system. This is especially true for new homes that come with pre-installed and pre-programmed automated garden systems, as was the case for home 7. Interviews revealed that the occupants were not able to detect when the irrigation was on due to the underground drip irrigation pipes and their poor understanding of the reticulation settings. In this case automation also gave a sense of disconnection from the practice and the occupants were therefore less engaged in its performance.

If used and programmed correctly, automation can positively influence the use of resources in the home system without it becoming directly interlocked with other practices. The semi-structured interviews with occupants of homes 3, 6 and 7 revealed that since moving into a home fitted with PV panels, they have modified their dishwashing practices, programming the dishwasher to run during daylight hours. In this case, the practice of washing the dishes was dis-interlocked from the practices of cooking, eating or working. On the other hand, dishwashing became interlocked with the skill and technology related to both the operation of the dishwasher and the understanding of the solar technology.

A third example of automation was the use of an automatic pump to conduct the practice of pool cleaning. Home 6 has a pool pump on a timer, functioning twice per day, once in the morning (8.00 to 10.30) and once in the evening (16.30 to 18.45). Whilst the practice of pool cleaning is interlocked with the practice of swimming, it does not depend on any other practice, and functions independently of the home SOP. This practice, however, is also dis-interlocked from the solar system which could power the pool pump thereby avoiding the use of grid electricity. The occupants of home 6 were not aware of this advantage, lacking the skills to reduce the energy related to the practice of pool cleaning.

4. Conclusion

Policy and regulations for residential houses often consider the physical infrastructure alone and tend to focus on the energy or water performance of the building. However, they fail to include users as an integral part of the system. Behavior change programs that are based on socio-psychology theories (Ajzen, 1991; Cialdini et al., 1991; Festinger, 1957; McKenzie-Mohr, 2011) attempt to influence consumers through information campaigns or feedback technology. However, this approach also ignores the fact that homes are complex systems made of people, technologies and practices that are reproduced in bundles across space and time. This research applies the concept of SOP to homes and uses practice theory to provide an understanding of occupants' everyday practices and the intricacy of the interactions between home occupants, the building infrastructure and natural resources.

Detailed quantitative and qualitative data collected over one year were used to analyze resource intensive practices in eight Australian homes in order to provide a holistic insight into the home SOP and understand what is required to enable effective resource savings. Results revealed that practices are performed in a sequential temporal spectrum as part of a routine and are influenced by interlocked practices as well as the routine of other home occupants. Moreover, the manner by which practices are performed are dependent on intrinsic human needs which may be challenging to influence through behavior change programs alone.

Rigid and habitual routines that are highly interlocked have smaller standard deviations related to the time that practices are performed in comparison to more flexible routines. These rigid routines may prove harder to influence. Routines, however, are re-aligned when there is a change in context (e.g. at the weekend). Personal showers and hand irrigation lengths follow a similar pattern every time they are accomplished. For instance, individuals tend to have personal showers of the same length everyday but longer showers that have meanings other than getting clean also occur. The lognormal distribution shape of personal showers indicates that shorter showers are unlikely to happen. Similarly, the use of the heating system is not only directly related to the temperature, but also to other interlocked practices and personal expectations.

Information campaigns that do not address users' needs and fail to understand the intricacies and interlocking of the home SOP are unlikely to have significant impact on energy and water use. Automation, on the other hand, can enable resource intensive activities to be dis-interlocked from an established routine and make change within the SOP easier and more flexible.

This paper has demonstrated through a rich data set how practices are shaped by the routines that they are part of and how a SOP perspective providing a holistic insight into the home could be beneficial to influencing household metabolism and technology into the future.

Acknowledgments

This research is funded by the CRC (Project number RP3009) for Low Carbon Living Ltd supported by the Cooperative Research Centers program, an Australian Government initiative. The authors would also like to acknowledge Dr Xin Liu for the revision of the statistical analysis.

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Publication III

Eon, C., **Breadsell, J.,** Morrison, G. & Byrne, J. (2019) Shifting Home Energy Consumption Through a Holistic Understanding of the Home System of Practice. In: Newton P, Prasad D, Sproul A, et al. (eds) Decarbonising the Built Environment: Charting the Transition. Singapore: Palgrave Macmillan, pp. 431–447. DOI: 10.1007/978-981-13-7940-6_23

Status: published (peer-reviewed)

23

Shifting Home Energy Consumption Through a Holistic Understanding of the Home System of Practice

Christine Eon, Jessica Breadsell, Gregory Morrison and Joshua Byrne

Introduction

Energy reduction in residential buildings is considered to be one of the most straight forward ways of reducing carbon emissions. Many OECD countries and jurisdictions currently have energy efficiency policies in place, usually targeting the improvement of building shells for higher thermal efficiency, the installation of energy efficient appliances and the

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P. Newton et al. (eds.), *Decarbonising the Built Environment*,
https://doi.org/10.1007/978-981-13-7940-6_23

adoption of renewable energy. While valuable, these measures do not provide a holistic approach to the energy reduction challenge.

Previous research has shown that highly energy efficient or net zero energy buildings (i.e. buildings that produce as much energy through onsite renewable energy generation as they consume) do not achieve their full potential despite performing better than conventional buildings (Watson 2015). There are a number of reasons for this underperformance, including poor construction practices; nevertheless, the unpredictability of occupancy constitutes an important factor. Previous research has shown that identical buildings can consume very different levels of resources mostly due to their occupants, which may not only own different appliances, but are also likely to follow different routines and have distinct behaviour patterns (Hansen 2016; Strengers & Nicholls 2017). Household and occupants' level of skills and understanding of specific technologies also impact the dwelling's metabolic system—that is, its resource flows (Pettersen et al. 2017).

A popular approach to decreasing the negative impacts of occupancy on residential energy use has been through the implementation of methods grounded in social psychology. These methods attempt to persuade change without consideration of the full picture; that is, people's environments, lifestyles, needs and everyday practices. An alternative and more contemporary approach to influencing residents is based on social practice theory (Røpke 2009; Schatzki 2002; Shove et al. 2007; Warde 2005). Rather than targeting the individual in isolation, practice theory emphasises people's daily activity patterns and interactions with their technology, dwelling and urban infrastructure contexts. Practice theory also considers skills and abilities and intrinsic motivations for undertaking certain practices (Eon et al. 2018a). As an integral part of the home, occupants need to be considered when innovative buildings and associated technologies are planned for, designed and constructed. Energy reductions are more successful when enabled through the integration of good design into the home system (Smale, van Vliet & Spaargaren 2017).

This chapter introduces the concept of home system of practice (HSOP) and discusses how this notion can be useful in shifting energy consumption in residential buildings in both the long and the short term. Firstly, the layers that form the home system are briefly described, then the more customary theories for changing consumer behaviour are reviewed and finally we advance how effective comprehension of the HSOP can act as an enabler for achieving more sustainable built environments—as designed as well as operated.

The Home System

The home is a complex environment which can be conceived as a combination of three systems: the physical, the metabolic and the social systems (Fig. 23.1). The physical system is an ensemble of objects,

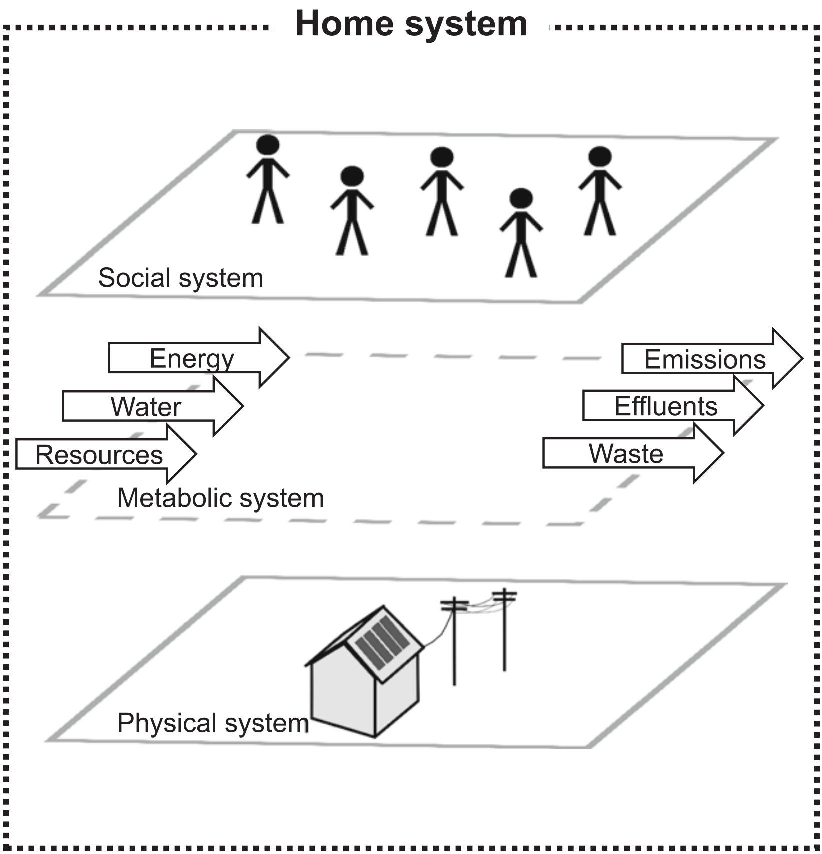

Fig. 23.1 The home system complex: social, metabolic, and physical systems (*Source* Adapted from Eon et al. 2018a)

technologies and infrastructure that make up the building. The social system consists of the building occupants, who are affected by their cultural beliefs, values, knowledge, skills, their personal networks and wider society. The metabolic system involves the movements of materials, water and energy, which flow through pipes and cables and are internally processed through the daily operation of appliances and fittings. The metabolic system is affected by its interactions with the physical and the social systems (Eon et al. 2018a). To effectively reduce energy use in the home, it is necessary to influence both the physical and the social systems.

Effective technologies for reducing energy consumption and carbon emissions in the residential sector are all well-studied and increasingly affordable. These include energy efficient building envelope design and low carbon materials, energy efficient appliances and renewable energy systems. The social system, on the other hand, is not so well understood and is often ignored. It is typically not until after new building technologies have been implemented and failed in their objectives to reduce energy consumption that the occupants come into focus and an attempt is made towards shifting their customary behaviours (Gram-Hanssen et al. 2017).

Traditional Methods for Shifting Behaviour

Conventional methods for shifting occupant behaviour are grounded in four major psycho-social theories: cognitive dissonance, planned behaviour, normative conduct and habitual behaviour. The theory of cognitive dissonance posits that individuals are conflicted when they recognise that their values and their actions are inconsistent and work to realign them, resulting in either a change in behaviour or a change in attitude (Festinger 1957). The theory of planned behaviour proposes that behaviours are a product of attitudes, social norms and the perceived control individuals have over the outcomes of their own actions (Ajzen 1991). A change in behaviour would therefore require an alteration of these three factors. The theory of normative conduct suggests that individuals are influenced by wider societal norms and unspoken judgements (Cialdini, Kallgren & Reno 1991; Schultz et al. 2007). Information about customary community behaviours and expectations is believed to shift individual behaviours. Finally, the theory of habitual behaviour considers that behaviours become automatic and unconscious when repeated regularly (Aarts, Verplanken & Van Knippenberg 1998). Hence, breaking established habits would require either a drastic change in context or frequent prompts (Steg & Vlek 2009).

Common interventions are based on the above theories and include: the provision of information and feedback to increase awareness; the delivery of social norms to make accepted and unaccepted behaviours explicit; the request for a clear commitment or highlighting of hidden personal values to promote cognitive dissonance; and the delivery of prompts to break established undesirable habits (Abrahamse et al. 2005; McKenzie-Mohr 2011).

These interventions have been deployed in research and practice through a range of approaches that generally fall into three categories classified here as social, technological and knowledge-based interventions (Table 23.1). The most successful interventions often integrate social, technical and knowledge-based methods together, such as through real-time feedback, coaching and information campaigns; however, there are few long-term studies of the kind.

The use of in-home displays or dashboards, have become increasingly popular for conveying information and prompts and seeking some response from the users. A driver here is that house metering technology has become more accessible and enables real-time feedback that is often not possible through more conventional methods such as coaching or personalised letters. Nonetheless, opinion about the effectiveness of feedback displays is divided; some researchers claim that they are effective in the reduction of resource use and identification of faulty equipment (Berry et al. 2017; Stromback et al. 2011), while others have found that they are not effective in the long term as they do not become embedded into users' routines and their use is discontinued after the novelty wears off (Brynjarsdottir et al. 2012; Hargreaves, Nye & Burgess 2013). It is also argued that feedback systems are developed by technologists and do not necessarily meet user requirements.

Table 23.1 Conventional methods for shifting behaviour

Insights and interventions	Social interventions	Technological interventions	Knowledge-based interventions
Information provision	Audit, coaching	Website	Mass campaign, letters, emails, factsheets
Feedback	–	Website, SMS, in-home display	Bills, letters, emails, direct metre readings
Social norms	Social interaction	In-home displays, website	Letters, marketing campaign
Commitment	Verbal or written	Website, in-home display	–
Value activation	Coaching, audit, peer interaction	–	Survey
Prompts	–	SMS, email, in-home display, website, alarms	Stickers, written reminders

Information campaigns through media advertisements are popular among governing bodies and utilities (e.g. water and electricity providers), who see this as a means for attempting to rapidly 'broadcast' awareness through society.

Social psycho-social theories address resource use from a top-down perspective, persuading home occupants to change individual attitudes, perceptions and behaviours based on information being provided through the methods on Table 23.1. Nevertheless, behaviours are influenced by the wider society and culture (Shove, Watson & Spurling 2015; Stephenson et al. 2010) and changing them entails a societal transition, being based on a more systemic approach.

The Home System of Practice

The concept of HSOP (Eon et al. 2018a) emerged from practice theory, which offers an alternative to understanding and shifting actions by focusing on everyday practices as opposed to resident behaviour, knowledge and attitudes (Schatzki 1996; Shove et al. 2007). Practice theory suggests that individuals do not use energy resources directly, but rather as instruments to achieve specific outcomes (Hargreaves 2011). For instance, energy is used in the practice of cooking with the objective of preparing food for consumption; water is used in the practice of personal hygiene through a shower; and driving a car is used in multiple practices such as shopping, getting to work and dropping children at school.

Practices conducted by users are affected by three elements: meaning, skill and technology (Gram-Hanssen 2014; Schatzki 1996). Meaning is the reason behind the execution of a practice; skill is the understanding of how to execute the practice; and technology encompasses the objects and infrastructure necessary to undertake the practice. It follows that affecting one or more of these elements should result in a modification of the practice and subsequently the resource use, enabling (as opposed to persuading) occupants to save energy while continuing to meet their needs (Brynjarsdottir et al. 2012).

As technologies and infrastructures evolve and are adopted, existing social practices become obsolete and are replaced by new ones (Shove, Watson & Spurling 2015). Practices are also place and time dependent, being adapted to the configuration of different settings and circumstances.

The repetition of practices in a habitual routine become interdependent and interlocked (i.e. interconnected) in a system of practice (SOP) (Watson 2012). For instance, the practice of composting is interlocked with the practice of food preparation; in other words, composting cannot exist unless food waste is generated. Likewise, practices are often reproduced in a sequential manner, interlocking with preceding and subsequent practices (Eon et al. 2018a). For instance, the practices of showering, eating breakfast and driving to work are all constrained by the practice of working and its schedules (Southerton 2013; Torriti 2017).

In a home occupied by multiple individuals, each individual possesses a unique SOP. These SOPs interlock with each other as some practices are shared between individuals (e.g. eating a meal), occur sequentially (e.g. showering) or take place as a consequence of another set of household activities (e.g. cleaning up after children). This network of SOPs in the home forms a HSOP (Fig. 23.2), which is part of the social

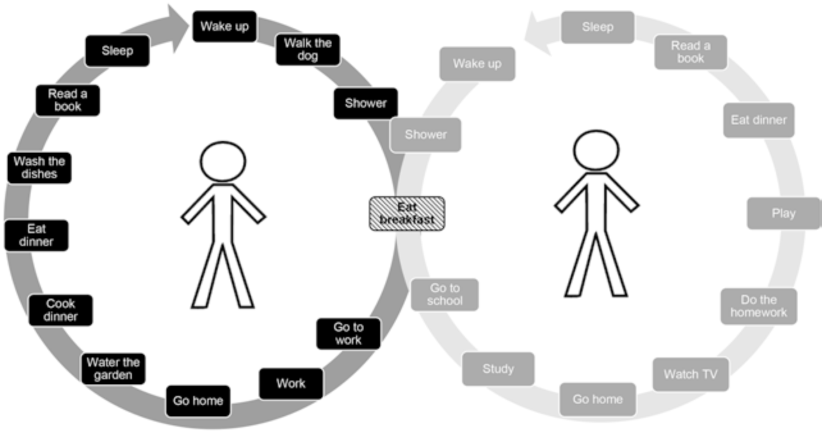

Fig. 23.2 Interlocked practices and routines in the HSOP (*Source* Adapted from Eon 2017)

system of the home. The HSOP can be regarded as a form of home equilibrium, and while complex, works in harmony to achieve desired outcomes for household members (Eon 2017).

Shifting Energy Consumption Within the HSOP

Shifting domestic energy consumption requires a deep understanding of the HSOP; that is, the interconnections that exist between an individuals' own practices as well as within the HSOP as a whole and incorporating the meanings, skills and technologies-in-use behind those practices that use energy. These are explored in the following section.

Implications of the Interlocking of Practices

Practices can have different degrees of interlocking; being highly or lightly interlocked in the HSOP. Research has shown that practices occurring during workdays usually happen within tight timeframes as they are limited by predetermined activities, such as work or school and their timetables (Eon et al. 2018a; Torriti 2017). In such cases, practices have a high degree of interlocking and are more strongly bound in the home equilibrium. This means that altering these practices, their times, duration or order, can prove hard as not only the practices themselves need to be affected, but all other interlocked practices in the HSOP. Conversely, practices that occur during non-working days or that are not bound to recurring scheduled activities, are deemed to be lightly interlocked. These are usually more flexible, have varying timetables and durations and are less dependent on the household routine, being therefore potentially easier to modify.

Whenever a new practice is introduced in the home, interlocked practices need to be re-aligned so that the new practice becomes incorporated in the HSOP (Fig. 23.3). Unless a new home equilibrium is reached and the new practice becomes embedded in the HSOP, it is not adopted by the home occupant. This tends to be the case with persuasive approaches, such as the use of feedback systems. While occupants usually value information about their energy use, the practice of accessing the feedback system platform fails to become integrated in the HSOP and does not have significant lasting effects. Reasons can vary from lack of time and being busy, to forgetting about it (Eon et al. 2018b).

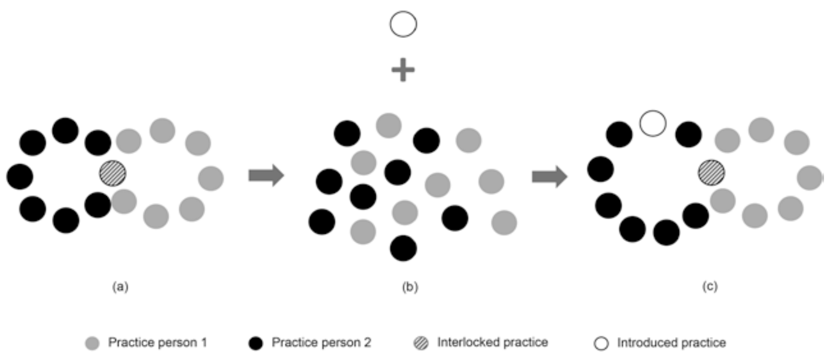

Fig. 23.3 Conceptual diagram of the equilibrium of practices in the home (*Source* Adapted from Eon 2017. *Notes* **a** Original home equilibrium. **b** Destabilisation of the home equilibrium through the introduction of a new practice. **c** Realignment of practices and establishment of a new home equilibrium)

A HSOP realignment does not necessarily mean that practices themselves are affected. While the timing of practices may realign and reach a new equilibrium, the meanings, skills and technologies of the practices may remain the same; that is, the manner in which occupants perform specific practices to achieve a particular meaning may not be affected. As resources are consumed indirectly through the performance of practices, the realignment of the elements may result in the same level of resources being consumed during the practice (Eon et al. 2018a).

The Implication of the Meaning of Practices

The technology and related skills required for carrying out a certain practice are relatively constant over time in a specific context. In contrast, more than one meaning can be attributed to the same practice (Shove 2003). For example, research has shown that the practice of using a heater can be associated with multiple meanings or associations; for example, warmth, comfort, health and habit (Eon, Morrison & Byrne 2018). Different meanings impact differently on the resources required for the execution of a particular practice. For showering, it has been shown that meanings such as cleanliness or refreshment are associated with shorter showers and thus less energy and water consumption. Meanings such as warmth and relaxation, on the other hand, are associated with longer showers and therefore higher resource use (Breadsell et al. 2019).

Individuals who assign multiple meanings to the same practice and thus use varying amounts of resources at each instance may be able to make a conscious decision to only adopt one of its more resource-efficient meanings and associated consumption patterns. Conversely, individuals who have one sole meaning for a practice may not be willing or may not have the skills to reduce the associated resource use.

Requesting that occupants change the meanings of their practices without providing a suitable alternative to meet the same need is challenging. If the heater is turned on with the purpose of comfort, it may be hard for its use to be reduced without negatively impacting the user's lifestyle. Information campaigns that have urged consumers to reduce their shower lengths, for example, have failed as they have not properly addressed the meaning behind the practice. In this case, the adoption of an alternative technology, such as a more efficient shower head or water heating appliance, may be a more suitable solution for the purpose of reducing energy consumption in the home.

Enabling Change in the HSOP

To enable change to consumption patterns in the home, one of three scenarios needs to take place:

- a new practice needs to be incorporated in the HSOP leading to a new home equilibrium;
- one of the elements of the targeted practice needs to be modified; or
- a practice needs to be dis-interlocked or disconnected from the HSOP in order to act independently of the other occupants.

Individuals that perform habitual and highly interlocked practices are unlikely to change them unless there is a major modification in context (e.g. a change in lifestyle, family structure or to the technology element of the practice) causing practices to realign. Practice theorists posit that rather than persuading individuals to change behaviour and realign existing routines, the elements of practice should be targeted (Eon et al. 2018a; Spurling et al. 2013).

A change in meaning can be challenging as it is the reason behind the execution of a practice (Shove, Pantzar & Watson 2012); that is, meaning relates to a need that an individual wants to fulfil and that directly impacts on the perceptions of lifestyle, comfort and wellbeing. The skill associated with a practice is learned through the observation of other practitioners over the years, being family, society and culture dependent (Gram-Hanssen 2010; Scott, Bakker & Quist 2012). Affecting skills might therefore entail a shift in an individual's perception; which is also problematic to achieve in the short term. In contrast, the technology element of the practice can be more easily adjusted as it usually consists of a one-off change that does not affect the HSOP nor has a major impact on established habits and comfort (Eon et al. 2018b). This is supported by research that suggests that consumers are favourable to more efficient technologies but perceive convenience, practicality and cost as factors in take-up (Dolnicar & Hurlimann 2010). Technology changes can often be made when an individual is moving to a new house or purchasing new appliances.

Innovative technologies must be designed to meet occupant needs and be properly understood to avoid the risk of generating undesired rebound effects (Wolff et al. 2017). Scott, Bakker and Quist (2012) propose that enabling change in practice should be conducted through practice-oriented design, comprising the following steps: understanding the baseline practices; challenging the status quo by identifying alternative solutions; and co-creating solutions with the users. This process encourages the development of innovative technologies capable of meeting users' needs including more efficient use of resources. An example of this is the redesigning of bathing practices by Kuijer and De Jong (2009).

Another solution to enable energy reduction in the home is through unlocking practices from the HSOP; that is, making them independent of other occupants or other systems of (low carbon) energy supply. This can be achieved through the use of automation that can be built into the physical systems of the home. For instance, the practices of dishwashing, clothes washing and pool cleaning can be automated to occur at times when renewable energy is being generated but when occupants are not necessarily present to carry out the task themselves. Battery storage will expand the opportunity here. Similarly, appliances on standby can be programmed to be switched off when not in use and air conditioners can be controlled to function optimally in line with external factors such as temperature. While the aforementioned practices can be executed manually, they are considered a hassle by occupants and seldom integrated into established routines (Hobman, Stenner & Frederiks 2017).

Manual practices are bound in space and time in a tightly interlocked routine and can be changed through a change in the elements. Automated practices, in contrast, are bound only in space as they can function at flexible times and operate in conformity with the physical home system and independently from the HSOP. For instance, a timer could be installed to the reticulation system so it is independent of the rest of the HSOP. Careful consideration needs to be given when designing and deploying automated technologies as they are required to meet occupant needs and skills to work effectively and produce the desired outcomes for the household—and society more broadly.

Conclusion

This chapter outlined the theoretical concept of the HSOP, which can be used to provide a deeper understanding of the social system associated with the home and inform solutions for enabling energy reduction at a household level. More traditional methods have attempted to persuade occupants to change through the use of information campaigns and feedback technology. However, their effects are usually short-lived. Interventions aimed at affecting specific practices may ignore the underlying reasons for these practices and their interconnectedness within the home system. The effective modification of occupant behaviours and everyday practices requires a holistic understanding of the HSOP, which includes occupant practices, routines, and their interconnections.

While HSOPs can be realigned, they constitute a challenging task without a more fundamental change in context. Affecting the technology elements of practices on the other hand may be more readily accepted as they do not impact occupant meaning, comfort and lifestyle. This extends to the use of automated technology that can be operated independently of users. Even though the idea of utilising automation for improved house performance is not new, aligning it with the concept of HSOP can assist with improved design, deployment and adoption of technologies that enable low carbon practices.

Acknowledgements This research was funded by the CRC for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative.

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Publication IV

Wiktorowicz. J, Babaeff., T, **Breadsell. J**, Byrne. J, Eggleston. J & Newman. P (2018) "WGV: An Australian Urban Precinct Case Study to Demonstrate the 1.5°C Agenda including Multiple SDGs" *Urban Planning* 3(2), pp. 64-81; http://dx.doi.org/10.17645/up.v3i2.1245

Status: published (peer-reviewed)

Urban Planning (ISSN: 2183–7635)
2018, Volume 3, Issue 2, Pages 64–81
DOI: 10.17645/up.v3i2.1245

Article

WGV: An Australian Urban Precinct Case Study to Demonstrate the 1.5 °C Agenda Including Multiple SDGs

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Submitted: 31 October 2017 | Accepted: 5 March 2018 | Published: 24 April 2018

Abstract
The WGV project is an infill residential development in a middle suburb of Perth, Western Australia. Its urban planning innovation is in its attempt to demonstrate net zero carbon as well as other sustainability goals set by urban planning processes such as community engagement and the One Planet Living accreditation process. It is a contribution to the IPCC 1.5 °C agenda which seeks to achieve deep decarbonization while also delivering the UN Sustainable Development Goals (SDGs). Solar photovoltaics and battery storage are incorporated into the development and create net zero carbon power through an innovative 'citizen utility' with peer-to-peer trading. The multiple sustainable development features such as water sensitive design, energy efficiency, social housing, heritage retention, landscape and community involvement, are aiming to provide inclusive, safe, resilient and sustainable living and have been assessed under the SDG framework.

Keywords
decarbonizing; sustainable development; Sustainable Development Goals; sustainable precinct; zero carbon

Issue
This article is part of the issue "Urban Planning to Enable a 1.5 °C Scenario", edited by Peter Newman (Curtin University, Australia), Aromar Revi (Indian Institute for Human Settlements, India) and Amir Bazaz (Indian Institute for Human Settlements, India).

1. Introduction

WGV is the name of a new infill development focusing on meeting the 'missing middle' of medium density housing in Australia (Thomson, Newton, & Newman, 2017). WGV is in White Gum Valley, a low density suburb of Fremantle which is undergoing redevelopment as the first generation of housing from the 1950s is being replaced or restored with a denser and more sustainable housing product. It has been created by LandCorp, the Western Australian government's land development agency, with a charter to demonstrate innovation in urban planning and development. This article aims to show how WGV demonstrates how it achieves the two key components of the UN's 1.5 °C agenda:

1. Net zero carbon, a goal now being required by global commitments if climate change is to be kept below the 1.5 °C warming limit as suggested by IPCC;
2. A series of other sustainability outcomes that can be related to the UN Sustainable Development Goals (SDGs) which all nations are committed to achieve, especially SDG 11 which aims to make settlements 'inclusive, safe, resilient and sustainable'.

As a LandCorp development WGV must also be a commercially viable urban development product that can be sold into the market. It must, therefore, be able to create innovation within housing market constraints.

This article sets out to examine the extent to which WGV aspires to, and is achieving the 1.5 °C and SDG goals as well as being a marketable product. It will do this by examining the urban planning context, the urban planning process to deliver this, the results that can now be seen and what these suggest are the conclusions for urban planning.

2. Urban Planning Context

2.1. The 1.5 °C Agenda and Urban Planning

Climate change impacts on development and growth globally with the main contribution resulting from urban carbon emissions (Wang, Zhao, He, Wang, & Peng, 2016, p. 1066). The Paris Agreement in 2015 was an important step in creating a global climate change response that was shared and equitable for the parties involved. This was a key development as it has the potential to limit global temperature increase to 1.5 °C above pre-industrial levels (Roberts, 2016, p. 71). The IPCC are now assessing the options for achieving the 1.5 °C agenda (Boucher et al., 2016, p. 7287). The Paris Agreement has introduced a 5-year submission cycle for Nationally Determined Contributions (NDC), through the creation of voluntary short-term domestic climate policies together with the measurement, verification and monitoring of the NDCs for all parties. However, cities have a chance to commit to both short and long term processes that can help drive the 1.5 °C agenda.

Cities make a large contribution to greenhouse gas (GHG) emissions (Kennedy et al., 2009) as they are epicenters for economic activity and therefore represent a challenge but also an opportunity for climate change policy (Corfee-Morlot, Cochran, Hallegatte, & Teasdale, 2011, p. 169; Solecki, 2012, p. 557). Cities are where most economic growth now happens and so in their choices over infrastructure, technology and urban planning outcomes they can play an important role in developing mitigation strategies to reduce carbon emissions (Rosenzweig, Solecki, Hammer, & Mehrotra, 2010). For the first time the UN have set an urban goal, as part of the SDGs, which sets out seven indicators for urban development (as set out below). Therefore urban planning needs to try and achieve these seven indicators in every part of the urban development process and thus these goals must play a pivotal role in shaping future trends for infrastructure, land use and urban activity (Corfee-Morlot et al., 2011, p. 169; Kennedy et al., 2009; Yam et al., 2016) as was concluded by the UN Habitat Conference (UN Habitat, 2015).

Cities offer a platform for local level adoption of multi-scale approaches to climate change (Ostrom, 2010, p.27) with over 10,000 climate actions recorded (C40, 2015). Cities within Australia have been leaders in the push for sustainable cities, for example the City of Fremantle (where WGV is situated) has been at the forefront of climate action mitigation and adaptation with policies such as Carbon Neutrality which was the first in Western Australia in local government (City of Fremantle, 2011). Cities can "bend the climate curve" at a global scale with a 2-pronged approach of ambitious mitigation and transformative adaptation actions (Roberts, 2016, p. 71). Cities can act as the "starting point for the use of low-carbon ideas and technologies" (Wang et al., 2016, p.1066) to help achieve 1.5 °C and promote the benefits of low-carbon cities. The 1.5 °C agenda is an important opportunity for local governments as they play a key role in urban planning and are vital in creating the vision of low-carbon, sustainable, climate resilient and vibrant cities (Roberts, 2016, p. 71).

Without adaptive and innovative urban planning, it has been shown that urban expansion alone can raise temperatures by 1–2 °C (Georgescu, Morefield, Bierwagen, & Weaver, 2014, p. 2909). Cities that are "green, inclusive and sustainable" (The World Bank, 2010) are becoming increasingly important and therefore are a key focus for urban planning. This article outlines how urban planning in WGV can demonstrate how to achieve the 1.5 °C agenda.

2.2. The SDGs Agenda and Urban Planning

The SDGs are succeeding the Millennium Development Goals (MDG) and are a universal international consensus on sustainable development where a range of collective goals have been agreed upon including ending poverty and reaching gender equality (Sachs, 2012, p 2206). The SDGs are a transition from the MDGs and are furthering and expanding the pursuit of these goals into the future (Sachs, 2012). In 2000, the member states of the UN agreed upon the vision for the MDGs and recognized the need for global cooperation in the spheres of "development, peace and security, and human rights" (Singh, 2016). The MDGs were an expression of international public concern over significant issues such as "poverty, hunger, unmet schooling, environmental degradation and gender inequality" (Singh, 2016). To combat these global challenges a set of eight goals were established to enable the establishment of a set of quantifiable and time-bound objectives to ensure awareness is raised on these issues (Griggs et al., 2013, p 305; Sachs, 2012, p. 2206).

The transition from MDGs into SDGs was enabled through a significant consultation process within and by the UN which began in 2012. The SDGs were adopted in September 2015 and provide the current international framework for addressing global sustainability, with a framework of 17 goals, 169 targets and numerous indicators (Wellard, 2017, p 16) (see Figure 1). Having a cities goal (number 11) was a major step forward for urban planning in a global context.

The SDGs are interconnected and somewhat lacking in a structure to enable their delivery with so many different areas that are meant to be achieved simultaneously. The key features for delivery of the SDGs are partner-

Figure 1. The UN SDGs. Source: Global Goals (n.d.).

ships and demonstrations and hence an obvious place to do this is where economic growth is being focused, in the cities of the world. The SDG that focusses on cities is SDG 11 which states "making cities inclusive, safe, resilient and sustainable"; this incorporates seven indicators that have been selected to measure and monitor SDG 11's delivery (Table 1).

This article is seeking to show that the WGV example is tackling both the challenge of 1.5 °C in terms of energy and GHG innovations and that it can simultaneously achieve multiple SDGs using the urban planning framework. The SDG Framework and the Urban SDG Indicators will both be used to assess WGV as well as the demand and hence saleability of the development.

Urban planning should be an effective tool for achieving the SDGs as it often uses established frameworks and guidelines that can be selectively applied or adapted to meet the targets for achieving the SDGs. The world now needs many demonstrations of how to achieve these multiple goals through integrated urban developments. Shared-learning from such demonstrations can contribute to the international cooperation required to address the risks posed by climate change and its impacts through the SDGs (Griggs et al., 2013, p 305).

2.3. The WGV Context and Urban Planning

WGV is an infill residential development that evolved into a demonstration housing project, located in the capital of Western Australia, Perth. Perth has a Mediterranean climate with an average of 8.8 hours of sunshine per day, 300 cloud-free days a year ideal for solar energy (BOM, 2016). The development aims to offer an example of innovation in sustainable housing featuring a range of innovations but having a special focus on whether the solar energy can be enough to create a net zero emissions development. It is also an important demonstration of how to turn a middle suburban redevelopment site into a workable, saleable product at medium density, an agenda of interest across Australia and other car dependent cities in North America (Newman, 2015; Newman, Beatley, & Boyer, 2017; Thomson et al., 2017). The residential development is situated on the site of a former school which ceased to operate in 2008 and provided a site of 2.3 ha with approximately 100 housing units now being built in a medium density format and with a highly mixed tenure. Figure 2 is an artist impression of the site, which in early 2018 is about 70% completed.

WGV aims to demonstrate that precinct-scale design can contribute to sustainable development by incorporating various building typologies, climate sensitive designs, urban greening, water and energy management strategies, as well as including affordable housing options and a sense of place and community.

This article outlines how the aspirations of the WGV development and actions implemented to date demonstrate inclusive urban planning and design that can lead to the achievement of various SDGs as well as being zero carbon. By using the SDGs as a template against which to assess WGV, we can identify to what extent the WGV development has contributed to achievement of the SDGs. This article illustrates the demonstrated attempts to realize the ambitions of achieving both the 1.5 °C agenda and the SDGs at the WGV residential development.

3. The Urban Planning Process

The urban planning process is outlined to show how it incorporated both the 1.5 °C agenda and the SDGs.

This article has been developed based on data from various research projects that are utilizing WGV as a

Table 1. Indicators used in analysis of Goal 11: "Make cities and human settlements inclusive, safe, resilient and sustainable". Source: compiled based on UN SDGs indicators.

Target
11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.
11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.
11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.
11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage.
11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.
11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.
11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.

Figure 2. Artist impression of the WGV residential development, in the suburb of White Gum Valley. Source: LandCorp (2015).

case study. The data is drawn from a combination of semi-structured interviews with diverse stakeholders involved in the urban planning process, archival records, correspondence with WGV planning stakeholders, resident interviews of their expectations for moving into the precinct and current resource use, modelling as well as building monitoring.

While the WGV development was not specifically designed with the seventeen SDGs in mind, archival records show that it was developed with the general principles of sustainable development as a driver. Therefore, rather than assessing WGV against specific SDG indicators, this article takes a qualitative approach and assesses the WGV development process and outcomes against the principles of the SDGs and the 1.5 °C agenda. This assessment takes a localized approach, examining how an infill residential precinct in a developed country might contribute to achieving the SDGs at a local level.

As the construction of the WGV development is not fully complete, this article will focus on the as-designed phase of WGV with some early results that can help answer the question about its zero carbon goal. Future research and publications will follow the completed project, including a longitudinal study of resident resource use in the various dwellings in WGV and comparison of the as-designed and as-used electricity and water technology features.

The urban planning process methodology was typical of any LandCorp development where a strong emphasis is put on innovative design and parallel community engagement to see the extent to which it can deliver on the innovations in that community, but also how it can complete their obligation to be a commercial success.

3.1. The Urban Planning Process and 1.5 °C

Sustainable development through urban planning is necessary for cities to successfully adapt to climate change as it is aimed at achieving urban livability while avoiding adverse impacts, such as resource depletion and GHG emissions, within and outside the urban perimeter (AlQahtany, Rezgui, & Li, 2013, pp. 177–78). The core principles that have been accepted for sustainable urban planning according to AlQahtany, Rezgui and Li (2013, pp. 177–78), include: being responsive to market needs; integrating with multiple systems including transport, energy, housing and utilities; using partnerships; considering social, economic and spatial inequalities caused by climate change; and considering local culture and context. By utilizing the opportunity presented by this conflux of issues, the SDGs and the 1.5 °C agenda can be furthered through the use of sustainable urban planning and this is what set the context for LandCorp's process.

The reduction of non-renewable energy use and carbon emissions was a key focus for WGV and is central to its vision, as is necessary for achieving the 1.5 °C agenda. Through various initiatives and innovations such as energy efficient design, use of renewable energy and tech-

[1] Figures based on average Perth consumption for single residential dwellings, when adopting WGV's Design Guidelines and Sustainability Upgrade Package.

nologies, the reduction of grid energy consumption was set at 60% for WGV and 100%[1] in dwellings taking advantage of a WGV sustainability rebate package. Energy reduction measures such as the use of solar power, embedding of energy efficiency requirements in the design guidelines, and a precinct layout ensuring that homes are north facing, therefore benefiting from solar passive orientation, were major urban planning initiatives to reduce carbon and improve occupant thermal comfort.

In order to meet the 1.5 °C agenda it is necessary for rapid transformation so that any new development can make a significant contribution to the necessary changes in global emissions. Rapid transformations cannot be done using large scale centralized power systems; however, in cities where new developments are happening all the time an organic and exponentially increasing process can occur if the new technologies for energy efficiency are implemented as part of the new development. This is termed disruptive innovation as it is demand led and can cause dramatic change in short periods of time (Green & Newman, 2017a). Roof-top solar and lithium-ion battery storage were seen as having the potential to create such disruptive innovation. These were brought in through the involvement of academic advice (from Curtin University in partnership with industry) and were made possible to implement with assistance from a Federal Government grant to demonstrate how they can be used to contribute to savings, both monetary and carbon.[2]

During its design phase, WGV was established as a 'living laboratory' for a four-year research project supported by the Cooperative Research Centre (CRC) for Low Carbon Living and Curtin University (Burbridge et al., 2017). This research project was set up to provide collaborative innovation guidance, monitoring of energy and water usage and technology performance, as well as sharing the learnings with industry, government and the wider community.

Energy efficiency and other low carbon measures that were required in the design of WGV include:

- Climate responsive design and landscaping to harness the sun's energy to provide natural heating and cooling solutions, including intelligent use of trees for seasonal shading;
- WGV Design Guidelines set a minimum seven-star[3] energy efficiency rating;
- Mandated rooftop solar of 1.5kW for all attached and detached single dwellings with extra panels (upto 3.5kW) provided for single lot dwellings (through the WGV Sustainability Package Rebate);
- Battery storage and solar panels for the apartment developments;
- A shared Electric Vehicle for use by the community;
- Solar hot water systems or heat pump technology;
- Energy efficient electrical appliances;
- Energy efficient lighting solutions;
- Low energy space heating and cooling systems;
- Education material and support provided to residents.

Innovative research programs conducted as part of the project include:

- CRC for Low Carbon Living research program and partnerships to monitor energy use and water use, technology performance and facilitate knowledge sharing;
- Australian Renewable Energy Agency (ARENA) research program and partnerships to test viability of solar battery storage on strata buildings;
- A unique solar power and battery storage technology research trial in a shared strata-building setting at the Gen Y Demonstration Housing Project;
- A governance model to allow shared solar photovoltaics (PV), battery and monitoring systems to be used in medium density apartments; the governance models involving peer-to-peer (P2P) trading and using blockchain technology to be tested at 50 units of WGV;
- A study of household resource practices with comparison to individual baseline practices from before the residents move into WGV.

As well as the technology to enable rapid transformation of the energy provided, there was a necessary consideration for the management system in the WGV precinct and in this we have focused on how to create a Citizen Utility as set out by Green and Newman (2017a, 2017b). The context for this is set out below.

There is a growing trend in Australian energy markets where energy consumers have started to produce their own renewable energy—over 30% of households in Perth now have roof top solar panels representing some 700MW of power. Households are doing this to complement the grid sourced electricity they have traditionally relied completely upon. High retail energy prices coupled with low energy sale prices are incentivizing households to generate energy behind the meter and to store any surpluses. For the first time in history, network operators are now having to consider a future where householders are treated as both producers and consumers. However, whilst owner occupied low-density suburban households have benefited most from the renewable shift, several barriers still exist for those in strata (common property) arrangements as in WGV. Shared roofs have in the past been difficult to make available for the use of solar panels due to strata title governance requiring all residents to agree. This project aimed to get around that barrier by building solar and storage into the shared contracts

[2] It is worth noting that since the purchase of the PV and batteries the cost of these have continued their dramatic decline and are now being mainstreamed in a number of urban developments in Perth.
[3] Nationwide House Energy Rating Scheme—7 Star is above the mandidatory 6 star performance benchmark.

of all residents and providing a clear set of benefits by enabling them to have much better options for power into the future. This approach has been called a 'citizen utilities' approach, where a distributed, decentralized, decarbonized and democratized energy market is created (Green & Newman, 2017a). The Citizen Utility at WGV was therefore set up as a model for how a multi-residential medium density strata title company, that manages the shared spaces in a building complex, can also manage the power using a blockchain software system involving P2P trading (Green & Newman, 2017a, 2017b). One of the complexes was also fitted out with a shared electric vehicle linked into the solar energy and the Citizen Utility.

The importance to urban planning of these innovative energy models is that to phase out large scale fossil fuel power systems will require local urban developments that can become completely zero carbon with full electrification of buildings and transport (Kennedy, Stewart, Westphal, Facchini, & Mele, 2018). The technology for individual buildings and individual vehicles is well established but how to join them together into an urban system is the big question. WGV seeks to help answer this. The project is just one precinct but it is establishing a model for how it can be fitted into an urban system consisting of multiple precincts joined together through P2P trading. WGV was the first example of P2P to be established in Australia and possibly the world.[4] Thus citizen utilities across multiple precincts can create whole cities with their buildings and transport powered through these distributed, linked systems exchanging their energy services (Glazebrook & Newman, 2018). Considered in aggregate, Citizen Utilities will give rise to Precinct Utilities and Urban Utilities: decentralised and distributed utility services operating throughout the world's cities and suburbs. As WGV is one of the first of these in the world to be established and tested the project has considerable global significance with other precincts already copying the technology and the governance/management system created[5] (Kennedy et al., 2018).

The governance models developed at WGV to manage energy and GHGs were set up to research the shared benefits, risks and costs between developers, owners, tenants, strata bodies and utilities. The models also include the energy system design, billing, legal addendums for dwelling purchasers and dwelling leases. The financial aspects of the governance models are being further studied, tested and demonstrated in three different strata lot developments over time. The models developed were set up to be adaptable and scalable to suit different development types. The project thus provides scalable and generalizable models for shared ownership of solar and storage in medium density developments. The WGV site serves as a demonstration of the effectiveness of the governance model in enabling greater solar PV and storage to be adopted across apartment housing in Western Australia and across other parts of Australia and the world (Green & Newman, 2017b). Once established any housing, whether high density or low density, will be able to make the most of being in a local Citizen Utility. The urban planning implications of these Citizen Utilities are not known so the project has many years of examining such matters.

3.2. The Urban Planning Process and the SDGs

The first step in innovative and perhaps controversial urban regeneration projects was to develop an effective community engagement process to support the inclusion and participation of diverse voices. The second step was to develop the innovations in sustainability using an accreditation process and innovative approaches to urban design, affordable housing, landscapes and water. And the final process was to create a Master Plan with associated scenario planning.

3.2.1. Community Engagement and Community Culture

The community in the City of Fremantle where WGV is located is well known as a center for sustainability (Beatley & Newman, 2009) and strong commitments to carbon neutrality as one of its core principles. The development at WGV needed to take advantage of this commitment to sustainability and to further encourage and develop this culture, while providing a practical demonstration for sustainable living in Australia. Through energy saving initiatives, affordable living options and a wide range of shared amenities, WGV aimed to become a community where it was easier and more affordable for people to live in a sustainable manner. To achieve this goal, the developers of WGV created a partnership with the City of Fremantle and other stakeholders to develop a series of strategies and incentives, such as building attractive community spaces, community housing and introducing new residents at the development to community activities, to help achieve this sustainable standard of living. A further incentive for residents to commit to WGV's vision is a funding package worth up to $10,000 for eligible single-lot buyers where the price and installation of technologies such as solar power, water tanks, advanced tree provision and smart meters, is offset.

WGV aimed to be 'inclusive' in the following ways. It set out to provide a range of affordable housing typologies and rental/ownership options, with a mix of 23 single residential developments, two apartment sites, a Gen Y demonstration housing project and one affordable housing apartment site. It aimed to address the rising cost of living through the reduction in use of mains water and retail electricity; thereby offering lower operating costs for residents. A sense of community is supported through the provision of community-based re-

[4] https://onestepoffthegrid.com.au/peer-peer-solar-trading-kicks-off-wa-housing-development
[5] https://onestepoffthegrid.com.au/tag/peer-to-peer-trading

sources such as barbeque and picnic facilities, nature play areas, and informal seating to foster community contact and promote livability at WGV. Transport in WGV is an issue as it is not centered around a major public transport system; however, a regular bus service is within a short walking distance from the WGV precinct. Several alternative transport modes were developed in WGV such as walking and cycling paths, provision for electric car recharging, an electric car-share program on site, and bike parking spaces. Help with the building and construction process was provided to future owners through workshops on sustainable house and landscaping design. Lessons learnt throughout the development of the precinct are being shared between the government and industry stakeholders, research partners, and the residents through online publications and research-related events.

Archival records together with interviews with stakeholders demonstrate that the development process was characterized by the following features:

- Visioning for sustainable development and a site/context analysis early in the business case development stage;
- Incorporating community participation through workshops at an early stage (before detailed planning was completed) that enhanced local context, sense of place and community aspirations, particularly relating to affordable and sustainable housing;
- Bringing together various planning-related professionals such as urban planners/designers, engineers, landscape architects and estate architects to ensure collaboration between stakeholders. This collaborative and participatory approach enabled multi-disciplinary planning professionals to simultaneously consider the positive and negative impacts of each other's proposed planning actions upon each other's plans, in the context of the developer's overarching vision for a sustainable development. This ensured fundamental design requirements for solar access (including to adjoining sites), communal open space and active building facades were included.

These three elements in the planning processes were necessary to ensure that WGV could simultaneously reduce urban GHG emissions and achieve the SDGs as outlined in the results section below.

Germinating from the abovementioned community workshops arose an understanding of the community's desire for a residential development that was in keeping with the strong environmental and community-oriented values of the existing local community. One key aspiration was the desire to secure a site for a housing cooperative for a group of local artists known as SHAC (Sustainable Housing for Artists and Creatives). At the time, SHAC was unincorporated and non-financial which presented logistical challenges in terms of securing land and financing a building.

Consistent with SDGs 16 and 17, a local partnership between SHAC and a local community housing organisation (a not for profit social/public housing provider called Access Housing) was facilitated via the developer. The partnership process guided the artists' cooperative toward incorporation as a legal entity, which enabled its recognition within a legal and financial context. In an innovative partnership, the community housing provider entered into a novel agreement with SHAC to purchase a parcel of land at the WGV development and build housing for SHAC. The community housing provider then enabled an inclusive design process giving SHAC early input into the building's design, incorporating many of their unique needs as residents, including artistic spaces for them to work onsite (Ward, 2016).

This partnership approach between tenant and landlord represented a new way to develop an affordable housing project for this community housing organisation and demonstrates the importance of grassroots empowerment and inclusion in the implementation of SDG 16 (Lawson-Remer, 2015). The outcome is access to sustainable housing for people who experience financial challenge due to the atypical labor market patterns of the arts industry (Throsby & Zednik, 2011). Further, the early introduction of artists and creatives into this residential development supported the function that culture and art play in facilitating civic development and inclusion (Plant, 2016).

3.2.2. Sustainability Accreditation

In recent decades, various certification systems have been developed to support sustainability in the urban planning process that could be used by developers to further the SDG and 1.5 °C agenda (Newman et al., 2017). Initially limited to the building scale, some systems have since recognized the need to encapsulate a more holistic and wider community scale approach to sustainability (Haapio, 2012). Some of these certification systems have been criticised as they often do not include clear and specific targets aimed at performance and that evaluation of final outcomes can be deficient (Wangel, Wallhagen, Malmqvist, & Finnveden, 2016, pp. 200, 204, 210). However, most innovative developments use accreditation to help provide a systematic approach to precinct scale sustainability (Rauland & Newman, 2015; Webb et al., 2017).

One Planet Living (OPL) is an accreditation scheme developed by Bioregional, a UK firm that created BedZED in London. The OPL scheme is an international sustainability initiative based upon the idea that people need to live within the limits of one planet's natural resources. OPL provides a framework, built around 10 principles (see Figure 3), which guide sustainable development. The use of OPL at WGV innovatively addresses the concerns of certification systems raised by Wangel

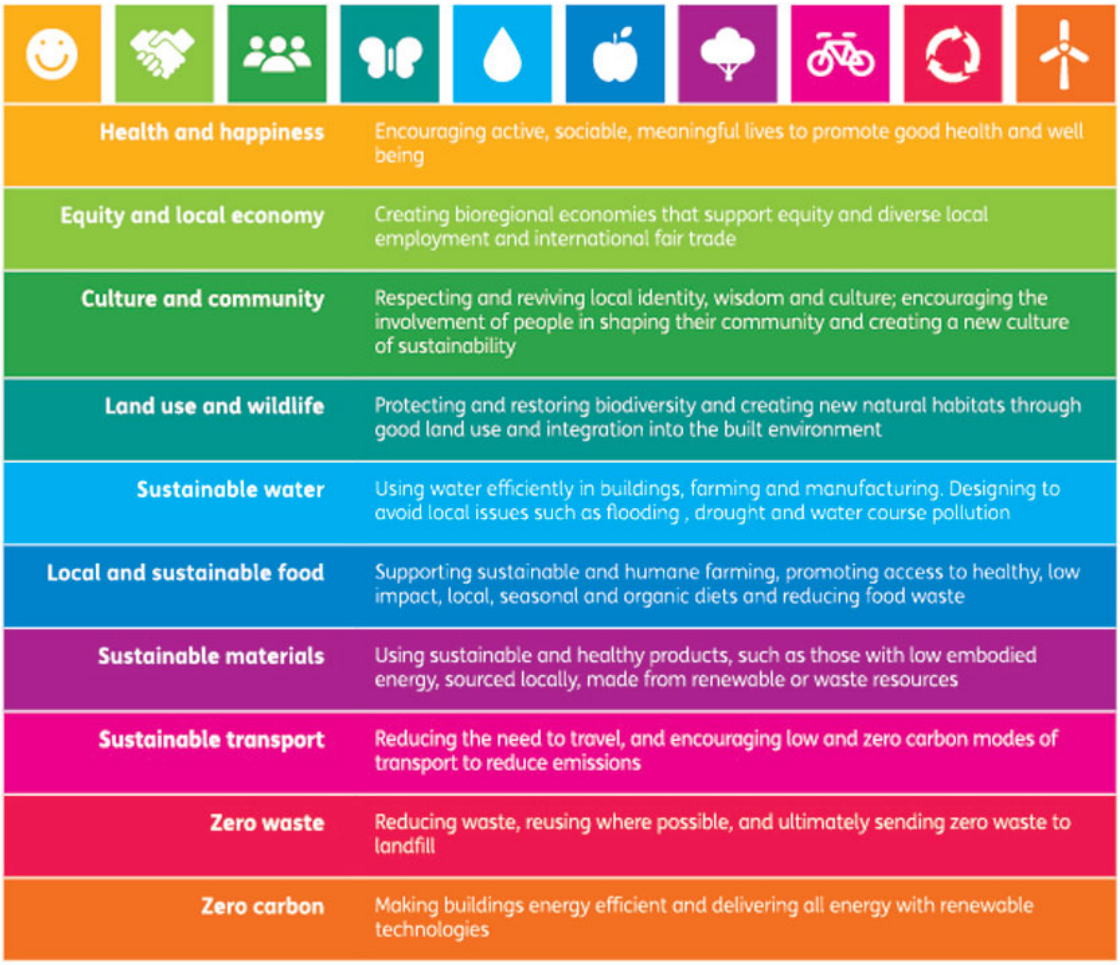

Figure 3. The OPL Goals. Source: Bioregional (n.d.).

et al. (2016) through specific performance targets, post-planning evaluation while taking a holistic approach to sustainable urban planning.

WGV is Western Australia's first residential project to achieve national recognition for its adoption of the OPL scheme to guide each stage of the urban planning and development. It is only the second project in Australia and only the eleventh worldwide to achieve an international endorsement as a One Planet Community through OPL. The City of Fremantle is one of the first One Planet Council's in Australia, therefore the required One Planet Assessment Report for WGV links in well with the City's One Planet Strategy and provides a solid framework for community members to implement sustainable living practices within their own homes. The main goal of OPL is to create neighborhoods where it is easy, attractive and affordable for people to live enjoyable and healthy lives using an equitable share of the earth's resources. As it requires zero carbon and has a range of 'inclusive' requirements, it is an ideal accreditation system for guiding the 1.5 °C agenda with the SDGs.

At WGV, the OPL's 10 principles were used to help guide the development and to demonstrate to the community, and potential buyers, that the project is a pioneering, real world, highly innovative, urban development.

3.2.3. Urban Design

The WGV project applied a multi-faceted design approach to sustainability with affordable housing and numerous environmental initiatives integrated into the design. The partnership between various stakeholders was seen as the basis for the development to be set up as a 'living laboratory' where energy use, resident behavior, energy initiatives and the implementation of the WGV Design Guidelines (LandCorp, 2015) can be monitored and assessed. WGV features innovative and pioneering energy, water and climate responsive design, innovative housing design for each of the development sites, e.g., the Gen Y project and a free open source website for the exchange and sharing of information on the design process.

The Gen Y Demonstration Housing Project is a prime example of quality urban design with its efficient use of the residential block through density and shared infrastructure and services. The increase in density has not come at the expense of livability for its residents and neighbors with each apartment having private and communal areas, generous ceiling heights and high thermal efficiencies. The Gen Y Demonstration Housing Project has been accredited with a gold medal level life cycle analysis by eTool (Beattie, Bunning, Stewart, Newman, & Anda, 2012), meets the principles of the OPL sustainability framework and has been designed to meet the essential requirements of Liveable Homes accessibility standards. The development was awarded the Australian Urban Design Award for Urban Design, Policies, Programs and Concepts: Small Scale in 2017.

A key aspect of the development project is the climate responsive layout which integrates solar passive design principles which ensure natural light, cross ventilation to each apartment and use of sustainable materials such as green concrete using low carbon furnace slag that increases thermal mass. Initial conversations with residents indicated that although they have moved from housing that has had air conditioning and heating systems that were regularly used, they are comfortable in the new dwellings that do not have these, verifying the climate responsive design. The three apartment developments on site have been designed to use renewable energy, water sensitive practices and battery storage technologies which include the installation of a 9kW Photo Voltaic system with battery storage, a 10,000L underground rainwater harvesting tank, and performance monitoring for all key services. The performance monitoring undertaken through the living laboratory research will provide valuable input for future developments on how the urban design principles perform with residents living at WGV, ensuring the results can be utilised by other developments targeting the SDGs and 1.5 °C agenda.

3.2.4. Affordable Housing

Affordable housing is critical for any development striving to be a model for multiple SDG goals. In Australia, it is estimated that 13% of the population is living under the poverty line, many of these children and old aged pensioners (Australian Council of Social Services, 2016). WGV addresses the lack of affordable and diverse housing in Perth through a range of dwellings and the inclusion of 15% affordable housing stock in the development (Housing Authority, 2016). The partnership between LandCorp, Access Housing and SHAC came together to deliver a community housing development specifically for local artists and their families at WGV. This initiative aims to support the local creative industry and encourage greater diversity and culture within the community. The partnership provides affordable housing for artists who work in the cultural and artistic center of Fremantle but have been priced out of the residential housing market and were travelling long distances (upwards of 50kms) to work and cultural events, often not using public transport. The SHAC development is part of a diverse range of housing and living options within WGV and includes apartments, townhouses and single homes that has attracted a broad cross section of society to WGV, resulting in a strong diversity of residents.

Along with the SHAC development, WGV is home to the Gen Y Demonstration Housing project, which is a practical demonstration of sustainable and cost-effective housing to suit living in the 21st century as well as two other demonstrations of social housing: a Baugruppen Model housing co-op and a privately funded housing co-op. WGV thus provides a practical demonstration of several new housing models that can be replicated to provide affordable housing for a range of people.

The various apartments of the WGV project also explored how to address the problem of the 'missing middle' of medium density housing, where cities like Perth have a plethora of either low-density single family homes in outer suburbs or higher-density apartments in inner areas, but not medium density dwellings in middle suburbs (Thomson et al., 2017). This project demonstrates a solution where the gap between single homes and apartment blocks can be bridged through some increase in density while also integrating well within the landscape of low-density housing surrounding the area.

The diversity of housing options was a key way that WGV was inclusive of the local community and could facilitate SDGs.

3.2.5. Landscape and Water

The creation of an attractive and highly liveable environment was seen as central to the design for WGV where local biodiversity, shade and shelter and opportunities for community interactions are supported. Through careful planning, 25% of the existing trees were retained in the subdivision design. Beyond this, there was a prioritization on the reuse and repurposing of materials to minimize waste. Before site work commenced on the project, a tree assessment was undertaken to determine suitable timber for harvesting and reuse with the development. Limestone recovered during project civil works was also incorporated into the landscape to celebrate local materials.

There was a fauna relocation program undertaken prior to site works commencing and the strategic provision of habitat structures has been considered within the new landscape. The planting of new trees was a priority with the project aiming to match the predevelopment canopy density while increasing dwelling density. This is an important strategy to improve livability but also contribute to the urban forest of the greater area. The re-engineering and revegetation with native plants of a large stormwater sump adjacent to the precinct was undertaken in partnership with the City of Fremantle to create a public space that was both attractive and engaging with the public while maintaining biodiversity and fulfilling its original drainage function (see Figure 4).

Overall the landscape design aimed to reflect White Gum Valley's character, support local biodiversity and promote community use of public spaces. 30% of the street trees are edible fruit species to support local food production and foster community sharing of resources. Public spaces include BBQ facilities and shaded picnic areas, nature play areas, informal seating and a network

Figure 4. Left: installation of drainage cells as part of the retrofitting of the stormwater sump; right: the completed stormwater sump with a newly landscaped parklet for community use. Source: LandCorp (2015).

of walkways and cycle paths to encourage active, outdoor lifestyles.

A range of positive benefits is set to be achieved as a result, including:

- Improving community health and wellbeing through the creation of an attractive and engaging outdoor environment;
- Providing habitat and native food sources to support local wildlife;
- Activating public open spaces to foster community cohesion and improved safety;
- Encouraging shared local food production to build community;
- Utilizing locally sourced materials, including repurposing of demolition materials to minimise waste.

Integrated Urban Water Management (IUWM) is a key feature of the precinct. The project is targeting a reduction of mains water consumption by 60–70% compared to the Perth average per capita consumption across the various housing typologies. To meet this goal, there is leading in-house and ex-house water efficiency measures, rainwater harvesting on the single residential lots and the Gen Y Demonstration House (for toilet flushing and washing machines), and a community bore water supply for irrigation. Each of these initiatives is supported by a combination of Design Guidelines (controls) and developer incentives (sustainability package) to increase successful implementation.

In addition to mains water reduction through efficiency and source substitution, water sensitive design has been applied to ensure stormwater is carefully managed across the landscape to promote local infiltration and groundwater recharge.

3.2.6. Master Plan and Associated Scenario Planning

Once the outline of a potential product was determined meeting all the above design objectives and providing a saleable product, it was possible to draw up a Master Plan and assess various scenarios that provided the planners and developers with necessary densities and expected outcomes for WGV. Such modelling was done using the Kinesis Modelling tool (Beattie et al., 2012) to assess the cost of the housing products, the carbon emissions, water consumption, transport and proportion of affordable housing. The project was then put to the market.

4. Results and Discussion

The results are set out to show how well WGV has turned out in terms of the 1.5 °C agenda, the SDGs and the saleability of the product.

4.1. WGV and Net Zero Carbon for the 1.5 °C Agenda

The results from the Kinesis modelling are summarized in Figure 5. They show that WGV was overall likely to be around 59% lower in carbon emissions, 75% lower in water and 21% lower in operating costs. Transport is almost identical as the site it is not well placed for public transport. This is further discussed later in the article.

The Kinesis modelling was undertaken at the completion point of Structure Planning, prior to detailed design and the incorporation of innovative programs like the strata solar energy storage trial on the multi-residential buildings, and the sizing of solar energy systems for the single residential lots to meet a net zero energy status. At the time of publishing this article, detailed modeling of the 'As Designed' scenario that incorporates the full suite of initiatives in partnership with industry and researchers was still being finalized. However it was clear that the potential for a zero carbon power system was now possible—at least in terms of design. As an example, the first multi-residential building to be completed, occupied and monitored (the Gen Y Demonstration House) is close to meeting 100% operational power requirements. Ongoing assessment through the seasons will be required to determine the extent to which the building can meet its operational energy needs. Likewise, the modelling indicates that the residential dwellings will

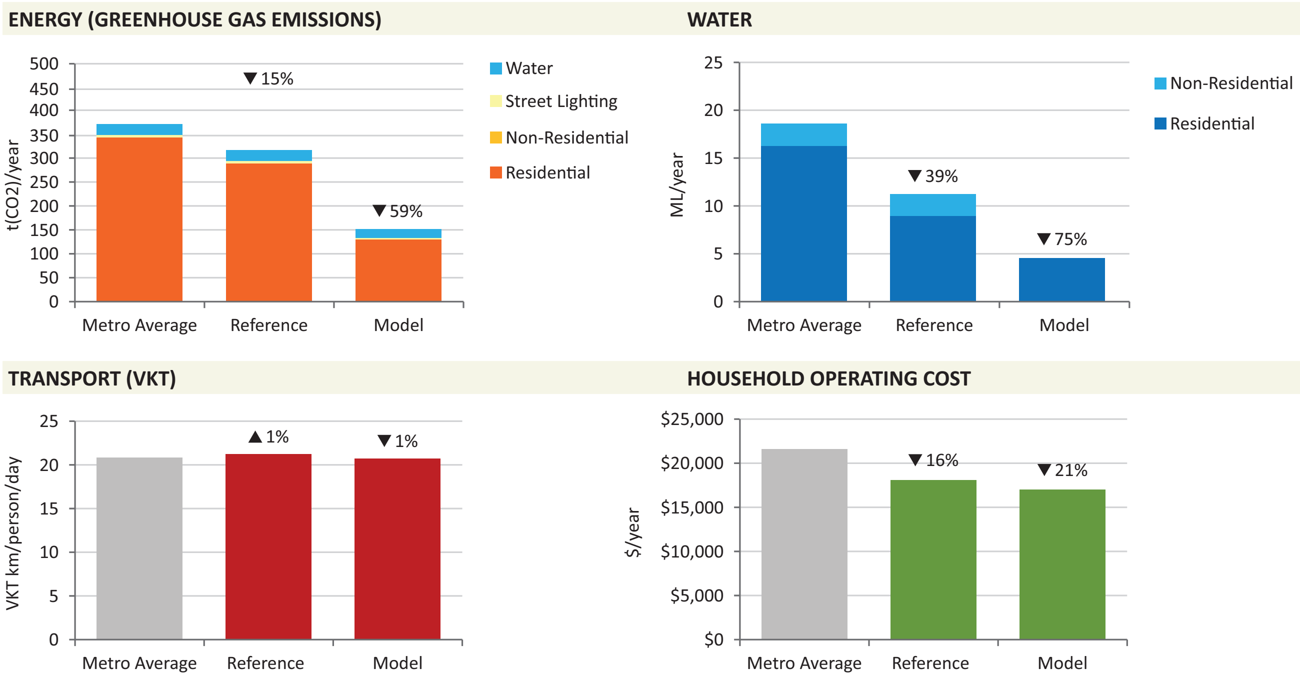

Figure 5. Results of early scenario modelling on WGV.

meet net zero energy, assuming the homes are operated as intended as early data shows between 72% and 98% of the power needs will be met from the solar and batteries. Thus, with the solar energy being exported to the grid (once batteries are filled) this means more renewables are being produced than energy consumed.

The establishment of a monitoring program across the whole site with detailed monitoring of particular developments like Gen Y and SHAC will provide the extent to which the design for zero carbon has been translated into real living situations.

4.2. WGV and the SDGs Agenda

Table 2 summarizes the work at WGV to create an urban development that can be close to zero carbon and at the same time help achieve the SDGs. The Table shows for each SDG how well the SDG has been met in WGV—major, medium or minimal—and what in particular was done.

Table 2 shows that the major focus of the 1.5 °C agenda, achieving a zero to low carbon development, is likely and that at the same time the development has contributed significantly to the SDGs. It demonstrates that, of the 17 SDGs, 12 SDGs were achieved in a major way, and five in a minimal way. This would suggest that a significant urban development demonstration has been achieved in the design of the WGV project. Initial modelling of the infrastructure performance and interviews of the residents indicate that WGV is on track to achieve these goals as planned from the design stage.

Another way to use the SDG framework is to examine the indicators that were set up by the UN for the SDG 11 urban goal. These are set out in Table 3.

Out of the seven indicators only one shows up relatively poorly, the transport indicator, as WGV is not a transit oriented development. However residents are already finding innovative solutions to transit problems, with some returning to their habit of bicycle riding that was not used in their previous households. Others are staying closer to home for recreation with their small children and utilizing the shared spaces instead. For SHAC in particular, the residents have been able to work onsite in the artist studios, or close by in the center of Fremantle, reducing the need to travel the long distances they were in previous housing. The first steps towards making this area more transit oriented through urban planning are happening along the corridor into the Fremantle CBD where a new development around ten times the size of WGV is being planned with opportunities to scale up many of the innovations in WGV; this should include a transit system with innovative smart systems and an autonomous electric bus service that could also be brought to WGV. This would help considerably in completing the agendas for both 1.5 °C and the SDGs.

4.3. WGV and Market Results

As the West Australian Government land development agency, LandCorp is obliged to deliver its projects on commercial terms. As such, the broad range of innovations described in this article were scrutinized to ensure they were technically and financially viable. Except for the research grants identified, WGV has met the necessary business case considerations of a successful land development based on market return. In addition, the offerings were very well received by the market, with all lots sold in good time at a period where the market was

Table 2. SDGs and how the WGV residential development contributes to their achievement.

UN SDGs	UN SDGs Defined	WGV Details and Extent	Overlaps with other SDGs
1 NO POVERTY	End poverty.	Major: affordable and social housing.	10, 16
2 ZERO HUNGER	End hunger, achieve food security and improve nutrition.	Minimal: planting of edible fruit tree varieties; promoting home food growing in the Design Guidelines; connecting residents with local community gardens through the Resident Information Pack.	3, 12
3 GOOD HEALTH AND WELL-BEING	Ensure healthy lives and promote well-being.	Minimal: attractive and engaging outdoor environments; connecting residents with activities and networks through the Resident Information Pack.	
4 QUALITY EDUCATION	Ensure quality education for all.	Minimal: educational demonstration project of sustainable living.	
5 GENDER EQUALITY	Achieve gender equality.	Major: strong women's leadership in social housing.	
6 CLEAN WATER AND SANITATION	Provide safe and affordable water and sanitation for all.	Major: reduction of water usage, water efficiency, water sensitive design.	3, 17
7 AFFORDABLE AND CLEAN ENERGY	Ensure access to affordable, reliable, clean energy for all.	Major: solar and battery storage, energy efficiency, renewables.	9, 12, 13, 17
8 DECENT WORK AND ECONOMIC GROWTH	Promote decent work for all and sustainable economic growth.	Major: citizen utility, sharing of energy through peer to peer network, 'pro-sumer'; affordable housing.	
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Build resilient infrastructure; promote inclusive and sustainable industrialization and foster innovation.	Major: innovative design and demonstration project fully monitored.	7, 11
10 REDUCED INEQUALITIES	Reduce inequality within and among countries.	Major: Gen Y housing project, SHAC "sustainable housing for artists and creatives" housing project.	

Table 2. SDGs and how the WGV residential development contributes to their achievement. (Cont.)

UN SDGs	UN SDGs Defined	WGV Details and Extent	Overlaps with other SDGs
11 SUSTAINABLE CITIES AND COMMUNITIES	Make cities and human settlements inclusive, safe, resilient and sustainable.	Major: shared amenities, community gardens and activities, consultation and innovative technologies.	
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Ensure sustainable consumption and production patterns.	Major: renewable energy, production of resources, resource efficiency.	2, 7, 9
13 CLIMATE ACTION	Take urgent action to combat climate change and its impacts.	Major: zero carbon, renewable energy, accreditation.	7, 9, 11, 12
14 LIFE BELOW WATER	Protection and sustainable use of marine resources.	Minimal: advising residents on ethical purchasing programs through the Resident Information Pack, storm water cleaning in innovative sump.	
15 LIFE ON LAND	Protection and sustainable use of land resources.	Medium: habitat and food sources for local wildlife.	
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	Promote peaceful and inclusive societies, provide access to justice, and provide strong institutions.	Major: SHAC, Gen Y housing demonstration project; community engagement.	1, 3, 11
17 PARTNERSHIPS FOR THE GOALS	Work together for sustainable development.	Major: community consultation, partnerships with local, state and federal government; research bodies; private enterprise; and not-for-profit sector.	9, 10, 11, 16

down. Market interest has also been strong on the multi-residential units. This is important context as it demonstrates both the financial viability and market appetite for quality projects that provide leadership in a low carbon future. The challenge is how these concepts can be upscaled and delivered into other regions around the country and the world.

5. Conclusion

Rapidly growing cities need to tackle the agenda of 1.5 °C to keep the extremes of climate change from impacting on global environments, societies and economies. Cities also need to implement urban planning and development that achieves the SDGs in an integrated and systematic way. WGV is an example of how this can happen using established accreditation processes such as the OPL framework.

WGV is a development where precinct-scale planning has been focused upon improving the livability of the development through various building typologies, climate sensitive designs, urban greening, water and energy management strategies, as well as a sense of place and community engagement strategies. Partnerships and early planning of innovations enabled solutions to be found to many problems faced in everyday urban precincts and thus were able to move the development towards achieving its three goals of zero carbon for 1.5 °C, inclusive design for the SDGs and a marketable product to enable mainstreaming.

By using the SDGs as a template for assessing WGV we can see how targets can be reached and the ways in

Table 3. Urban SDG indicators and how they apply to WGV.

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable Targets:	**WGV Achievements**
11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.	Housing affordability mainstreamed through different housing and tenure types and through reduced operational costs. Basic services all available through community utility.
11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.	Public transport is not much more available as WGV is not close to economic activity or on a transit route of any significance, however it is close to schools, local shops and local green spaces. Walkable and cyclable internal street designs and the availability of a shared EV all assist. Universal access has been built into homes and internal roads.
11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.	Inclusive community already exists in the area and WGV builds on that with a landscaped BBQ area, internal streets encouraging walkability and community events organised by residents. The Citizen Utility can use infrastructure management and planning for greater community engagement in urban living processes.
11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage.	Many features of cultural heritage were incorporated into the new development including naming some streets with Nyoongar words, restoration of the old Community Hall restored for public use, local artists engaged in designing elements of public space, reuse of trees removed during the building process on the site.
11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.	New solar/battery systems and water sensitive urban design (especially storm water sump) are much more resilient for future climate change or disaster management. Citizen Utility will mean very strong social capital that is also critical to resilience.
11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.	Waste management and air quality improved by community infrastructure.
11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.	Green spaces created, existing trees retained and canopy cover planned into the development; Citizen Utility will ensure area regenerates organically.

which they can be made possible. This article illustrates the demonstrated attempts to realize the ambitions of achieving both the 1.5 °C agenda and the SDGs at the WGV residential development through thoughtful and inclusive urban planning. The lessons from it can now be mainstreamed and translated to other environments and cultures.

Acknowledgements

This project had a number of partners all of whom played important roles: LandCorp, Urbis, Coda, Tabec, Josh Byrne & Associates, Balance Group, City of Fremantle, Access Housing, Australian Government Research Training Program Scholarship, CRC for Low Carbon Living, Australian Housing and Urban Research Institute (AHURI), and the Australian Renewable Energy Agency.

Conflict of Interests

The authors declare no conflict of interests.

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Publication V

Breadsell, J., Eon, C., Morrison, G. & Kashima, Y. (2019). Interlocking practices and their influence in the home. *Environment and Planning B: Urban Analytics and City Science.* 46(8), pp. 1405-1421; https://doi.org/10.1177%2F2399808318824114

Status: published (peer-reviewed)

Special issue article

Urban Analytics and City Science

EPB: Urban Analytics and City Science
2019, Vol. 46(8) 1405–1421

DOI: 10.1177/2399808318824114
journals.sagepub.com/home/epb
SAGE

Interlocking practices and their influence in the home

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Abstract

When people move into sustainable houses, they bring practices with them that have temporally evolved along with their daily lives. A common misconception is that change to individuals' resource use can be persuaded without consideration of previous practices. However, it has been observed that energy efficient or smart buildings do not always perform as expected due to a lack of occupant skills, time or motivations. The successful adoption of technology is dependent on the understanding of these underlying practices, which should be considered at the building planning stage. The recently developed concept of the Home System of Practice was employed in this research to study home dwellers through living laboratory mixed methods, allowing for an in-depth examination of their daily lives, routines, habits and practices. The personal hygiene, thermal comfort, clothes drying, garden watering and waste practices of 14 households were examined. Results identified Home System of Practices with different degrees of interlocking and highlighted how various combinations of meaning, skill and technology elements of a practice as well as contextual influences can affect resource use. These insights can be used by urban planners to facilitate a co-creation process with end-users and develop innovative solutions to enable resource reduction while ensuring that resident needs and comfort are maintained.

Keywords

Social practice theory, Home System of Practice, interlocking

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Introduction

As sustainable residential developments or smart cities are built, innovative technologies are introduced with the aim of increasing resource efficiency, and residents are expected to adapt to their new environment. Mainstream approaches that focus on persuading sustainable behaviours (e.g. Ajzen, 1991) through prompts, information provision and feedback are often incorporated after the residents have moved into their new homes. However, people bring practices with them that have evolved over years or decades. Persuading change without consideration of previous practices, lifestyle, needs, motivations or skills is often unsuccessful (Brynjarsdottir et al., 2012). A longitudinal comprehension of household practices is required for a more effective influence of sustainable design practices (Gram-Hanssen et al., 2017). An improved understanding of the established routines and habits of households enables city planners to cater for resident needs and preferences when designing innovative technology and to map resource flows at a home level. Learnings can potentially be scaled from home to precinct development and even city wide and incorporated in the smart cities of the future.

This paper builds on the recently developed concept of the Home System of Practice (HSOP) (Eon et al., 2018) to study the flows of energy, water, food, waste and movement of residents before they move into a low carbon development. The notion of HSOP establishes the home as a network of practices conducted by different residents on a daily basis as part of an established routine. Individual practices and routines in a home are interconnected and overlap, creating a unique system equilibrium which drives and influences the home resource metabolic flows. There has been an identified need in the literature to move away from the traditional social practice theory (SPT) studies of car-driving and daily showering themes to explore the wider terrain of interlocking work–leisure–household–family practices (Keller et al., 2016). Obtaining insights into the HSOP helps to plan and design for better houses and urban spaces that enable the transition to regenerative developments.

SPT and HSOP application in resource consumption research

From Schatzki's work in the 1990s (Schatzki, 1996; Schatzki et al., 2001) to Shove and colleagues' work within the next decade (Pantzar and Shove, 2010; Shove, 2003; Shove et al., 2012, 2007), SPT has emerged as one of the most prominent approaches to understanding sustainable actions and lifestyles.[Is it "Shove, 2003a" or "Shove, 2003b"? Please check throughout this article.] SPT focuses on enabling the reduction of resource use and waste through emphasising people's interactions with the infrastructure and social systems around them, which is vital in the undertaking of their practices, which ultimately use resources (Foulds et al., 2013; McKenna, 2016; Scott et al., 2012). Practices are routine actions that can be considered to be composed of three interconnected elements: technology, meaning and skill (Eon et al., 2018). As opposed to socio-psychology approaches to understanding users, in SPT the practice is the unit of analysis, rather than the individual and their beliefs (Reckwitz, 2002; Røpke, 2009; Shove et al., 2012; Warde, 2005). There is an extensive body of research focusing on daily practices, particularly relating to household resource consumption with the end-goal of transforming society into adopting more sustainable energy, water, waste and transport practices (Gram-Hanssen et al., 2017). There has also been extensive discussion in the literature of the benefits of a SPT approach as opposed to other methods focusing on behavioural aspects (Browne et al., 2014; Hargreaves, 2011; Moloney and Strengers, 2014; Shove, 2010, 2011). Ultimately, a SPT approach allows for a holistic interpretation of the world that is populated by social practices, unlike psychological approaches that focus on the individual as the unit of analysis. This allows for policy recommendations that are based on residents' daily actions, not just their beliefs and values.

Examination of daily actions within households has prompted us to propose a SPT inspired concept, the HSOP (Eon et al., 2018), to provide us with a deeper understanding of the interlocking of multiple systems of social practices within households. To illustrate, let us start with individual householders. They perform daily practices sequentially as part of a routine, which is usually repeated on a daily basis (Eon et al., 2018; Macrorie et al., 2014; Spurling et al., 2013). These practices interlock in an individual system of practice (SOP), that is these practices influence and constrain one another and are influenced by temporal and spatial factors. For instance, established work hours may dictate the time that breakfast is taken or the time allocated for a morning shower. However, in households with multiple actors that have predetermined activities such as work or school, the days that these occur on have a high degree of interlocking among practices not just of each householder, but also of those multiple household occupants (Eon et al., 2018; Torriti, 2017). It is important to note that technologies strongly influence the synchronisations that occur within and between practices. For instance, they enable efficient interlocking of practices such as automatic pool cleaners being able to run when there is solar power available or tumble dryers allowing clothes to be dried in the middle of the night (Eon et al., 2018; Friis and Haunstrup Christensen, 2016). The consumption of resources is therefore closely related to the temporal patterns of the practices of households, both of individuals and of the household as a whole (Friis and Haunstrup Christensen, 2016; Torriti, 2017).

In a home with multiple residents, different individual SOPs interlock with one another, creating a HSOP. In other words, some components of individual SOPs are adjusted to one another to meet the overall constrains within a household. Once equilibrium is reached, this drives the everyday operation of the home as a system of routines. Practices in the HSOP can realign and reach a new equilibrium whenever new practices are introduced or there is a change in context (e.g. weekends, moving into a new house). Nevertheless, the degree of interlocking – whether it is only lightly or heavily interlocked – can affect the ease with which such a realignment can occur. In this paper, we show how the HSOP concept provides an insight into the nature of interlocking among social practices within a household as a metabolic system and discusses potential implications of the degree of interlocking on the ease or difficulty of practice realignment and change in different types of households.

Methods

The Living Laboratory (LL) provides an opportunity to study the HSOP in a user-focused environment (Burbridge et al., 2017; Keyson et al., 2017). This paper views homes as embedded LLs to study residents' daily domestic practices and explore the HSOP in greater detail than isolated self-reporting through interviews or a survey (Herrera, 2017a, 2017b). This research combines SPT with methods from LLs to build a picture of household's daily practices (Herrera, 2017b). The use of in situ methods enables study participants to reflect on their social, physical and temporal daily practice influences (Herrera, 2017a).

In total, 14 households were studied, with 16 residents from these households participating in the study (Table 1). The households were investigated through a longitudinal, explanatory design mixed methods process featuring in-depth home interviews, quantitative resource data collection and LL methods (Liedtke et al., 2015). The objective was to understand their daily practices influencing the home metabolic system. This included a structured home interview of residents' energy, water, waste, food and transport practices, followed by

Table 1. Participants, their occupations and dwelling type.

House	Dwelling type	Residents (participants)	Occupancy lifestyle	Sustainability features
A	Townhouse, own	1 female adult	Works full-time	None
B	House, own	2 adults, 3 teenagers (2 adult participants, male and female)	1 adult full-time, 1 adult 4 days a week, teenagers study full-time and part-time work	Solar PV system, rainwater tank, vegetable patches, three compost bins, two worm farms
C	House, own	1 female adult, 2 teenagers (1 female adult participant)	Adult 4 days a week, teenagers part-time work	Solar PV system, garden bore
D	House, rented	2 adults, 2 teenagers (mother is participant)	Self-employed, full-time artist and teacher	None
E	House, rented	2 adults (mother and son) (mother is participant)	Adult 4 days a week, son works night shifts	None
F	House, rented	2 adults, male and female	Both work full-time	None
G	House, rented	3 adults (mother and 2 children) (mother is participant)	Mother is part-time shift-worker, 18 yo full-time student, 22 yo seeking full-time work	None
H	Semi-detached house, rented	1 adult, 1 teenager part-time (father is participant)	Self-employed, full-time creative	None
I	Unit, rented	1 female adult	Retired	None
J	Apartment, rented	1 female adult	Self-employed, full-time artist and casual tutor	None
K	Apartment, rented with flatmate	2 adults (1 female adult participant)	Full-time fly in-, fly out-professional	None
L	Staying with parents, who own house	3 adults, 1 child (3 years) (mother is participant)	Self-employed, part-time artist and teacher, another part-time job	Solar PV system
M	Staying with two different friends, who own houses	3 adults and 2 adult (1 male adult participant)	Works full-time	None
N	Staying with a friend, who rents house	2 adults (1 male adult participant)	Self-employed, full-time creative	None

an audit of appliances and daily routines. Participants were also asked to complete a workbook based on LL methods (Liedtke et al., 2015) over a period of two weeks, answering more detailed quantitative and qualitative questions on their resource consumption habits, including the previous year's utility data, social networks related to sustainability, questionnaires on appliance use and resource practices.

The Low Carbon Readiness Index (O'Brien et al., 2018) was also used. This Index assesses individual norms, household norms and perceived societal norms through a Likert Scale questionnaire. It enables assessment of some aspects of the meaning of HSOP. Text probes were sent periodically over two weeks to gain in situ qualitative contextual results on current practices, minimising the impact of recall during interviews (Thoring et al., 2013). The text probe method is a combination of cultural probe methods developed in the past two decades that require people to take photos of objects during their daily life (Crabtree et al., 2003; Gaver et al., 1999; Thoring et al., 2013). The data were analysed through thematic coding using NVivo, resulting in 43 nodes being identified featuring themes of comfort, convenience, sustainability and affordability as advocated by Shove (2003) and Thorpe and Gamman (2011).

The case study for this paper consists of households moving into the sustainable residential development White Gum Valley (WGV), located in Fremantle, Western Australia. This paper focuses on residents before they move into WGV to create a clear picture of their HSOP.

Results and discussion

This section discusses the variety of practices performed by the households relating to energy, water, waste, transport and food. First, the aforementioned practices are presented in terms of their meaning, technology and skill. Then, it is discussed how other factors such as context can influence the performance of practices. Finally, these insights are integrated into a deeper discussion of the HSOP and the implications for smart cities.

The three practice elements

Meaning

Meaning refers to the symbolic meanings, ideas, values, understandings, assumptions and aspirations of a practice (Eon et al., 2018; Shove et al., 2012). The meaning element can differ between different people performing the same practice, resulting in various levels of resource use. This is demonstrated with multiple examples in this section through the practices of showering, clothes drying and thermal comfort.

Showering. Previous research has shown that the meanings of refreshment, cleanliness, relaxation, warmth or social expectation can be associated with the practice of showering (Pink and Mackley, 2015). Eon et al. (2018) showed that the meaning of a shower defines its temporal duration. These results have also been identified in this study as shown in Figure 1.

The relaxation showers or baths were the longest, being on average 12 minutes in length. The showers that are situated between other practices are bound by the time restraints of what needs to be done, and therefore are quicker. These occurred at all times of the day, and the meanings for them varied within the eight cleanliness or freshness themes identified. Shove (2003) defines freshness as a state of mind that is related to the action of refreshing the

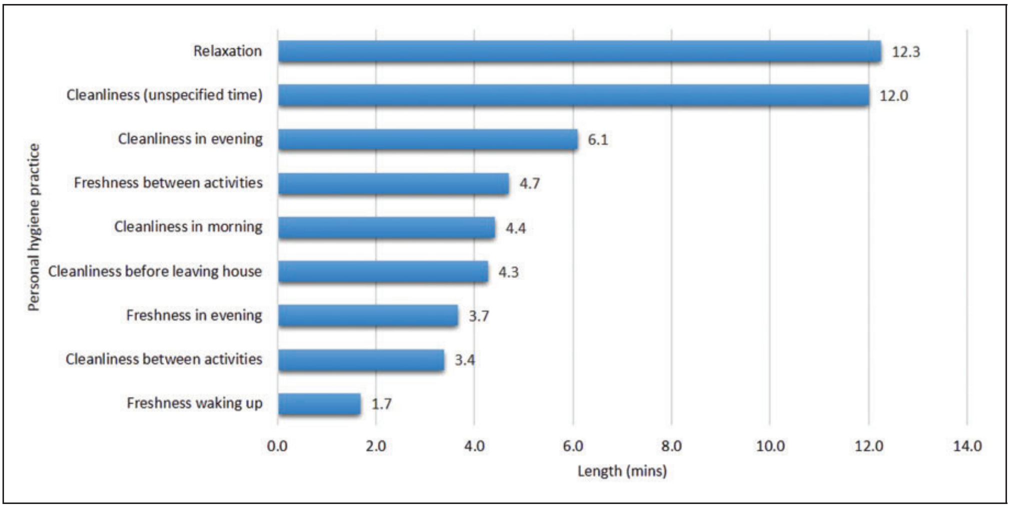

Figure 1. The average length of personal hygiene practices based on meaning. Data from 12 residents, two left out due to incomplete data (house B male and house N).

body with water or changing clothes, while cleanliness is related to the removal of bodily contamination. A freshening up after waking practice was the quickest, often being less than 2 minutes in length and was performed either with a shower, a wash with a towel or a bucket. Freshening up via shower between activities may also be used to take a break, similar to relaxing, which can explain the increased length.

Clothes drying. The majority of households did not use a tumble dryer to dry their washing, instead opting for air drying on clothes lines. Only three households own a tumble dryer, with two reporting it being used (houses G and K). The residents associate dryers with excessive energy use and perceive the climate in Perth convenient for air drying. Children often performed the practice differently than their parents due to a difference in the practice meaning. In house G, the mother reported a preference for air drying laundry and conserving energy. The teenagers living in the house, however, prefer to use the dryer because they need their clothes quickly before performing other practices. The teenagers' meaning of laundry practices is associated with convenience while their mother's is associated with environmental impact and reducing energy consumption and costs. This confirms discussions raised in Gram-Hanssen (2008), where different individuals assign multiple meanings to the use of the tumble dryer.

Thermal comfort. The practice of thermal comfort varied depending on whether households had visitors. Despite all households reporting that they usually maintain thermal comfort through warm clothes or blankets, they all stated that they switch to using mechanical heating or cooling when people visited. This confirms results found in Hitchings (2013) where the same practices were reported.

Normative meaning of low carbon and comfortable lifestyle in the home. Through the use of the Low Carbon Readiness Index developed by O'Brien et al. (2018), individual, household and perceived societal norms were assessed. The results in Figure 2 show that most participants think

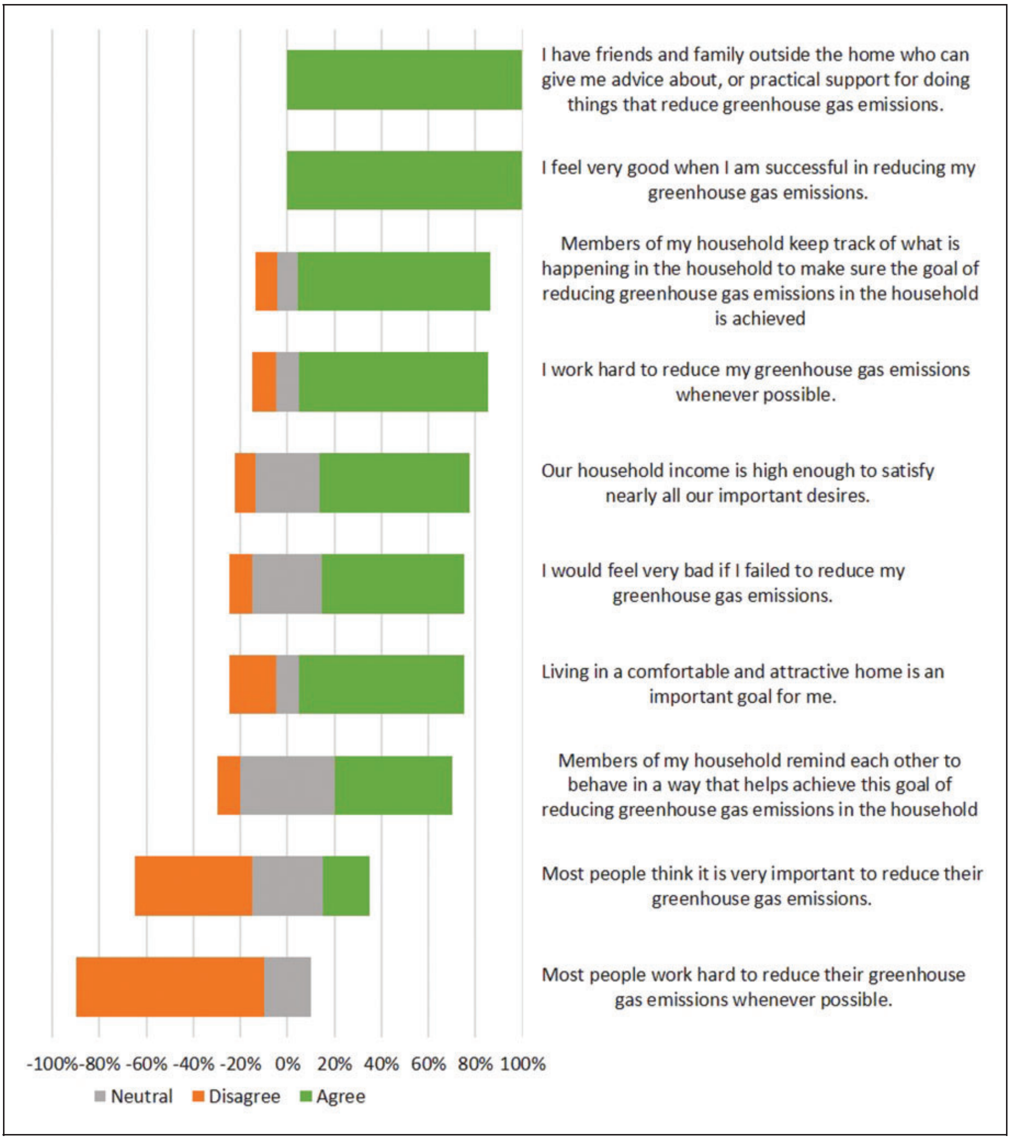

Figure 2. Residents' answers to questions from the Low Carbon Readiness Index (based on O'Brien et al., 2018). Data from houses D, G, H, J, L, N left out due to incomplete data.

others in society do not believe it is important to reduce their carbon emissions and do not work towards it, even if their friends and family do. The home occupants also have a goal of living in a comfortable house. It could be posited that when hosting visitors, the residents want to blend in with the rest of society and use mechanical heating or cooling. Despite the fact that they may personally be concerned about the emissions, the social norm of being perceived as living in a comfortable home may hold a stronger meaning for them. This seems to suggest that many of these householders see themselves, their own households and their close social circle as a haven or avant-garde of low carbon living. Most households also generally have a high enough income to justify the occasional use of mechanical heating and cooling.

Technology

The technology element of practices comprises of the physical elements of the house as well as the appliances used to perform a practice (Eon et al., 2018; Gram-Hanssen, 2014). Technologies can enable or constrain a practice to be executed in a particular way, such as a heater being used for thermal comfort and a hose being used for watering the garden.

Thermal comfort. Households in this study used several different technologies to achieve the same practice meaning. Seven households use non-mechanical ways of maintaining their thermal comfort throughout the day. This consisted of using blankets, jackets and scarves when cold and opening windows or wearing less clothing during warmer weather. If still uncomfortable, most households would then turn on a fan to circulate air around the room. These practices indicate that most households are already aware of and practice energy-efficient ways of keeping thermally comfortable as outlined in Hobman et al. (2017). Eight households utilised reverse cycle air-conditioning, gas or electric heaters to keep comfortable. These households often reported the children using these forms of heating more than the adults. Houses B, D and F reported to be comfortable when the oven was on for cooking during winter, which would simultaneously heat the living areas of their house. This particular use of technology was only effective in houses that have a small living area.

Garden watering. Automated systems were also observed in this study as an alternative technology to replace certain manual practices. For instance, house L has garden sprinklers set to automatically function at certain times, days and lengths. This removes the need for human interaction with the technology used for irrigation, except for its initial setup. However, if the times are set to be too long or too frequent, it could hinder sustainable water consumption. This was the case with house L, where the female participant reported that the current irrigation settings were too long. Changing the setting on the automatic system to shorten the watering length would reduce the water used during this practice; however, this would require the resident to actively engage in the performance of the practice, which is currently not a part of her SOP. These results are similar to those in Eon et al. (2018), where residents were found to be watering their garden on days contrary to the local regulations but did not have the skills to change the automation settings.

Skill

The final element of a practice is the skill (Eon et al., 2018; Scott et al., 2012). This refers to the know-how, technique and competence needed for executing the practice in the desired manner. Skills relating to mundane practices are usually learnt at a very young age through observing others. They are often culturally and societally dependant and passed down through the generations. Once the skills of a practice are learnt and repeated successfully to achieve a sought outcome, they become habitual and largely automatic. The exception is when a significant shift in technology occurs, making previous practices and associated technologies obsolete. In this case, skills need to be relearned and reassociated with a meaning. Differences in skills are illustrated in this section through the example of waste practices.

Waste practices. If people have never learnt the skill of disposing of waste in a particular way they will be unable to perform that practice, even if they have a strong meaning and desire to do so. For instance, most residents separate plastics, cans, cartons and cardboard from the rest of the waste for recycling; however, only 60% of them compost garden or kitchen waste

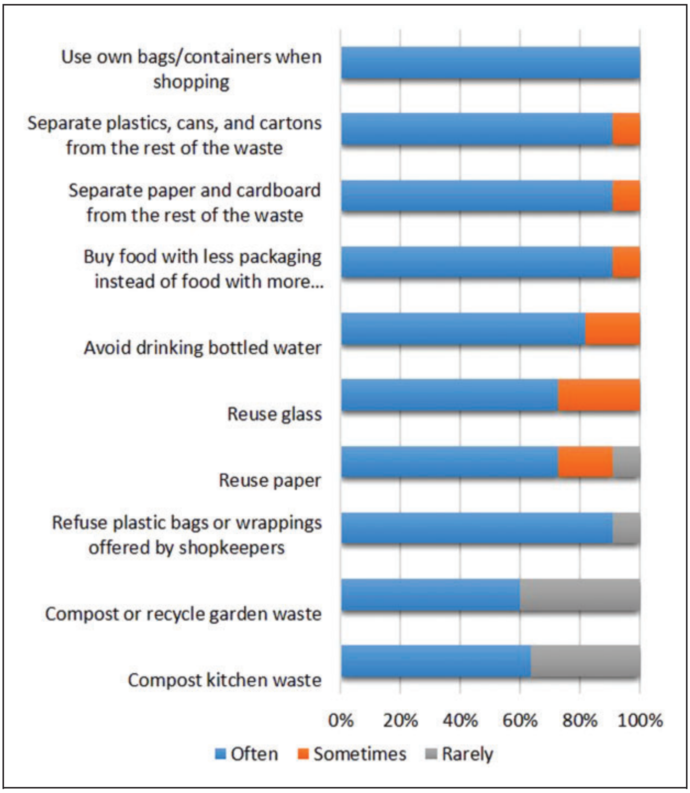

Figure 3. Waste practices of 12 residents, two left out due to incomplete data (house B male and house N).

(Figure 3). Households who rarely perform these practices do not have the technology or more importantly the skills, to do so.

Combination of technology, meaning and skill

Different combinations of technology, meaning and skill can affect the duration of a practice being performed as well as the resource flows associated with that practice. For example, the female resident of house J performs the practice of personal hygiene twice a day but adopts different technologies, skills and meanings each time (Figure 4). For instance, a shower taken for relaxation involves washing her hair; this is generally lengthy and involves multiple skills. A shower for getting clean between activities is shorter as the primary meaning is cleanliness before performing other practices. A shower before leaving the house is associated with the meaning of the social norm of cleanliness and therefore requires additional time to ensure her presentation is adequate. In contrast, a towel wash uses different skills than a shower and has a different meaning. This resident only uses a towel wash to freshen up between activities and so it is a short practice.

Contextual influences on practices

Many households reported contextual factors influencing their practices, which are beyond the three practice elements. For instance, most households attempt to combine errands into

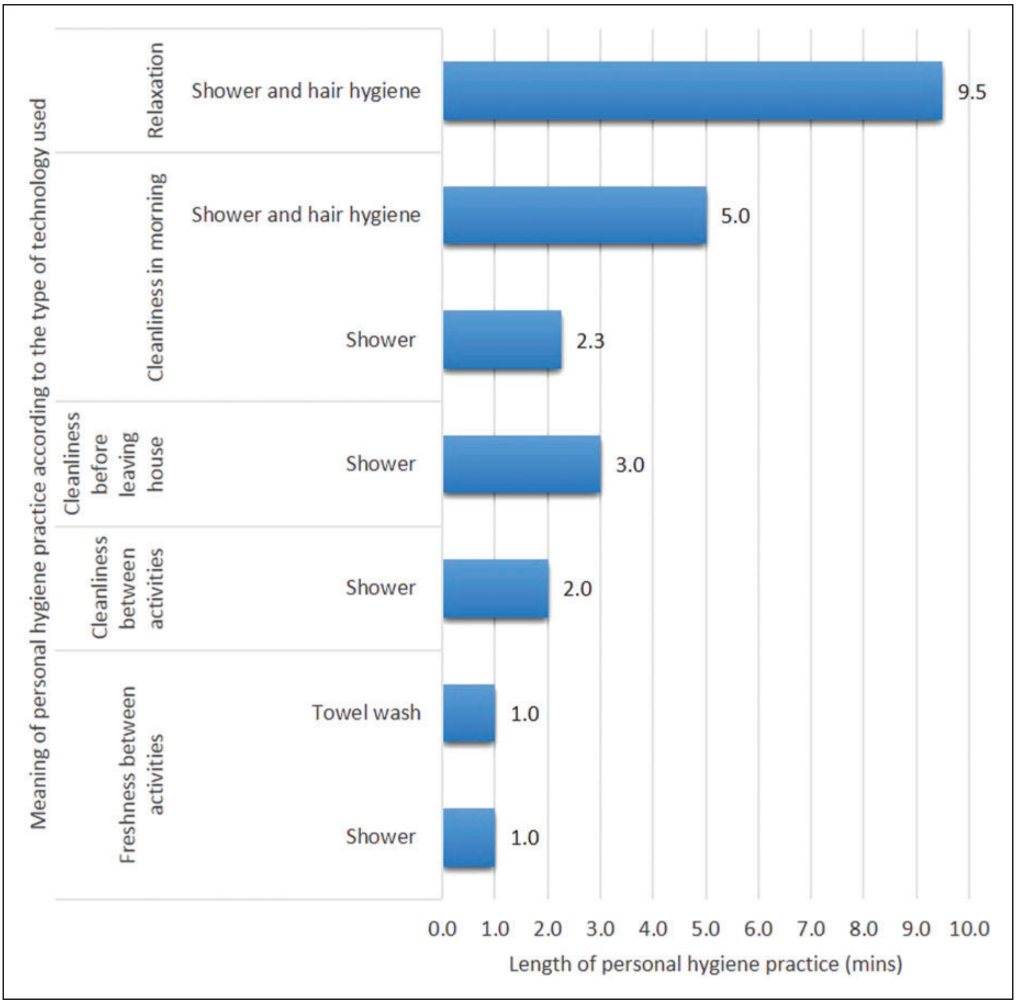

Figure 4. House J's various personal hygiene practices, their length, meaning and technologies.

the same car trip. These trips are often situated around working hours, particularly in houses where the residents work full time and travel to work by car. The convenience of not leaving the home at the end of the working day is the main reason for this practice. Households that are frequent users of public transport, and/or cycling, and/or walking reported being car dependent for large shopping trips. These car trips usually occur at the weekend, outside of working hours and the car is required primarily for the convenience of either getting to the location of the shops or for transporting items home afterwards. This is in contrast to week trips when public transport is used to travel to work or attend other activities.

Other contextual influences on practices were tenancy agreements and property landlords. Eight of the households live in rentals, while three others live with friends or family. This means that changes to the physical structure of the dwelling or property maintenance requirements are currently outside of their control. For instance, the landlord of house D wants a lush water-intensive garden while the resident prefers native plants that do not require as much watering.

HSOP interlocking typology

The HSOP can have different degrees of interlocking. A household of full-time workers, for instance, is likely to have a HSOP with a higher degree of interlocking compared to a household of retirees. The implication of a highly interlocked HSOP is that practices are less likely to be influenced as they are constrained by a very rigid routine with a high degree of habituality. Lightly interlocked HSOPs, on the other hand, may lack a regular routine. They are more flexible and adaptable to change. A summary of the studied HSOPs is outlined in Table 2 and explored further based on their level of interlocking.

Highly interlocked HSOP

The highly interlocked HSOP exists in households that have residents who work full or part time and/or have children. A work routine demands residents are out of the house during certain times and social norms encourage people to have adequate personal hygiene. This results in personal hygiene practices often occurring before people leave the house for work, shopping or socialising. For highly interlocked HSOP houses, the residents usually travel to and from work the same way each day, and often combine shopping trips with the journey to or from work, clustering together over time and space into bundles of practices (Nicholls and Strengers, 2015; Schatzki et al., 2001; Shove et al., 2012; Shove and Walker, 2014; Torriti, 2017). An example of this is the resident of house A, who always walks to the shop near her work before the start of her shift to get her lunch and dinner items. The resident of house K also lives a highly structured life as she works on a mine site four days a week outside of the metropolitan area. This means she follows the same routine of showering, eating and travelling each workday and has to leave all shopping, bulk cooking and socialising practices to her days off.

As a detailed example of a highly interlocked HSOP, house F has been selected as a case study. Figure 5 shows the practices and routines of the two adult residents on a Friday. The female wakes up earlier than the male, goes to yoga and then returns home to eat breakfast and shower at similar times to the male, requiring co-ordination between them to use the same technology for these practices (shower, bathroom, kitchen, cooking appliances). They then both leave the house at a similar time to go to work taking different routes, the male alone in the car while the female is picked up by a neighbouring colleague as they car-share to work together. The house is then empty until the residents return that evening after having gone to the beach together with friends. Finally, they cook dinner and eat together. The female resident waters the garden while the male washes the dishes, both utilising the same resource (water) but in different practices, with different technology, skills and meanings. These results concur with those found in other studies focusing on temporal aspects of household practices where there are clear set times for certain activities, dictated by the time and location of others, forming bundles of practices (Eon et al., 2018; Friis and Haunstrup Christensen, 2016; Southerton, 2013; Torriti, 2017). However, in contrast to previous studies, this study focuses on individual home systems, allowing for an in-depth understanding of household dynamics.

Table 2. HSOP identified for each house with comments on the interlocked practices.

House	HSOP	Comments
A	Highly interlocked	Resident works full-time, has structured personal hygiene, travel, shopping, cooking and work routines. Weekends flexible with socialising but retains same travel practices (car).
B	Highly interlocked	Male adult works full-time and has a very structured routine of personal hygiene, cooking, eating and travel. Female adult works part-time and her days off feature shopping, housework, cooking and laundry. Weekends are structured around shopping, leisure and travel, with various modes of transport being used (car, bike, walking).
C	Highly interlocked	Works four days a week, structured travel, exercise, cooking and personal hygiene on those days. Days off always feature exercise, shopping, housework and socialising. Retains same travel practices (car).
D	Lightly interlocked	Full-time artist, travels frequently for long periods of time around the country for work. Unstructured days when in Perth feature shopping, working, socialising and housework.Frequent car use practices.
E	Highly interlocked	Works four days, structured travel, personal hygiene, cooking and shopping practices. Travel practices use car, bike and walking.
F	Highly interlocked	Two full-time adult workers, very structured routines focused on personal hygiene, exercise, travel, work and socialising during the week. Weekends feature shopping and leisure. Consistent travel routines to work via car and car-share, use bikes and public transport for local travel to shops and socialise.
G	Lightly interlocked	Shift worker with various shift times, interlocked practices of shopping, work and walking the dog. Consistent car use practices.
H	Lightly interlocked	Highly unstructured lifestyle based on daily activities. Regular personal hygiene practices, all others vary. Travels via car or walks locally.
I	Lightly interlocked	Retiree who showers and eats at regular times but other activities are lightly interlocked. Consistent car use practices.
J	Lightly interlocked	Artist and part-time tutor. Practices vary depending on daily activities. Regular personal hygiene practices. Consistent car use practice but walks locally.
K	Highly interlocked	Fly-in, fly-out professional on regular schedule. Set activities each day and times (personal hygiene, eating, shopping, transport). No car, uses bike and public transport locally, plane and bus to work.
L	Lightly interlocked	Part-time artist and mother, some days structured around work and son's day care. Travel, shopping, cooking and personal hygiene vary depending on the day's activities. Consistent car use practices.
M	Lightly interlocked	Full-time academic who has been living in two houses for many years, travels frequently for work meetings in various locations and days do not follow a regular pattern. Consistent car use practices.
N	Lightly interlocked	Very unstructured practices depending on daily activities across all hours. No car, uses public transport and walks locally.

HSOP: Home System of Practice.

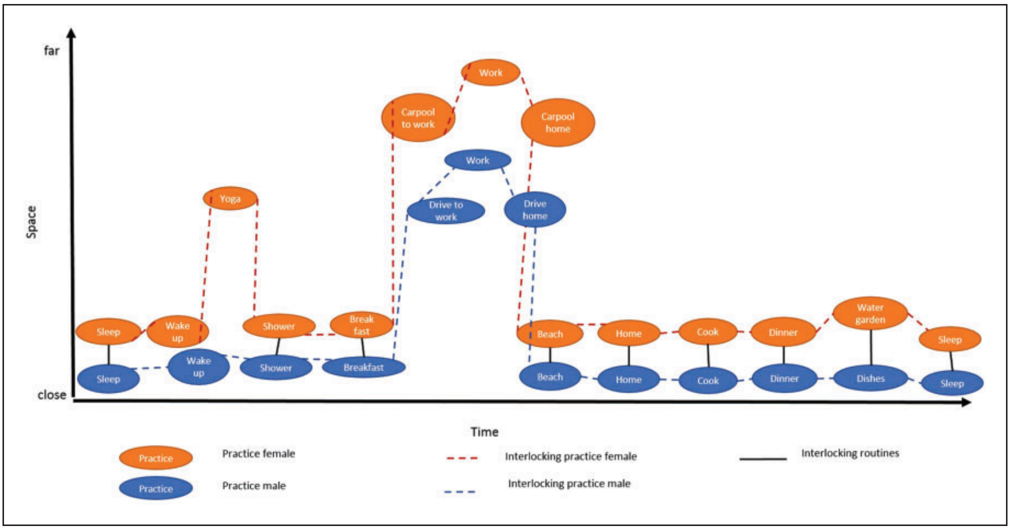

Figure 5. Example of the daily activities and routines of two adults across time and space in house F.

Lightly interlocked HSOP

In contrast to the highly interlocked practices illustrated above, other households exhibited a less interconnected HSOP with very few bundles of practices occurring. These households are those who do not have structured work hours prescribing when other practices can be pursued. These households have various times for showering, travelling, shopping and cooking throughout the day. House N, for instance, only showers prior to leaving the house, which may only occur every few days. Despite also having a lightly interlocked HSOP, house I has regular daily showering and cooking practices although all other practices are performed at different times. Across all lightly interlocked houses, the length of the practice is often the same, regardless of when the practice is performed (e.g. shower length remains similarly dependent on the meaning, not the time the practice is performed).

The implication of HSOP for smart cities

Users are an integral part of smart cities and the intricate interactions between home residents, the built environment and natural resources need to be understood if smart cities of the future are to be accepted by society. Policy and design of smart cities often considers the physical system alone, focusing on the energy and water performance of buildings and efficient movement of people. Previous research has found that people use energy-efficient technologies differently than anticipated by designers (Gram-Hanssen, 2012), resulting in unexpected outcomes or rebound effects occurring (Sorrell et al., 2009).

As this research shows, imposing technologies that do not fit in the SOP of individuals and households means that they will not be adopted, particularly when the HSOP is highly interlocked and there is little room for implementing new practices. The implication of a highly interlocked HSOP is that modifying practices, bundles and associated resource use can be very challenging as all elements are interconnected and interdependent as part of an established routine set to achieve specific purposes. Influencing households that are lightly interlocked may be easier due to the reduced number of practice bundles that occur, which are generally harder to dis-interlock and reform into new practice compositions (Eon et al., 2018; Spurling et al., 2013). There are still socially convenient times to perform particular practices such as cooking or cleaning that can be influenced to move the time that the practice occurs at, influencing resource consumption (Powells et al., 2014). The LCRI results also show that while individuals and households believe it is meaningful to reduce their carbon emissions, this meaning is altered when visitors are over. Understanding the intricacies of this and how to influence future meanings of practice requires an in-depth understanding of the household dynamics of multiple houses, as shown in this study.

Understanding the timing of resource-intensive practices in the home such as heating and cooling, showering and garden watering, allows for smart city technology to be designed with the end-user in mind and fitting into their lifestyle and routines. Co-creation with the user during the planning phase of smart cities will allow this to occur as outlined in Scott et al. (2012). Automation could enable resource-intensive activities to be dis-interlocked from an established routine and make change within the HSOP easier and more flexible (Eon et al., 2018).

Conclusion

This paper focused on identifying and providing insight into the existing practices and HSOP of Australian residents prior to them moving into a sustainable residential development. Understanding resident practices is important to be able to design buildings and spaces that are functional and meet user needs. This is relevant given that resource efficient or smart buildings do not always perform as expected, for instance, due to occupants' lack of skills, time or motivations. Influencing already established practices, especially highly interlocked practices, may be difficult if not impossible.

Through an in-depth analysis of the elements of meaning, technology and skill, we have examined the personal hygiene, thermal comfort, clothes drying, garden watering and waste practices of 14 houses. Households were identified as either lightly or highly interlocked dependent upon the residents' HSOP. Households with working residents or children have a regular routine they must adhere to that interlocks with their showering, travel, shopping and socialising practices, forming bundles of practices. Households that comprise of the self-employed or retired have less structure driving their daily practices, resulting in them being performed at various times of the day. However, the duration of the practice concurrent with the meaning remains within a similar range.

This research, while reliant on self-reported data, used multiple collection methods over two weeks on the themes of energy, water, waste, travel and food. This minimised the limitation of the self-reported data by cross-checking answers from multiple reporting methods. It also focused on the individuals of each home, allowing for an in-depth understanding of their practices and rhythms. Unlike other studies that have simply taken data from the home as a whole to compare with other households data, this study provides a detailed analysis of the in-home variations in practices and how these bundle together.

Future research will examine the HSOP of these 14 households after having moved to the new sustainable residential development, examining the interaction between occupants and the innovative technology (including solar panels, batteries and electric vehicle) in the new context.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research is funded by the CRC (Project number RP3033 and RP3012) for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative and the contribution of an Australian Government Research Training Program Scholarship.

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Publication VI

Breadsell, J., Morrison, G. M. & Byrne, J. (2019). Household energy and water practices change post-occupancy in an Australian Low-Carbon Development. *Sustainability.* 11(20), 5559; https://doi.org/10.3390/su11205559

Status: published (peer-reviewed)

sustainability

Article

Household Energy and Water Practices Change Post-Occupancy in an Australian Low-Carbon Development

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Received: 18 September 2019; Accepted: 5 October 2019; Published: 9 October 2019

Abstract: This research comprises a longitudinal study of a cohort of residents moving into a low-carbon development and their pre- and post-occupancy household practices that consume energy and water. They are the early adopters of living in low-carbon households and provide valuable insight into the influence of design and technology on household practices. Household energy and water consumption levels are measured and normalised to the metropolitan average to discuss the influence of design and technology on use. Heating, cooling and showering practices consume the largest proportion of household energy and water use and so the changes to thermal comfort and personal hygiene practices are examined along with a consideration of the influence of lifestyle and family composition on cooling practices. Household water and energy use decreases due to technology and design influences post-occupancy. However, the personal practice history of residents influences water and energy consumption. Changes to the meaning element of personal hygiene practices show how these are interlocked and unlikely to change in their duration when there are other demanding practices to be undertaken.

Keywords: energy use; water use; pre- and post-occupancy; low-carbon development; social practice theory; Australia

1. Introduction

Improvements in the household efficiency of energy and water use are an appropriate response to the environmental and climate emergency [1] and the United Nations Sustainable Development Goals [2]. Cooling, heating and personal showering are the most resource-intensive practices in many countries around the world, including in Australian homes [3,4]. However, there are dynamic social influences on innovative design and technology practices that can be unforeseen and disrupt these objectives, particularly in households [5,6]. Globally, low-carbon, energy- and water-efficient houses are considered an effective way to reduce household energy and water consumption and associated greenhouse gas emissions. However, there is still a gap between the anticipated and measured performance outcomes [7]. Paired with the need for higher urban density, particularly in cities across Australia, these houses are being built in low-carbon developments or precincts that also foster community living [8–12]. Pre-occupancy and post-occupancy studies are important to examine how residents engage with the design and technology of these low-carbon developments [13]. Resident's resource use is heavily influenced by their social, home and work routines and these must be considered when designing a low-carbon development and influencing resource use in the home to ensure an efficient home is built [14–25].

Despite a growing body of literature and industry practices that support building low-carbon houses, it is estimated that on average 20% of the expected energy savings in households are not achieved due to occupant practices [7,26]. In Germany, household energy use studies collated by [27] found that for households designed for low-energy use or through passive design, the measured energy use was above the expected output. The lack of building sector knowledge and strict regulations regarding passive house design has been suggested as reasons for this occurring. Research from [28] found that indirect rebound effects are most likely to occur in the home, particularly with the prevalence of large domestic appliances and air conditioners. The non-technical measures of household behaviour or practices that can reduce or prevent the rebound effect occurring have been analysed to a lesser extent [29]. Studies have found that the behavioural and social practice effects of occupants is underestimated when assessing the energy consumption of energy-efficient households [27,29]. Therefore, further research on household resource practices is required if these effects are to be addressed [30]. Of the multitude of household practices that are performed each day, thermal comfort and personal hygiene practices use the largest proportion of total energy and water used in Australian households [3,31]. Therefore, this paper assesses household and individual practices for energy and water, pre- and post-occupancy in a low-carbon development in Australia.

2. Social Practice Theory

This paper focuses on the practices of thermal comfort and personal hygiene through quantitative and qualitative information collected through monitoring and sensing. A practice is the unit of analysis in social practice theory, which is the study of everyday practices, the mundane actions that make up people's lives, such as cooking, cleaning, showering and staying warm [32–36]. People do not use resources such as water or energy directly, but rather with the objective of achieving a desired outcome [37]. This research uses the three element model of analysis as outlined in [38] and based on [39]'s work: meaning, technology and skills. The meaning is the understandings, assumptions and values associated with the practice; the technology is the artefacts that are used in the practice and the skills are the knowledge and competences necessary to execute the practice. These elements are interconnected and a change in one element can change the practice and its' resource consumption [40]. When practices form bundles together through interlocking, this is termed a system of practice [41]. When multiple systems of practices exist in the space of the home, this is termed a Home System of Practice (HSOP). The reproduction of practices and their proximity in space and/or time influences their degree of interlocking and subsequent energy or water demand [15,38,42,43]. Some previous research has found that practices using water and energy such as showering, washing and thermal comfort using air conditioning occurs at particular times [15,24,38,44]. Energy consumption practices performed in the 17:00 to 21:00 time-slot contribute to the peak energy demand [45]. With the rise of renewable energy, there is now an uneven temporal distribution of domestic energy demand, whereby domestic routines are not able to utilise the renewable energy generated during the day unless there is storage available, and are instead continuing to be reliant on grid-supplied energy often generated by fossil fuels [46]. Influences on practices performed by individuals can be done through changing an element of the practice or by influencing the individual through their inter-personal networks [47]. Dis-interlocking practices through automation may be efficient to enable lasting reductions in energy, water and resource use in the home [38]. This is often a one-off change, allowing a set and forget mentality to drive the practice in future, thereby reducing the need for human intervention.

When people move into a new home, the space in which the HSOP is located changes. This can alter the meaning, technology and skills related to resident's practice, even though the outcome of the practice (e.g., getting clean, eating food or staying warm) might remain the same. Consequently, this study examines resident's HSOP pre- and post-occupancy in a low-carbon development to investigate how their energy and water practices change with this move.

3. Methods

3.1. Research Design

This research is based on a pre- and post-occupancy evaluation of household practices in a low-carbon development. Post-occupancy evaluation is a recognised method of studying residents of buildings and households to understand their experiences and resource use [13,18,48]. The residents of low-carbon and similar homes (passive houses, low-energy houses, net zero energy houses) are considered to have specific lifestyles, user behaviours, practices and views which, as early adopters of this technology, can be studied to improve the viability of the technology and design to the wider population [12]. With an increase in low-carbon homes around Australia, the study of these residents is vital in understanding how these buildings are integrated into society in the future. Therefore, this research will centre on a low-carbon development in Perth, Western Australia. Post-occupancy evaluation of homes in Europe has focused on studies of passive house residents, concluding that residents are generally more thermally comfortable than in their previous dwelling [48]. Post-occupancy evaluations of low-energy buildings in Australia have focused on resident's comfort and interaction with technologies in the dwelling [8,10,12,49]. These studies have found that many residents of a low-carbon development have little or no experience of the new technologies and how to effectively use them to remain comfortable in their homes [11]. However, individual user experiences are highly variable [9]. A pre-occupancy study was included in this research to enable a longitudinal study as a complement to the post-occupancy evaluation and examine any changes occurring in the low-carbon development.

In this paper, a low-carbon development is defined as a group of households that form part of a development with design performance requirements beyond the Australian National Construction Code, e.g., 7+ star Nationwide House Energy Rating Scheme (NatHERS) thermal performance and inclusion of a solar Photovoltaic (PV)system [50]. The low-carbon development studied in this research is called the WGV Development, located in the suburb of White Gum Valley. WGV consists of multiple dwelling types, stand-alone houses, semi-detached houses and apartments. The WGV development is located in Perth, Western Australia, specifically in the City of Fremantle suburb of White Gum Valley. This area has regular sea breezes most afternoons which assist in cooling the dwellings during warm weather. The average temperature is between 10 and 27.3 °C [51]. The homes are designed for a Mediterranean climate, with sustainability features that include passive solar design features that enhance airflow and sunlight levels to assist the regulation of thermal temperature. Approximately 1 in 4 stand-alone houses in Perth have private bores for garden irrigation, while the remainder rely on the utility water supply for this purpose, sourced from desalination plants (48%), groundwater (40%) or dams (10%) [52,53]. Some homes may also have rainwater tanks. At WGV, all lots are serviced by a community bore for irrigation, and all detached lots have rainwater tanks connected to toilets and washing machines [54].

3.2. Project Participants

A cohort study of 14 individual residents of 13 homes for the basis for this research with data collected both pre- and post-occupancy in the low-carbon development. A detailed description of WGV can be found in [55]. However, for this paper it is relevant to note that the residents studied have moved into a variety of dwelling typologies. Table 1 outlines the resident's occupations and these cohorts. One cohort (six residents studied) consists of owner occupiers of apartments sold at market rates in a commercial development named Evermore. Another cohort (five residents studied) consists of Sustainable Housing for Artists and Creatives (SHAC), who are leasing apartments and two studio spaces from a local social housing provider, with rental payment concessions received from the Australian Government. The third cohort (three residents studied) consists of owner occupiers of two semi-detached units, while the final resident studied is an owner occupier of a stand-alone (detached) house.

Table 1. Resident's occupation, house and development at WGV.

Dwelling	House	Occupancy Lifestyle
Evermore Apartments	A	Works full-time off-site
	B	Works 4 days a week off-site; daughter is a student who is at home most days
	C	Works 4 days a week off-site
	I	Retiree
	O	Works full-time off-site; son is a student who is at home most days
Sustainable Housing for Artists and Creatives (SHAC) Apartments	D	Works part-time off-site, part-time on site; son works part-time off site
	H	Works part-time off-site, part-time on-site
	J	Works part-time off-site
	L	Works part-time off-site, part-time on-site; has a 5-year-old who is a part-time school student
	N	Works part-time on-site
Semi-Detached House	F	Both residents work full-time off-site
Semi-Detached House	M	Both residents work full-time off-site
Detached House	G	Shift work full-time off-site; daughter is a student who is at home most days

3.3. Mixed Methods

Mixed methods were employed pre- and post-occupancy for data collection [56,57]. The data collection focused on the themes of energy, water, waste, food, transport and social network practices. This paper will address the practices relating to energy and water. A semi-structured interview was undertaken to gain an overview of the different ways the participants regulate their thermal comfort. Questions in the semi-structured interview ask residents how they keep thermally comfortable, the routines of their daily lives and how these have changed since moving to the low-carbon development. The use of interviews allowed for an in-depth and personal exploration of resident practices, along with follow up questions to explore themes that emerge. Interviews are a common data collection method. However, they can be prone to issues of recall or participants responding to what they think the interviewer wants to know [58,59]. To complement the interviews and overcome some of these issues, three other methods were included: workbooks, diaries and cultural probes. A workbook was completed over two weeks, allowing residents to respond to short-answer questions about their resource use along with 5-point and 7-point Likert scale survey questions. An example of a short answer question is: do you think there is a relationship between your energy consumption and your feeling of comfort at home? An example of a 5-point Likert scale question is: How often do you wear more clothes instead of turning on more heating? Very often, often, sometimes, rarely, very rarely. An example of a 7-point Likert scale question is: How often has your family used a fan since moving in to WGV?: every day, a few times a week, approximately once a week, a few times a month, once a month, less than once a month, never. Personal hygiene practices were provided through a personal hygiene diary during this time which noted time, duration and meaning for the practice. Finally, short answer questions were asked through text messages, based on the cultural probe methodology [60–62], during the workbook completion phase such as "how have you been keeping warm today?"

Interviewees were self-selected through an open invitation sent to households who had already purchased property in the low-carbon development or were intending to become a tenant through SHAC (n = 27). The original sample size was 16 individuals in 15 homes for the pre-occupancy data collection. However, one household decided to rent out their apartment and another chose to leave the study. Their results were removed from this paper. Pre-occupancy interviews were conducted between April and June 2017 for SHAC residents and between December 2017 and March 2018 for Evermore and single house residents. Post-occupancy interviews were conducted between December 2018 and

March 2019 for all residents. This extended period of time for data collection pre-occupancy was to allow for more residents to join the study. However, there is a bias towards those who would reside in the development in 2018 and 2019 due to the research time constraints.

Collecting quantitative data in the pre-occupancy dwellings was more limited than in the post-occupancy evaluation. Before residents moved into the WGV development, the only quantitative data available to the researchers were electricity, gas (combined to form the energy value) and water bills. These were requested for the previous year. However, there was a lot of variety in the bills provided due to residents not keeping them or only being provided with a portion of the water bill from landlords. The data available from each household is shown in Appendix A, and the energy and water figures for pre- and post-occupancy household values are taken from these. The quantitative data collection in the post-occupancy evaluation was more streamlined and extensive. Household levels of electricity and water consumption levels were provided once the residents moved into the dwellings. These were at 5 min intervals for all participating households except for Evermore residents which were at 15 min intervals due to the programming parameters of that building's data logging equipment. The water consumption data was also divided into source (rainwater or mains water) for the semi-detached house and stand-alone house dwellings studied, which featured dual plumbing. The apartments do not feature this and only have mains water consumption. Over a 3-month period, the households also contained a temperature and relative humidity sensor logging at 5 min intervals.

3.4. Data Analysis

This paper focuses on the energy and water results collected through quantitative and qualitative data methods. Data was analysed at the household level to be able to account for some residents not moving into the low-carbon development in the same house (i.e., children not moving in with their parents post-occupancy). This influences the energy and water consumption levels of the household as a whole and may have some influence on the HSOP, which will be discussed. Data was analysed through a comparison of the energy and water use changes pre- and post-occupancy and by normalising this to the Perth metropolitan average. The pre-occupancy data is limited due to residents not having access to a year's worth of complete bills. However, all post-occupancy energy use has been collected. As all the dwellings use bore water for irrigation, a daily landscaping contribution was added to the household total. For the semi-detached and stand-alone households, this figure was provided by monitoring data. For the apartment households, a daily landscaping contribution was arrived at by dividing the total outdoor water use by the number of apartments in the dwelling. Data on personal hygiene practices was provided through a personal hygiene diary which noted time, duration and meaning for the practice. These results were graphically presented to reveal trends in total shower times and averages. Meanings were grouped into themes, based on the reason given by the resident in the diary. The Likert scale data was analysed through a graphical representation of the results to view trends, which were then compared with the qualitative data. The qualitative data was analysed through the thematic analysis of interviews, short answer questions, and text probes. Thermal comfort practices were discussed in the interviews, as well as through text probes. This information was analysed through thematic analysis to identify the 43 overarching themes and different approaches to performing the practices. These themes related to practices that use energy and water and include comfort, convenience, affordability, freshness, habit, routines, lighting and blinds.

4. Results and Discussion

4.1. Overall Change in Energy and Water Use at the Household Level

This section explores the pre- and post-occupancy energy and water use at the household level. The data collected is summarised in Appendix A.

4.1.1. Energy Use

This section explores the changes in energy use per household pre- and post-occupancy as shown in Table 2, which also normalises the change in energy use to one against the metropolitan average. The average Perth metropolitan energy use is 20 kWh/household/day for households with electricity and gas. This is a figure from 2013. However, a more up-to-date figure was not available at the time of writing [63,64]. At pre-occupancy, almost all households were below this average. This may be attributed to the personal efforts of residents to minimise energy-consuming activities and to rely on non-auxiliary heating and cooling practices to stay thermally comfortable. These include using blankets, hot water bottles and layers of clothing to stay warm or naturally ventilating the home through opening windows and doors and removing clothing or having a cold drink to stay cool. The households that were above the average (households C and N) had either a high number of occupants, particularly young adults who were reported as being less conscious of their energy use (households C) or had a number of old and inefficient appliances (e.g., refrigerator, freezer, tumble dryer and air conditioner) and the residents would often be awake during the night, using electricity then, instead of during the day. This shows that pre-occupancy, the households were already mostly below the metropolitan average, and any changes post-occupancy would presumably increase this figure.

Table 2. Household energy use pre- and post-occupancy and normalised to the Perth metropolitan average use (20 kWh/day). NA values are due to no or inadequate energy bill data provided by the resident.

WGV Development	House	Pre-Occupancy Energy/Household/Day (kWh)	Post-Occupancy Energy/Household/Day (kWh)	Change Normalised to Metro Average
Evermore Apartments	A	NA	4.44	NA
	B	5.54	6.61	−0.05
	C	29.25	7.02	1.11
	I	NA	5.90	NA
	O	5.54	5.88	−0.02
SHAC Apartments	D	NA	14.08	0.45
	H	7.37	9.46	−0.10
	J	7.21	8.52	−0.07
	L	NA	6.79	NA
	N	21.16	5.67	0.77
Semi-Detached House	F	11.93	6.72	0.26
House	G	NA	12.30	NA
Semi-Detached House	M	NA	4.88	NA

The change in pre- and post-occupancy energy use has been normalised to one against the metropolitan average. This allows us to compare the changes in each household. While post occupancy, all households are under the metropolitan average energy use, not all households actually reduced their energy use. More than half of the households with available pre- and post-occupancy data actually increased their energy use. This is due to two households coming from extremely low consuming households previously (household B and O) and two residents who increased the amount of time they now spend at home once they have moved to WGV (household H and J). Changes in energy use can be partly attributed to design features, particularly for residents of household B, who are located on the 2nd and 3rd floor of the apartment block, and report difficulties in naturally ventilating their home. Household O also has a student who is at home using energy most of the day. This highlights the importance of understanding resident's daily routines and practices, as will be discussed in regards to their individual system of practice and HSOP in Section 4.2. Residents who have moved from low thermally comfortable dwellings where auxiliary heating and cooling was required to stay comfortable are now not as reliant on auxiliary systems. SHAC residents who have changed their work practices and work from home have a related increase in energy use. This has not occurred in all the SHAC dwellings however, even though all residents now work at least part-time from home. Households H and J undertake energy-intensive art practices, featuring photography, sewing and painting, which have high lighting requirements. Household D still has a young adult son at home during most of the day and night, who often invites friends around to participate in energy-intensive activities (gaming, leaving the fans and lights on). The installation of energy-efficient lights in SHAC reduces some of this energy use, but it is still close to the metropolitan average. These results show that changes to household energy consumption have occurred post-occupancy.

4.1.2. Water Use

This section examines resident's household water use pre- and post-occupancy as outlined in Table 3, which also shows the change normalised to one to show the change relative to the metropolitan average. The average Perth metropolitan water use/household/day is 622L, based on 2010 data [3]. Household's pre-occupancy water usage was mostly above the metropolitan average. All dwellings that were above the average water use had large gardens that were watered frequently and/or had two or more residents. The latter led to increased use of the washing machine and shower facilities (household D, L and G). Households H and L also reported having baths or long showers (approximately 15 minutes in length), increasing the water usage of these households. Post-occupancy, all the households are now below the metropolitan average. This reduction is attributed to design features, namely low-flow fixtures, no baths and reduced garden spaces post-occupancy that require watering.

Table 3. Household water use pre- and post-occupancy and normalised to the Perth metropolitan average use (622L/household/day). NA values due to no or inadequate water bill data provided by the resident.

WGV Development	House	Pre-Occupancy Water Use/Household/Day (L)	Post-Occupancy Water/Household/Day (L)	Change Normalised to Metro Average
Evermore Apartments	A	NA	131.40	NA
	B	210.01	233.48	−0.04
	C	409.65	133.35	0.44
	I	NA	114.78	NA
	O	210.01	109.51	0.16
SHAC Apartments	D	2186.44	371.90	2.92
	H	817.21	516.00	0.48
	J	NA	657.39	NA
	L	1873.26	110.14	2.83
	N	508.47	230.59	0.45
Semi-Detached House	F	295.85	359.53	−0.10
House	G	959.39	511.95	0.72
Semi-Detached House	M	NA	359.53	NA

Post-occupancy, household J was the only household to remain above the Perth metropolitan average water use (Table 3). This is surprising in that there is a female resident who is environmentally conscious of her water use although the high level can be attributed to watering a large pot plant collection on her balcony and inside. There were two households that increased their water consumption post-occupancy (households B and F). Household B's slight increase may be due to the fact that pre-occupancy, the household used rainwater in some inside fixtures and on the garden, the values of which were not captured in the pre-occupancy data. Post-occupancy, this household retained some of the pot-plant collection that requires watering. For household F, their WGV dwelling features an extensive fruit and vegetable garden that is used as their main source of food. This requires a large amount of water to establish, even though some of this was over the winter rainy season;

rain can be unreliable in Perth, even in winter. This increase however does include the use of groundwater on the garden (via the WGV community bore), as opposed to mains water usage in the majority of Perth gardens. These results show that changes to the household water consumption have occurred post-occupancy.

4.2. Changes to Individual Practices and the Home System of Practice

This section will explore the practices that residents undertake in their daily lives that also consume energy and water. Section 4.2.1 will focus on personal hygiene practices and how the meaning related to the practice influences the duration of the practice and corresponding water use. Section 4.2.2 examines the various technologies residents use to stay thermally comfortable pre- and post-occupancy in their homes. The average usage of these technologies and the influences on design that impact the resident's comfort in the low-carbon development is also discussed. Finally, Section 4.2.3 examines the cooling practices of three households and their lifestyles and routines, highlighting the relevance of understanding the HSOP in energy demand.

4.2.1. Personal Hygiene Practices

Water for personal hygiene practices using showers is the largest water use inside the household [3]. Previous research on personal hygiene has been conducted by [34,65–68]. In examining the personal hygiene practices of residents in this research, a focus was taken on the meaning of performing the practice, as done previously in [38,43,44,57]. Personal hygiene practices were usually performed by showering, with a few residents also having infrequent towel washes. Multiple meanings of showering affect the duration. This has been shown previously in [43,57] and is again shown here in Figures 1 and 2. Figure 1 shows the changes to personal hygiene practice duration pre- and post-occupancy. The average practice duration pre-occupancy was 6 minutes, while the average practice duration post-occupancy is 4.4 minutes. This can be compared to previous results for shower duration by Australian residents with an average between 6 minutes and 8 minutes [65]. The duration for all meanings decreased post-occupancy, except for cleanliness before leaving the home. This may be due to some residents not leaving their home as frequently in the low-carbon development due to working from home and therefore spending more time cleaning themselves when they do. The smallest change in meaning duration was for inter-activity cleanliness. Morning cleanliness also had only a small decrease in average duration. This highlights the interlocking of practices in resident's lives and how this meaning for personal hygiene practices remains dependent on the timing of other practices and is not dependent on the practice itself. Unexpectedly, the relaxation meaning was not reported by the residents post-occupancy. This may be related to the change in technology, as most of the relaxation practices were undertaken via a bath pre-occupancy and bathtubs were not present post-occupancy or choosing other ways to relax, such as swimming in the ocean instead. The cleanliness meaning was also able to be categorised into either evening or morning for all residents post-occupancy due to more detailed completion of the personal hygiene diary by residents. These results highlight the influence that meaning has on personal hygiene practices and subsequent water use in the household.

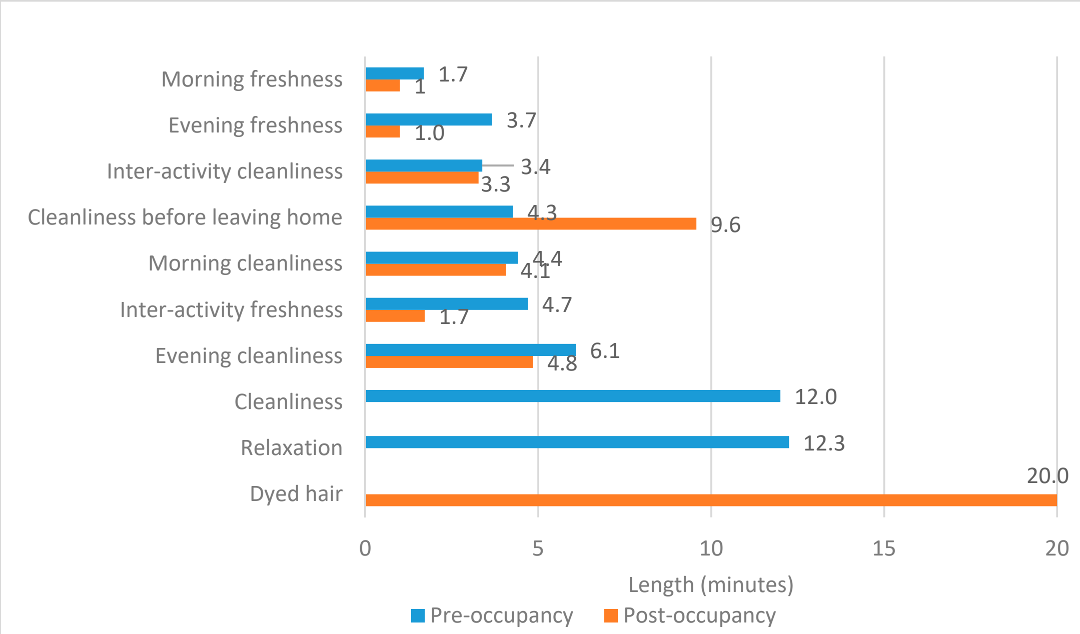

Figure 1. Average length of personal hygiene practices pre- and post-occupancy based on meaning.

Figure 2 shows the variation in the duration of showers post-occupancy for the 12 residents who provided this information through their personal hygiene diaries. Most showers are performed for either morning or evening cleanliness. There is generally a preference for either a morning or evening shower by the residents and not both. The showers that are taken for freshness are the shortest showers, while those situated between activities are also short. This relates to the interlocking of practices occurring in the home, whereby there are other practices requiring the residents' attention and they only have a set amount of time available for showering. When there are less practices to perform during the day, residents will have longer showers. Cleanliness showers that occur before leaving the home for resident N are the longest showers as this resident reports that he rarely leaves the home and therefore spends more time on personal hygiene when he does. This is in line with the findings that the frequency of showering is dependent on practices such as work in resident's lives [57]. The resident in household D had a particularly long shower when she was dying her hair, which required her to turn the water on and off multiple times and make sure her hair was thoroughly washed. This is in contrast to her other showers, and the practice of dying her hair was not undertaken often. These results highlight the variations that can occur in personal hygiene practices for individuals dependent upon the meaning.

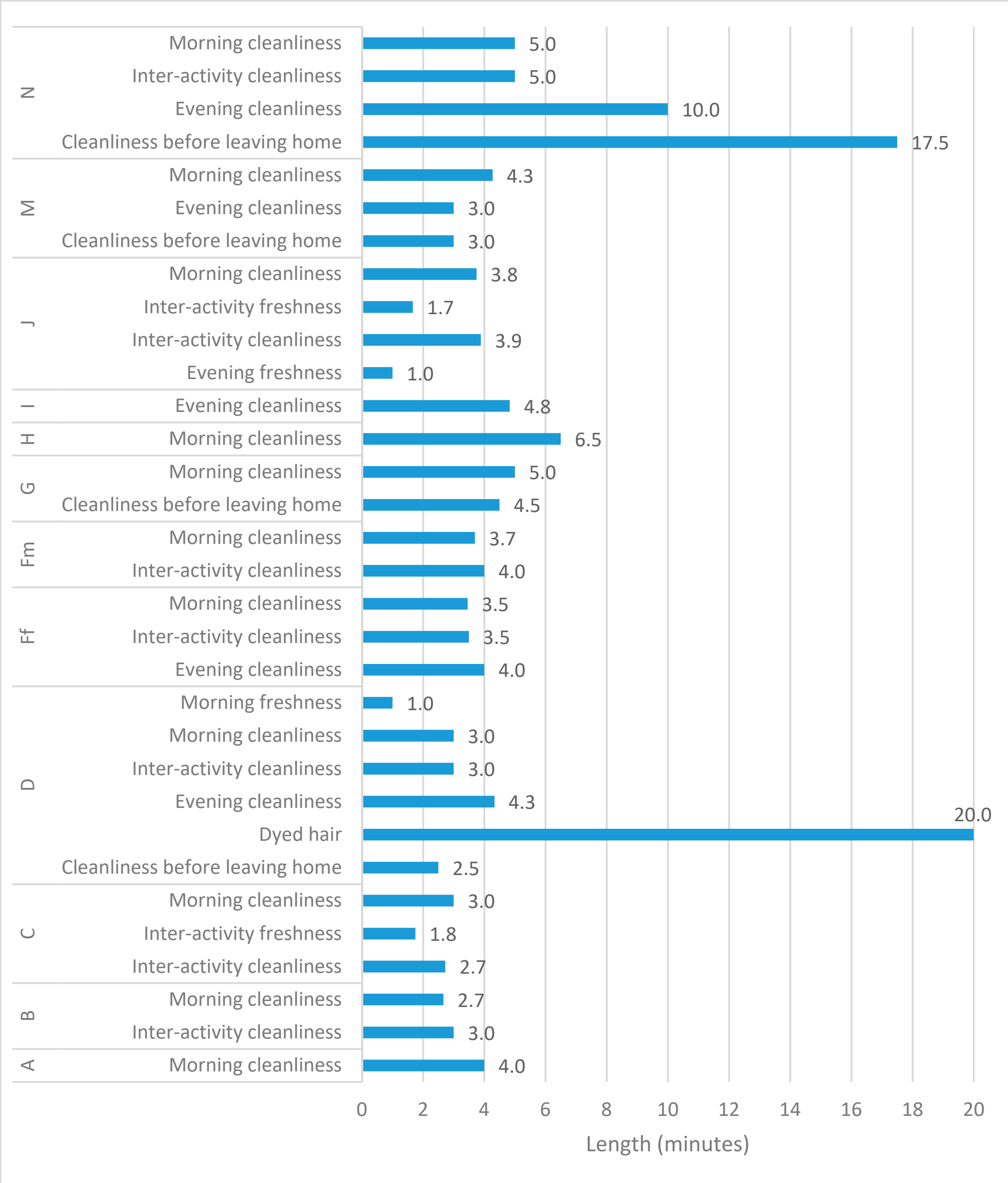

Figure 2. Meaning of personal hygiene practices by resident and length post-occupancy in WGV.

4.2.2. Ambient Heating and Cooling Practices

This section will discuss the ambient heating and cooling practices of the household's pre- and post-occupancy. Heating and cooling practices demand the largest amount of energy in household practices [31]. This section will focus on the technologies and skills needed by the residents to stay thermally comfortable and how this changes post-occupancy in WGV. It will also examine the indoor temperatures over the monitoring period and discuss comments raised by residents on how the performance of their heating and cooling practices has been influenced by the design of the dwellings.

Table 4 outlines the different mechanical technologies used in heating and cooling practices by household's pre- and post-occupancy, in addition to the use of clothing, blankets, hot water bottles or ice packs. Pre-occupancy, all homes practiced adaptive thermal comfort practices where residents take actions to restore or maintain their thermal comfort instead of relying on auxiliary heating or cooling. This includes opening and closing windows and doors, adding and removing clothing, using fans and taking hot or cold showers [49]. Post-occupancy, residents have reported less use of auxiliary heating and cooling in their homes, with adaptive thermal comfort practices being sufficient. Some households have had to learn new skills in their thermal comfort practices when the technology available has changed. Evermore residents have switched to the use of a reverse cycle air conditioner for heating, which was also used for cooling by some. However, most of the Evermore residents report being thermally comfortable in the homes through winter and rarely using the reverse cycle air conditioner. In the houses, the two semi-detached houses (household F and M) have underfloor hydraulic heating, which was mostly adequate to keep them comfortably warm. However, this was a new technology and required them to learn new skills for the practice. Household G in the stand-alone house changed to a reverse cycle air conditioner for heating purposes and this was used throughout the winter, mostly in the afternoon and evenings. SHAC residents had the least changes to the technology used in their thermal comfort practices. As air conditioners or reverse cycle air conditioners were not included in the design of the apartments, the majority of residents have continued with the use of portable electric oil heaters (column heaters) and fans to stay comfortable, not requiring a change in skills to perform these practices. These results highlight the importance of understanding the technologies used within a practice before attempting to alter these.

Table 4. Technology used in heating and cooling practices of households pre- and post-occupancy in WGV, additional to layers of clothing, blankets, hot water bottles or ice packs (AC = air conditioning and RC AC = reverse cycle air conditioning).

WGV Development	House	Pre-Occupancy Heating	WGV Heating	Pre-Occupancy Cooling	WGV Cooling
Evermore Apartments	A	Gas heater	RC AC	AC	Standing fans, RC AC
	B	Heater, Oven	None	Fans, RC AC	Ceiling fans
	C	Gas heater	RC AC	Fans	Ceiling fans, RC AC
	I	Oven	RC AC	Fans, RC AC	RC AC
	O	Heater, Oven	None	Fans, RC AC	Ceiling fans
SHAC Apartments	D	Wood stove, RC AC	None	RC AC, fans	Fans
	H	Electric oil heater	Electric oil heater	Fans	Fans
	J	Electric oil heater	Electric oil heater	Fans	Fans
	L	Fire, Electric oil heater	Electric oil heater	Evaporative AC, fans	Fans
	N	Electric oil heater	Electric oil heater	Fans, RC AC	Fans
Semi-Detached House	F	Electric heater	Underfloor hydraulic heating	Fans	RC AC, Fans
House	G	Electric heater	RC AC	Fans, AC	RC AC, Fans
Semi-Detached House	M	None	Underfloor hydraulic heating	Fans	Fans, RC AC

Figure 3 shows the self-reported frequency of the use of heating and cooling systems by household's post-occupancy in WGV. Evermore residents prefer the use of blinds and cross ventilation to keep a cool temperature in the apartments, with 80% reporting that they never use their heating and cooling. The use of ceiling fans or floor fans was reported across the day and the night and varied in frequency depending on how comfortable the resident was. The reverse cycle air conditioning systems were used by a retiree in Evermore, a shift worker in a house and a full-time worker in a house who has reported that he wants to be at a comfortable temperature to stay healthy and work productively at home. SHAC households do not have any air conditioning in their apartments for use in cooling or heating, which was a deliberate design decision by the developer and owner. Households all have ceiling fans in the living and bedroom areas, which are used as required, along with cross ventilation practices. These results highlight the differences in the use of technology by various residents.

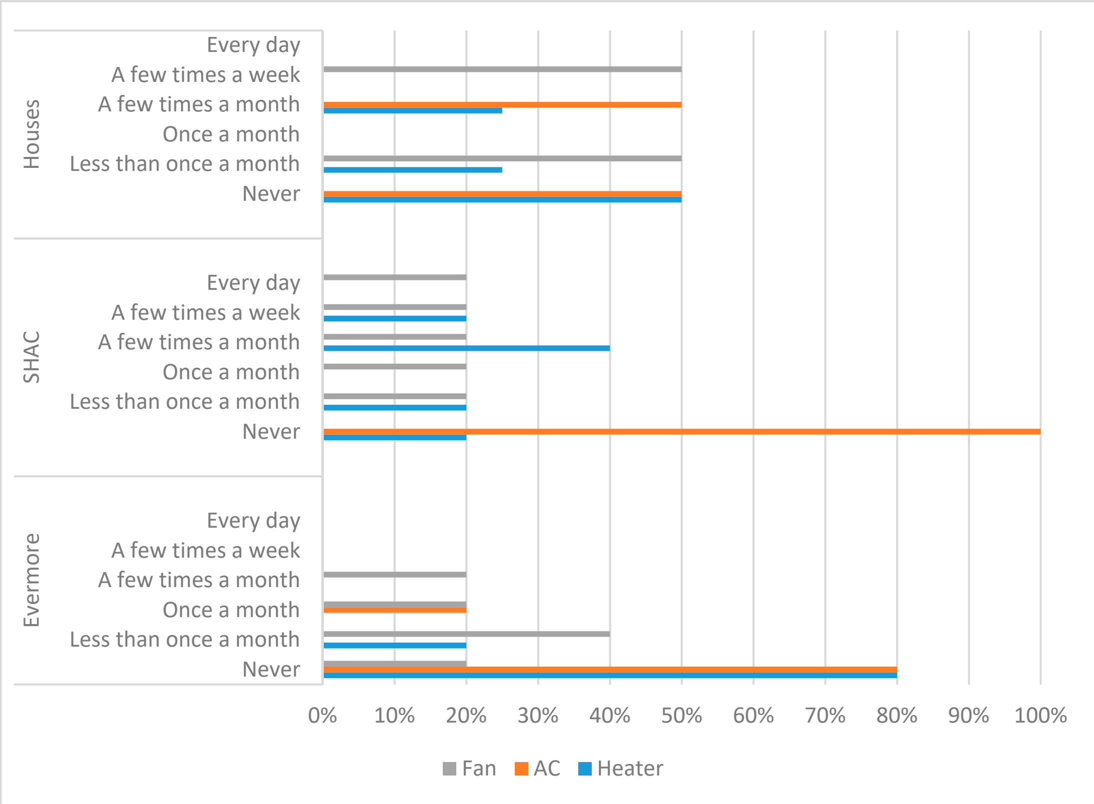

Figure 3. Frequency of the use of heating and cooling systems by households post-occupancy.

In relation to heating, the only resident who reported using a heater in Evermore was a retiree who is home most of the day and night and uses the reverse cycle air conditioner system. In the houses, a shift worker will use the heating in the reverse cycle air conditioner system a few times a month, while the underfloor hydraulic heating was used periodically in the semi-detached houses. The use of a stand-alone heater was reported most frequently by the SHAC residents. Some households, particularly those in apartments where winter solar gain is partially obstructed by trees or other buildings, have reported being quite cold in SHAC. The use of a heater across all the dwellings was during the morning and evenings, unless the resident was home, then it occurred during the day also.

Households who reported the use of auxiliary heating or cooling with visitors in their home pre-occupancy [43] now report that this is unnecessary because the thermal comfort of the dwelling is considered suitable, except for those who would normally use it for their own comfort. This has implications for considering the influence of social and societal norms when considering household energy use [69].

The measured range of temperatures in the households living areas over a 3-month period from December 2018 to February 2019 is shown in Figure 4. The thermal comfort range for living rooms in dwellings is considered to be between 20 and 25 °C, as compliant with the Australian National Construction Code [70]. All dwellings recorded temperatures above 25 °C, while six dwellings recorded temperatures under 20 °C in their living areas. The lowest minimum outdoor temperature recorded during the monitoring period was 11.3 °C and the highest maximum outdoor temperature was 39 °C. It should be noted however that these temperatures were recorded during the Perth summer. Indoor temperatures in winter may fall below the recommended 20 °C in some dwellings. The largest range of temperatures experienced in a dwelling was 22.3 °C in household B during the monitoring period from December to February. This may be due to the fact that this apartment is located on the 2nd and 3rd story of the Evermore apartment complex and the 3rd floor does not have any adjourning apartments to assist in temperature regulation. It is also believed that the residents may have moved the sensor from its original position on the 2nd floor during monitoring. However, the range of temperatures in a similarly designed apartment, household C, indicates that these apartments, possibly due to their design and location on the 2nd and 3rd floor, feature a large range of temperatures. The dwelling with the smallest range of temperatures recorded was household O in the Evermore apartment complex. This apartment is located on the ground floor with a ground coupled slab which aides in thermal stability. It is also located between other apartments so is protected from extreme morning and afternoon sun by the neighbouring buildings. In relation to household practices, the occupants of households B and O pre-occupancy shared the same dwelling pre-occupancy and reported similar thermal comfort practices. This highlights the influence that design has on the temperatures of a home, regardless of occupant practices.

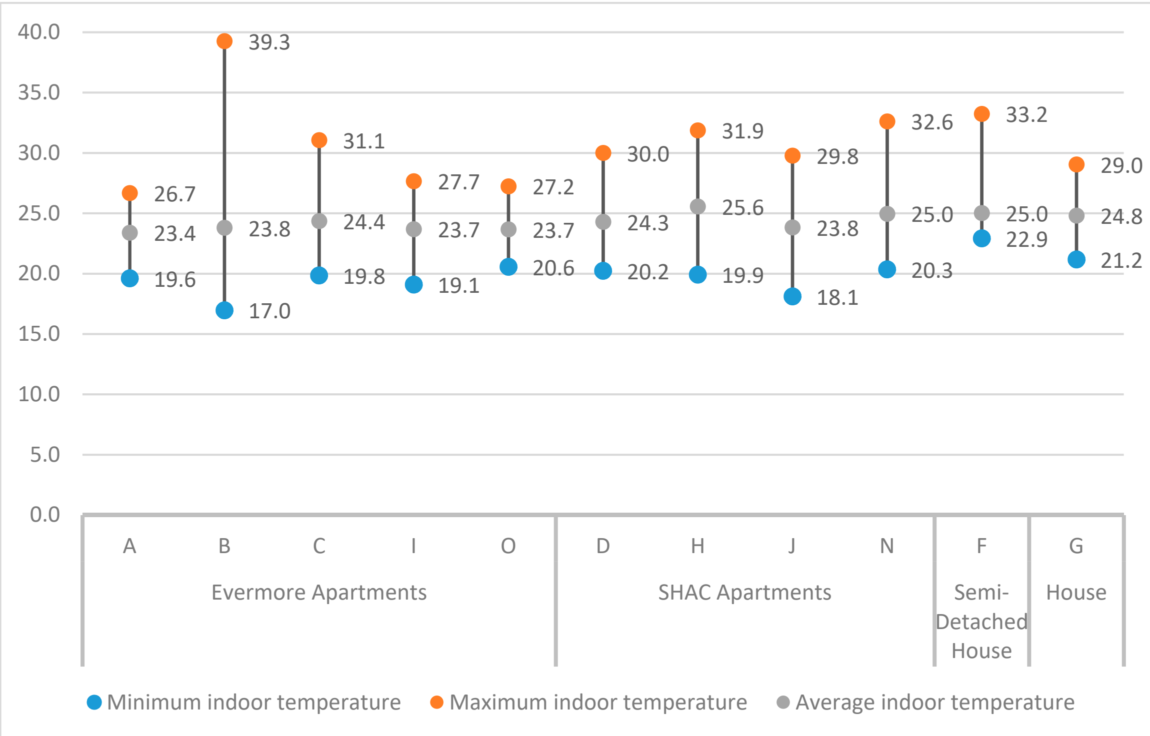

Figure 4. Minimum, maximum and average indoor temperatures in each dwelling's living area. House L in a SHAC apartment was excluded due to residents moving out of the dwelling during the data collection period. House M in a semi-detached house was excluded due to equipment malfunction.

Additionally, there is only a 2.2 °C difference in the average range of indoor temperatures recorded across all the dwellings and all fall within the recommended range of 20 and 25 °C, except household H which has an average of 25.6 °C. This suggests that the design of the dwellings is sufficient to provide thermally comfortable temperatures. When residents were asked how often they felt thermally uncomfortable in their WGV dwellings, 75% or above answered that for less than once a month they feel too hot or too cold. This indicates that their adaptive thermal comfort practices, auxiliary technological use as needed and the design of the dwellings are mostly adequate for their perceived comfort, supporting the range of temperatures recorded.

There were some comments made by residents on certain design aspects that have hindered their thermal comfort, particularly in Evermore. Due to the location of the two apartment buildings with a common area in between, a wind tunnel is created between the apartments. Paired with the strong westerly breezes that are common in the afternoon in this location, some residents choose not to open their windows facing into the common area due to the noise created by the wind. This prevents cooling cross ventilation practices being fully employed and may be influencing the use of auxiliary cooling practices instead. In addition to this, the windows in all apartments above the ground floor are restricted from other than partial opening due to building requirements. While this is for safety reasons, this hinders the flow of sufficient air through the windows to adequately cool the apartments, particularly at night. Some residents have taken out the restrictors in the windows to allow for an increased breeze to come through, although this compromises the safety regulations. This is because they are more comfortable having windows open instead of using fans or an air conditioner for their cooling practices.

These results outline the importance of understanding the technology that residents use in their practices and how this changes when they move house. Some residents had to learn new skills to be thermally comfortable, particularly residents in households F and M, who had never used underfloor hydraulic heating previously. There were some equipment failures with the heating during the winter of 2018, which impacted how the residents remained comfortable. They reported reverting to the practices they performed pre-occupancy to stay warm without the use of a heater, including extra layers of clothes and the use of additional blankets. The change in these practices influences household energy demand patterns, which are important for the design of energy-efficient homes that rely on renewable energy.

4.2.3. Influence of Lifestyle and the HSOP on Cooling Practices

This section will examine the cooling practices of the three houses in the low-carbon development to highlight the influence of household variability in cooling practices in relation to the HSOP. Previous research has examined the connections between lifestyle and family composition and energy use [15,17]. The thermal comfort range for dwellings living areas is considered to be between 20 and 25 °C, as compliant with the Australian National Construction Code [70]. Figures 5 and 6 show energy usage in households F, G and M during the hottest weekday and weekend day of the year during the monitoring period with complete data. These households were chosen because they are not apartments, which had some incomplete monitoring data. Households F and M are semi-detached houses and household G is a stand-alone house. Sunday 20 January had an outside minimum temperature of 21.8 °C and a maximum of 37.7 °C, while Thursday 7 February had an outside minimum temperature of 21 °C and a maximum of 36 °C. A hotter day occurred on Saturday 22 December 2018 (min 24.3 °C, max 39 °C). However, not all households had complete monitoring data for that day.

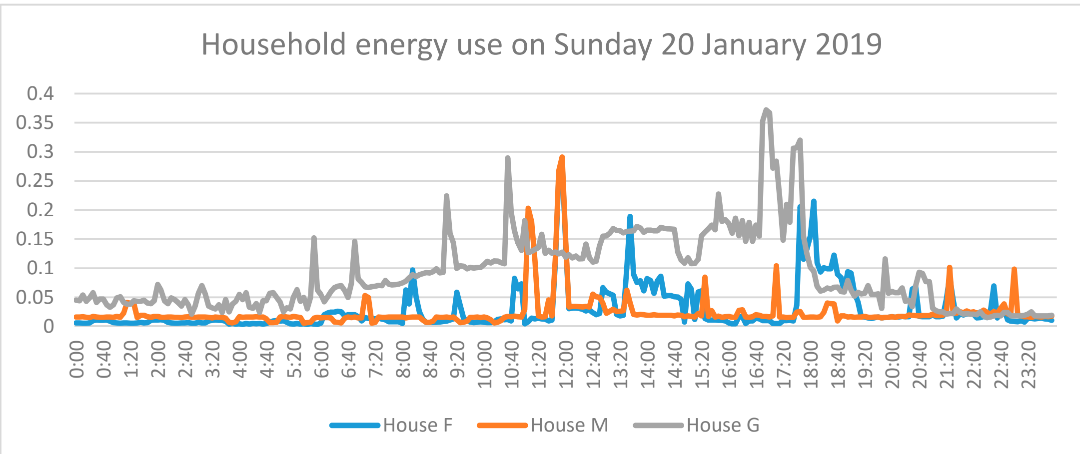

Figure 5. Household energy use (kWh) on Sunday 20 January 2019, the hottest weekend day during monitoring.

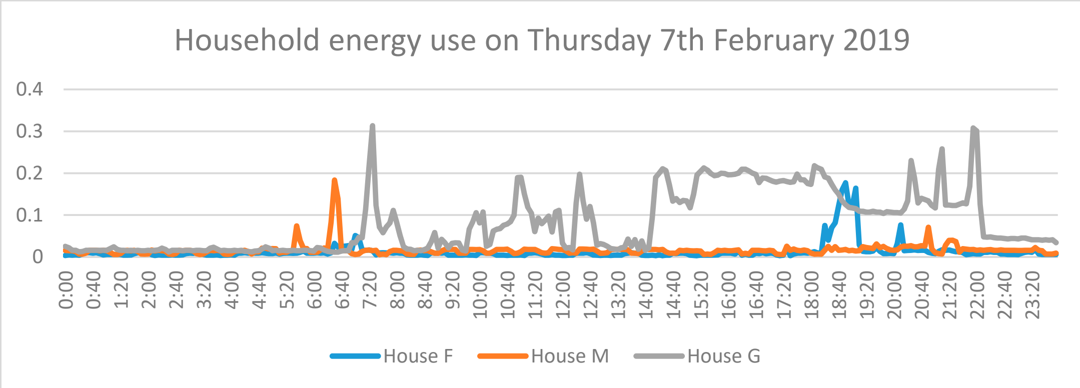

Figure 6. Household energy use (kWh) on Thursday 7 February 2019, the hottest weekday during monitoring.

On Sunday 20 January, the energy use shows that all the households are using energy through the day. In all the households, there are peaks in the morning when the residents wake up, between 11.00 and 13.00 when they would be preparing lunch and completing household chores and then again in the evening around 17:00–19:00 when preparing dinner. Household G has the air conditioning on during the day due to the high energy use from 09:00–18:00. This is supported by the indoor temperature sensor which records the temperature to be between 23.5 and 24.5 °C during this time and 25 °C or above outside of these times.

The energy use profile during a weekday, Thursday 7 February 2019 is markedly different for households F and M which consist of full-time, off-site (Monday to Friday) workers. There are small peaks in the morning between 05:00 and 07:00 when the residents wake up and prepare for work, then low energy use until the evening between 18:00 and 21:00 when the residents are returning home, preparing dinner and going to bed. In contrast, household G, which consists of a shift-worker and full-time student/part-time casual worker were home during the day and use energy throughout. There were similar peaks between 06:30 and 08:30 and 10:00 and 13:00 and then the air conditioner is switched on from 13:30 and 19:00. There is then an evening peak until 22:00 at night when the residents go to bed. The temperature in household G increases steadily from 25 to 29 °C during the morning before the air conditioner is turned on from 13:30 to 22:00, at 25 °C, when the temperature begins to rise again.

This data clearly shows the relationship between time of day, the HSOP and energy use. The HSOP recognises the interlocking of individual resident's practices in the space of the home influencing the practices of others and resource consumption [38,43]. In this example, the households where residents are out of the house on weekdays have low-energy use, with higher levels of consumption during the early morning and evening when the residents are home. This contrasts to the household with a resident home during the day due to differing work conditions, who is utilising energy through their practice of staying thermally comfortable. On a weekday where all the residents of the households are home and practices such as cleaning and washing are being undertaken, the energy use profiles of the households feature more peaks throughout the day.

5. Research Insights and Conclusions

This research provides insight from a pre- and post-occupancy longitudinal study of low-carbon development residents and with a focus on tracking the pre-occupancy practices of residents. However, as this research has shown, an understanding of pre-occupancy practices allows an assessment of how resident practices change post-occupancy when interacting with the design and technological elements of a low-carbon development. There were distinct changes in practice occurring when the technology changes in households. Lower household water consumption levels are primarily due to low flow fixtures and a smaller garden to water. Energy-efficient lights were also installed to reduce operational running costs of the home. The changes in the technology used to heat and cool the home also influence the household energy use. Reverse cycle air conditioners have less energy demand when running on the heating setting than gas or electric oil heaters when used to heat a large space [31]. Along with a change in technology used in the practice, a change in the skills of the resident performing the practice are also required. This was highlighted through the personal hygiene practices of residents. Those who had previously had access to a bath and used this for cleanliness and relaxation, post-occupancy had to rely on a shower to perform this task instead. Some residents then changed their practice for relaxation to a visit to the beach. The HSOP influence on household energy consumption patterns was outlined over two of the hottest weekdays and weekends of the monitoring period for three households with different routines. The marked difference in energy use based on time of day and the practices being performed enable an understanding of the increase in renewable energy and battery storage options. The HSOP and energy consumption patterns will often remain the same, regardless of where the energy is sourced from, which will be a consideration for builders and designers of low-carbon development and energy-efficient homes and technology.

As with any research, there are limitations to this study, although the authors have tried to minimise them where possible. The limited sample size may have affected the wider implications of the study. Residents who had not moved in to the low-carbon development by the beginning of 2019 were unable to participate. Future research might include a larger sample size of residents in a low-carbon development to see how these early adopters interact with the design and technology.

The use of household level data was chosen to be able to assess the influence of the house as a system, in relation to the social practice theory development of a HSOP. Without intensive monitoring of the residents, accurate individual energy and water use is difficult to estimate. The authors did originally divide the household level data by the number of occupants in the household, but this resulted in discrepancies with the qualitative findings reported by residents. For instance, household C had three adults pre-occupancy—two teenage sons and their mother. The individual data showed high consumption levels per individual. However, the interview revealed that the mother had low-energy and water consumption levels, while the sons would have long showers, use the tumble dryer, use their computers extensively and leave the lights on. This highlights the intra home heterogeneity in the performance of practices.

There were a number of households pre-occupancy who did not have access to their energy or water consumption data, or the data they provided was only for a few months a year. The authors chose not to use this incomplete data as it does not provide an accurate reflection of household energy and water consumption levels. This has reduced the households with available pre-occupancy data and influenced the extent to which the authors could comment on the possible impact of rebound effects. Future studies might aim to obtain more detailed energy and water data both pre- and post-occupancy to allow for this area of research to be explored. This would allow for the statistical analysis of changes in energy and water consumption to be undertaken with confidence. It may also provide an opportunity to consider other methods of analysis such as multi-criteria analysis [71,72] or the model of recursive cultural adaptation [73,74].

This study supported the previous literature finding that the meaning of a shower influences its duration. Changes to the meaning of a personal hygiene practice shows how practices are interlocked with others, and unlikely to change in duration when there are other demanding practices to be undertaken. The consumption of energy and water is reduced mostly by virtue of the design and appliances installed in the home. The influence of personal practices of thermal comfort still remains though, as does the influence of work routines on time of day energy and water use. However, changes to energy and water related practices post-occupancy in low-carbon developments were not as predicted. The design of the home and personal practice history influence the resident's practices for water and energy. Pre- and post-occupancy studies of low-carbon development residents are critical for understanding how technology is being used. This research has highlighted the personal influences on routine energy and water consumption along with the changes that can occur through design and technology alterations. These results can be beneficial to architects designing homes, technology companies, and energy and water utilities and those associated with striving to reduce household resource consumption.

Author Contributions: Conceptualization, J.K.B., J.J.B. and G.M; methodology, J.K.B., J.J.B. and G.M.; software, J.K.B. and J.J.B.; validation, J.K.B., J.J.B. and G.M.M.; formal analysis, J.K.B.; investigation, J.K.B. and J.J.B.; resources, J.K.B. and J.J.B.; data curation, J.K. B. and J.J..; writing—original draft preparation, J.K.B.; writing—review and editing, J.K.B., J.J.B. and G.M.M.; visualization, J.K.B.; supervision, J.J.B and G.M.M.; project administration, J.K.B., J.J.B. and G.M.M.; funding acquisition, J.J.B. and G.M.M.

Funding: This research is funded by the CRC (Project number NP 2006 for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative). All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Curtin University (HRE2016-0222).

Acknowledgments: The authors would like to thank Balance Services Group for assistance with the data download and all the stakeholders involved in the WGV Precinct project, particularly LandCorp and the City of Fremantle. The authors thank participants from WGV for their patience and involvement in this research.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Table showing the pre- and post-occupancy energy and water data available for the households that is used in Section 4.1.

WGV Development	House	Pre-Occupancy Energy Data	Post-Occupancy Energy Data	Pre-Occupancy Water Data	Post-Occupancy Water Data
Evermore	A	NA	Spring and Summer	NA	Spring and Summer
	B	1 yr inc gas	Spring and Summer	1 yr	Spring and Summer
	C	1 yr inc gas	Spring and Summer	1 yr	Spring and Summer
	I	NA	Spring and Summer	NA	Spring and Summer
	O	1 yr inc gas	Spring and Summer	1 yr	Spring and Summer
SHAC	D	NA	1 yr	Summer	1 yr
	H	1 yr	1 yr	Winter and Summer	1 yr
	J	1 yr	1 yr	NA	1 yr
	L	NA	Summer, Autumn, Winter	Spring, Summer, Autumn	Summer, Autumn, Winter
	N	Spring and Summer	1 yr	Autumn	1 yr
Semi-Detached House	F	1 yr inc gas	Summer	Summer and Autumn	Spring and Summer
	M	NA	Summer	NA	Spring and Summer
House	G	NA	Spring and Summer	1 yr	February

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Publication VII

Breadsell, J., & Morrison, G. M. (2020). Changes to Household Practices Pre and Post-Occupancy in an Australian Low-Carbon Development. *Sustainable Production and Consumption.* 22, pp. 147-161; https://doi.org/10.1016/j.spc.2020.03.001

Status: published (peer-reviewed)

Sustainable Production and Consumption 22 (2020) 147–161

Contents lists available at ScienceDirect

Sustainable Production and Consumption

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

Research article

Changes to household practices pre- and post-occupancy in an Australian low-carbon development

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ARTICLE INFO

Article history:
Received 2 October 2019
Revised 1 March 2020
Accepted 8 March 2020
Available online 9 March 2020

Keywords:
Household resource use
Social practice theory
Home system of practice
Australia
Post-occupancy evaluation, Low-carbon development

ABSTRACT

Limiting study to a narrow range of energy and water using activities is insufficient to provide a holistic understanding of household resource flows. Consideration of a wide range of social practices is needed. With the rise of low-carbon developments featuring energy or water efficient technology and design around the world, the way residents interact with the design and technology and community is vital to understanding if these households and developments will meet their intended design goals. The opportunity to study resident's pre-and post-occupancy resource consumption is a unique opportunity to examine how design, technology and community influence household practices. This article studied 13 Australian household's practices of waste management, food shopping, item purchasing, travel and laundry practices for two weeks before and after moving into a low-carbon development, while the home system of practice is in a stable phase. This provides an opportunity to comment on the state of interlocking of resident's home system, from lightly interlocked to highly. Post-occupancy, the presence of solar panels influenced when some residents put the washing machine and tumble drier on, however only when the resident was home. Many residents are conscious of putting these on during the day or use timers where they had not previously. Changes to resident's travel practices were not as broad as they anticipated before the move, while recycling rates increased, influenced by a supportive community and shopping practices became more localised through the use of smaller food retailers. Results show that resident's resource use is heavily influenced by their work and socialising routines, which are not commonly focused on when attempting to change household resource use behaviours. A traditional focus on psychological approaches targeting values and attitudes fails to adequately address these factors, whereby a social practice theory approach allows for their consideration in influencing resource use in the home.

1. Introduction

Resource use and waste generation around the world have increased as a result of population growth and rising consumption levels (Harder et al., 2014). Household consumption levels are affected through daily practices which involve those actions undertaken by individuals as part of their routine lives, which have varying impacts on the environment (Halkier, 2009; Kennedy, 2011; Terragni et al., 2009). The term sustainable consumption refers to the consumption of more efficiently or ethically produced goods and where consumers consider environmental and social aspects before purchase (Seyfang, 2005). Many studies have been completed on how household resources such as energy, water, waste and food are consumed and how these could be more sustainable (Delaney and Fam, 2015; Eon et al., 2018b, 2018a; Friis and Christensen, 2016; Gram-Hanssen and Bech-Danielsen, 2004; Hand et al., 2005; Hansen, 2016; Harder et al., 2014; Hess et al., 2018; Rathnayaka et al., 2015; Sahakian and Wilhite, 2014; Twine, 2015). These studies however, have not focused on residents of low-carbon developments (LCD).

LCDs have been designed to enable residents to consume less energy and water than the standard dwelling due to innovative design features. The residents of LCDs have been described as a special segment of the population with different lifestyles and consumption practices (Mlecnik et al., 2012). This paper is based on the concept that consumption occurs during the performance of social practices (Gram-Hanssen, 2008; Shove et al., 2009; Warde, 2005). Understanding the dynamics of everyday consumption practices allows for a comprehensive perspective on altering consumption practices (Greene and Rau, 2018).

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https://doi.org/10.1016/j.spc.2020.03.001

House, townhouse and apartment sizes in Australia are beginning to decline in floor size, indicating that a change may be occurring in preferences for house size (Australian Bureau of Statistics, 2019). As advancements in building codes require stricter building regulations of designs to increase energy efficiency and incorporate passive solar design principles, houses with low-carbon design features will become more prominent in the Australian market (Berry et al., 2019). This study aims to track whether resident's possessions and the related household practices may change too. Knowledge of how residents routines relating to various domestic practises emerge, develop and change provides an insight into sustainable consumption (Gram-Hanssen, 2008).

This paper will analyse domestic consumption practices through empirical evidence collected from resident's pre-and post-occupancy in an Australian LCD, located in Western Australia. This addresses the research question: "What changes occur to individual domestic practices and the home system of practice (HSOP) when residents' move into a LCD?" Pre-occupancy and post-occupancy studies are important to examine how residents engage with the design, technology and community aspects of LCDs (Meir et al., 2009). The focus on social practices in the space of the home has allowed for multiple practices to be studied, however there have been few studies that focus on these as a holistic study, rather most focus on one or two practices at a time. Understanding the dynamics of everyday consumption practices through a holistic study of household practices, therefore, allows for a comprehensive perspective on altering household resource metabolism (Fam et al., 2015; Greene and Rau, 2018). This paper will explore the routines of travel, waste management, food and item purchasing and laundry practices of residents for two weeks pre- and post-occupancy in the LCD. A discussion on how the practices interlock, or link together in a daily routine, in the HSOP, and the policy implications for sustainable household practices conclude the paper.

2. Theoretical overview: routines in domestic practices

This section outlines the theoretical overview of relevant topics to this paper as found through a snowball narrative literature review using keywords relating to the topics and from references from key literature in the area. This includes social practice theory which provides the framework for analysing the practices, and a summary of the practices themselves: travel, waste management, item purchasing, food purchasing and laundry practices. These practices all involve the use of resources of one form or another and are centred around the home as a place of performance or of influence on their performance in the case of travel or purchasing. These practices were chosen based on practices previously studied in isolation and in other studies of household resource consumption which will be outlined below. The intention was to cover the majority of household practices performed outside of the traditionally studied showering and thermal comfort practices that have dominated the social practice theory literature, to provide an understanding of their performance that may influence attempts to reduce individual's resource consumption to limit environmental impacts (Gram-Hanssen, 2008; Higginson et al., 2015).

2.1. Social Practice Theory

Traditional economic and psychological approaches view consumption as an isolated event and the consumer to be rational, thoughtful and responsible for their decisions and actions (Wahlen, 2011). However, researchers have increasingly demonstrated that consumers, whilst being rational, thoughtful and responsible for their decisions and actions, are also part of on-going practices that are bundled up in other daily practices, not a one off event segmented in time (Halkier and Jensen, 2011; Sahakian and Wilhite, 2014; Schatzki, 2019; Spaargaren and Mol, 2008). People do not use resources such as water or energy directly, but rather with the objective of achieving a desired outcome and consumption occurs at the time of the performance of the practice (Shove et al., 2010; Wahlen, 2011).

Social Practice Theory focuses on the study of practices, a collection of doings and sayings that form the basis of lifestyles and are made up of three elements: meaning, technology and skill (Breadsell et al., 2019d; Breadsell et al., 2019a; Breadsell et al., 2019c; Eon et al., 2019, 2018a). Meanings are the understanding, assumptions and values associated with the practice; technology is the artefacts used in the performance of the practice and skill is the required knowledge and competency to execute the practice. These have been described under various names by previous social practice theorist (Gram-Hanssen, 2010; Reckwitz, 2002; Schatzki, 2002; Scott et al., 2012; Shove et al., 2012; Warde, 2005; Breadsell et al., 2019d). These elements can change for each performance of the practice, particularly as skill or meaning alters but they are often routinely performed and inconspicuous in their performance (Wahlen, 2011). Routine practices form the basis for everyday life and reduce complexity, save time and energy (Wahlen, 2011). When routine practices are performed with little change over a long period of time, they form into habits that do not require much engagement in the active performance of them (Sahakian and Wilhite, 2014). These habits can be connected to places such as the home, shopping centres or transport routines where they are most commonly performed (Breadsell et al., 2019a; Eon et al., 2019; Eriksson et al., 2008; Foulds et al., 2016; Gram-Hanssen and Darby, 2018; Hampton, 2017; Khalid and Sunikka-Blank, 2017; Pooley et al., 2011). The study of what happens to these habitual practices when the context they are performed in changes, such as when people move houses, is rarely studied (Plessz et al., 2016). Longitudinal studies can identify any changes that occur, such as through diary studies, however these have only previously been studied in situ in the home environment (Wahlen, 2011). However, researching only one practice and the consumption of resources related to this practice does not provide the whole picture (Sahakian and Wilhite, 2014). Practices do not exist in isolation from other practices, or be performed in a bubble from contextual factors, they are influenced by other members of a household, neighbourhood and technological changes (Bartiaux and Reátegui Salmón, 2014; Kennedy, 2011). Practices also interlock with each other, forming a system of practice (Watson, 2012), influencing when and how a practice can be performed based on time and resource commitments (Breadsell et al., 2019a; Spurling et al., 2013; Spurling and McMeekin, 2015). This may take to form of a morning routine where the practices of showering, eating breakfast and driving to work are interlocked (Eon et al., 2019). Reconfiguring one aspect of daily practices forces other interlocking practices to be reconfigured as well (Shove and Walker, 2010; Spurling and McMeekin, 2015). Therefore, examining a broader system of practice, such as those found in the home, or a Home System of Practice (HSOP), is required (Breadsell et al., 2019a; Eon et al., 2018a, 2018b; Strengers, 2011).

A HSOP can be lightly or more highly interlocked depending on how routine the performance of practices are and the constraining factors influencing when practices can be undertaken (Breadsell et al., 2019a). A household of adults who work full-time off-site would be more highly interlocked than a household of a retiree who has few constraining factors on the performance of household practices. Households with highly interlocked HSOPs may find it difficult to change their practices as there are many influences on why they and how they perform practices, at particular times and with particular technology. For instance, a lightly interlocked household has more options to dry their laundry outside during winter when they are home during the day more than a highly interlocked household who are away from the home more frequently and who may have to resort to a tumble drier instead as their clothes would not be dry in time to be used again. The pre-occupancy interlocking status of the residents in this case study has been studied and discussed further in Breadsell et al., (2019a).

Previous studies on practices relating to household consumption have been undertaken on mobility practices (Cass and Faulconbridge, 2016; Greene and Rau, 2018), recycling (Wonneck and Hobson, 2017), food purchasing and meal times (Molander, 2011; Pfeiffer et al., 2017; Wahlen, 2011; Yates and Warde, 2017), appliance purchasing (Foulds et al., 2016), laundry (Hand et al., 2007; Higginson et al., 2015; Pink, 2005) and showering (Pink and Mackley, 2015a; Seebauer et al., 2016; Shove, 2003; Shove and Walker, 2010). The work undertaken by Foulds and colleagues has formed the basis for the pre- and post-occupancy studies of practices and also influenced the formation of this research (Foulds, 2013; Foulds et al., 2016). These practices and related studies will be discussed below, with reference to related social practice research with occasional inputs by other disciplines where relevant.

2.2. Travel practices

Travel practices have been defined as a consumption of distance practice, however there has been a lack of temporal and contextual studies into travel practices (Greene and Rau, 2018; Heisserer and Rau, 2017; Urry, 2007). People's travel practices, and the elements associated with that practice, change based on their stages of life, place and type of residence, and career (Urry, 2007). Travel behaviours or practices are largely habitual, embedded within daily routines and dependent on particular structural and locational factors (Barr and Prillwitz, 2011). Changes in these practices require subsequent changes in many daily practices that are interlocked with travel such as shopping, work and social interaction (Laakso, 2017). For many, the car is the dominant mode of transport for many activities, leisure, work and holidays (Kent, 2015; Urry, 2007). Travel practices are entwined with other practices and have powerful time and space dependent interactions (Urry, 2007). This encourages social networks to overlap, with quick, casual meetings. However many factors influence one's choice of travel method, such as being able to have multiple stops in a trip via a car, safety whilst walking or being sweaty after cycling (Cass and Faulconbridge, 2016; Harries and Rettie, 2016; Pooley et al., 2011).

2.3. Waste management practices

Each household in Australia is estimated to produce almost 1.5 tonnes of waste each year (Australian Bureau of Statistics, 2013). In Western Australia, this is slightly higher at 1.6 tonnes of waste per capita, with state targets to increase recycling rates by 15% by 2020(ASK Waste Management, 2019). Household waste consists of organics (46%), paper and cardboard (27%), metals (14%), glass (10%), plastic (2%), and rubber, textiles and other (less than 1% each) (ASK Waste Management, 2019). Recycling rates are high for households, with 97% recycling paper, cardboard, metal, plastic and glass through curbside collections (Australian Bureau of Statistics, 2013). Despite 23% of Australian households always composting food waste, the average Australia household throws out approximately AU$616 worth of food each year and over 80% report this as a concern leading to feelings of guilt (Australian Bureau of Statistics, 2013; Denniss and Bater, 2011). This equates to 15.9Mt of CO_2 emissions annually (Denniss and Bater, 2011). There are many benefits to composting including extending the lifetime of landfill sites, mitigating greenhouse gases and creating a useable product (Seng et al., 2013).

Larger scale studies at a neighbourhood or city scale reveals differences in recycling behaviours at a household level (Barr, 2007; Hayles and Dean, 2015). This is driven by differences in household practices through perceptions and social norms of convenience, disgust, cleanliness and environmental and health concerns; the skills to perform waste management practices including knowing what can be recycled or composted and how; and the technology to do so through indoor and outdoor garbage bins, and associated curbside collections or uses for composted materials (Harder et al., 2014; Wonneck and Hobson, 2017). Vague goals such as saving the planet, do not engage with relevant social practices or give people a chance to perform new practices, unless they also take account of the practices skills and technology in the performance (Sahakian and Wilhite, 2014; Wonneck and Hobson, 2017). Structured recycling systems and other members of one's social or neighbourhood circle recycling have been found to increase recycling rates in both behaviour and social practice based research (Barr, 2007; Sahakian and Wilhite, 2014).

2.4. Purchasing practices

Previous studies have examined purchasing practices through tracking individual items such as light bulbs (Schleich et al., 2014), single-use spoons, reusable water bottles and washing machines in a behaviour based study (Goucher-Lambert and Cagan, 2015). These studies have found that consumers with environmental impact or efficiency information available for a product at the time of purchase will have this influence their purchasing decision (Goucher-Lambert and Cagan, 2015), and that many low-income households will use goods for as long as possible before replacement and will often buy products second-hand, particularly clothing (Lettenmeier et al., 2012). Moving home often coincides with purchasing new modern appliances, influenced by the size of the home, spatial layout and beliefs around moving home being a fresh start requiring new items (Corrigan, 2011; Foulds et al., 2016; Gregson et al., 2007).

2.5. Food practices

Food consumption is responsible for significant environmental impacts and greater understanding about the meaning around food practices is needed (Halkier, 2009; Leray et al., 2016). One's relationship with food can change due to having a new kitchen, resulting in new skills, technology or meaning being applied for cooking and eating. This influences the practices and can increase their frequency if this is positive, or decrease if people are not satisfied with the kitchen or dislike some appliances (Foulds et al., 2016). The food practices based in the home also influence how often, where and why people eat out, which can be spontaneous or conscious decisions to streamline their daily lives and for convenience or reward (Pfeiffer et al., 2017; Yates and Warde, 2017). The food practices of bulk shopping and cooking are popular household food practices but depend on many other factors such as time, money, transport options, other events and the technology and skills to do so (Ozaki and Shaw, 2013). Bulk shopping and cooking are popular in households with highly interlocked practices and where the households have other time-competing practices requiring their attention such as work, children or social events (Plessz et al., 2016). However, households that only have small fridges or freezers to store food are restricted in their food practices and when a change occurs in a practice element, such as purchasing a larger fridge to store more food in it, this can free up time for other practices in the day and week (Shove and Southerton, 2000).

2.6. Laundry practices

After water use in the bathroom, laundry practices use the largest amount of water in household practices across Australia (Sapkota et al., 2018). Laundry practices are made up of a series of dispersed actions throughout the day: from gathering laundry that needs washing, allowing this to run a cycle in the washing machine, drying on the clothes line or tumble drier, to collecting and storing the clean laundry (Pink and Mackley, 2015b). This makes laundry practices similar to travel practices in that they are linked together and coordinated with other activities but are also highly energy and water intensive practices, strongly influenced by changes in technology over the decades (O'dell, 2009). Laundry practices are time and effort consuming as well as water, chemical and energy consuming (Gram-Hanssen, 2008). There are many influences on the performance of laundry practices: the weather, availability of clothes or linen that can be washed together, and the available time to undertake the practice (Wahlen, 2011).

Over the past few decades, there has been an increase in the number of washing loads households perform each week due to the types of clothes people wear, the number of, and the type of, fabrics of which they are made (Hobman et al., 2017; Elizabeth Shove, 2003). There are also a number of studies of household laundry practices in the social practice theory literature as it was one of the first practices to be examined in the household by theorists (Higginson et al., 2015; Pink, 2005; Shove, 2003; Shove, 2003). The change in technology used in laundry practice has made it easier to wash sheets and towels more frequently for hygiene reasons, while wanting to wear fresh clothes every day has been found to be positively associated with the number of wash and dry cycles that occur (Hess et al., 2018). There is a need to understand why people wash their clothes before policies or technologies that influence laundry water or energy use should be implemented (Strengers, 2011). If people are washing clothes for hygiene reasons or presentation reasons, there may be other ways that these results can be achieved without the traditional washing machine approach to laundry (Strengers, 2011). One study in the UK found that most residents do not use a tumble dryer as they perceived it to be wasteful, however when they moved into a passive house, they were not able to dry their clothes on clothes racks inside because it influenced the relative humidity of the house and they instead had to purchase a tumble drier (Foulds et al., 2016). As work participation rates by women and men in society rise, laundry practices have moved from being performed on weekdays to mostly being performed on weekends (Anderson, 2016). There has also been an increase in laundry being performed in the early morning due to the demand for other practices such as children's sporting activities, shopping or visiting friends during the day (Anderson, 2016). Laundry practices were traditionally tightly interlocked together (Mylan, 2015), however there has been some loosening in the time an individual actually performs the laundry practice due to technology, and therefore they can engage in other practices while the clothes are being cleaned. The same applies to drying practices, both on a clothes line and with a tumble drier (Friis and Christensen, 2016). Using automatic timers can assist in displacing or dis-interlocking these practices in time even further (Eon et al., 2019; Friis and Christensen, 2016).

3. Methods

3.1. Research design

This research is based on pre- and post-occupancy evaluation which is a form of research to assess the resident reactions and practice changes to building occupancy (Grijp et al., 2019; Meir et al., 2009; Mlecnik et al., 2012). Previous post-occupancy studies of low-energy buildings in Australia have focused on occupants comfort and interaction with technologies in the dwelling (Berry et al., 2014; Berry and Davidson, 2015; Moore et al., 2017; Sherriff et al., 2019). These studies have found that many occupants of low-energy buildings have little or no experience of the new technologies and how to effectively use them to remain comfortable in their homes (Whaley et al., 2019). However, individual user experiences are highly variable (Berry et al., 2019). The pre-occupancy study was included in this research to make this a longitudinal study to complement the post-occupancy evaluation and examine any changes occurring to practices in the LCD.

Practices are the mediator and carrier of implicit or tacit knowledge and as such, they can be studied to unveil the resources utilised in their performance (Røpke, 2009; Shove et al., 2007; Warde, 2005). This can be through observation of the practice and discussion with the practitioners themselves to understand and interpret the implicit background knowledge and meanings (Shove et al., 2007). A time of change is ideal for studying practices because participants are more actively aware of how the new situation can be accommodated into existing practices (Higginson et al., 2013). Studying a situation of change can allow learning of old practices and newly emerging practices to occur (Bueger, 2014). Studying practices in real-life settings and over multiple performances allows us to capture real motivations and needs of users (Dell'Era and Landoni, 2014; Higginson et al., 2015). It also acknowledges that practices are not performed in isolation, they are influenced by other practices. The discussion relating to the interlocking of practices in the home addresses this.This paper will follow the practices of daily travel, waste management, food and appliance purchasing and laundry practices, as well as using meal times as an example to study the interlocking of the HSOP, building on the work previously published (Breadsell et al., 2019a).

3.2. Project participants

This research is utilising residents of the LCD, titled "WGV", located in Fremantle, Western Australia as case study participants. A cohort study of 13 homes, with 14 residents participated in the research for two week before and after they moved into the development, with time allowed for the practices to settle back into normal routines. Focusing on user experiences allows this research to study residents on both an individual and household level to track resource consumption changes (Harder et al., 2014). Therefore some of the results have been presented per household (out of 13), others have been presented per resident (out of 14), depending on the practice studied. Practices are presented together to allow for comparison across the cohort, with some individual changes highlighted where relevant. This shows the common elements that many social practices have and provide insights into targeted changes that would be relevant for policy approaches. Some questions were not answered by all participants and as such do not have a full cohort in their response. Although this study has a small cohort, the resident practices have been studied in great detail, leading to a richer understanding of the influences on them (Hargreaves, 2011). The residents are from three different dwelling types in WGV, which comprised of apartments, semi-detached houses and detached houses. The first cohort are house owner/occupiers, where there are three residents in two semi-detached houses and one resident in a detached house. The second cohort are five owner/occupiers of apartments in a complex called Evermore. These apartments were sold at market rates with not concessions for homebuyers. sold at market rates, called Evermore. The final cohort are five renters of apartments and members of a housing co-operative in a government subsided, low-income apartment complex called Sustainable Housing for Artists and Creatives (SHAC). The participants and their lifestyles are outlined in Table 1.

Table 1
Resident's dwelling, house and occupancy lifestyle at WGV, and pre-occupancy HSOP interlocked status as determined in (Breadsell et al., 2019a).

Dwelling	House	Occupancy lifestyle	Pre-occupancy interlocking status
Evermore	A	Works full-time off-site	Highly interlocked
Apartments	B	Works 4 days a week off-site; daughter is a student home most days	Highly interlocked
	C	Works 4 days a week off-site	Highly interlocked
	I	Retiree	Lightly interlocked
	O	Works full-time off-site; son is a student home most days	Highly interlocked
SHAC	D	Works part-time off-site, part-time on site; son works part-time off site	Lightly interlocked
Apartments	H	Works part-time off-site, part-time on-site	Lightly interlocked
	J	Works part-time off-site	Lightly interlocked
	L	Works part-time off-site, part-time on-site; 5 year old part-time school student	Lightly interlocked
	N	Works part-time on-site	Lightly interlocked
Semi-Detached House	F	Both residents work full-time off-site	Highly interlocked
Semi-Detached House	M	Both residents work full-time off-site	Lightly interlocked
Detached House	G	Shift work full-time off-site; daughter is a student home most days	Lightly interlocked

Their pre-occupancy interlocking status of practices is also stated, this is discussed further in (Breadsell et al., 2019a) For households with children, the children did not participate in the research due to uncertainties if they would be moving into the WGV development. A more detailed discussion of the resident's pre-occupancy housing is discussed in (Breadsell et al., 2019a).

The WGV development is located in the City of Fremantle, a suburb near Perth, Western Australia. The area has a Mediterranean climate with regular summer sea breezes and average temperatures between 10 °C and 27.3 °C (Bureau of Meteorology, 2019). The dwellings studied have sustainability features including passive solar design principles to allow for airflow and sunlight levels to regular the thermal temperature; solar photovoltaic panels for on-site energy generation and Lithium-ion batteries for communal storage of energy in the SHAC and Evermore apartments; low-flow water fixtures; LED lights; and rainwater tanks with dual plumbing to use recycled water in the laundry, toilets and on gardens (Breadsell et al., 2019a; Wiktorowicz et al., 2018).

3.3. Mixed methods

Mixed methods were employed pre-and post-occupancy for data collection (Browne et al., 2015; Creswell et al., 2003; Creswell and Plano Clark, 2011, Creswell and Plano Clark, 2007; Liedtke et al., 2015). The data collection focused on the themes of energy, water, waste, food, transport and social network practices. This paper addresses the waste, food, transport and laundry practices and social network influences. Other papers have published the data on energy and water practices (Breadsell et al., 2019c) and the social network and sense of community (Breadsell et al., 2019b). Data was collected through three methods replicated both pre- and post-occupancy in WGV. Firstly, a one-hour semi-structured interview[1] was undertaken to gain an overview of the different ways the participant's daily lives are structured. Secondly, a workbook was then completed over two weeks, allowing residents to respond to short-answer questions about their resource use[2] along with 5[3] point Likert scale survey questions (Bratt et al., 2015; Browne et al., 2015) Not all of the Likert scale data has been presented in this paper, only those with relevant answers to the focus of this paper. Thirdly, travel practices were provided through a travel diary over this time which noted time, duration, purpose and form of travel (Urry, 2007). The authors decided not to examine the tourism travel practices of the residents as these occur outside the HSOP (Verbeek and Mommaas, 2008). Finally, short answer questions were asked through text message during the workbook completion phase such as "can you tell me or send me a picture of how you got around today?" The range of data collection methods enabled the strengths and weakness of each one to be compensated by others (Liedtke et al., 2015). For instance, interviewees may not accurately self-report frequency of practices, therefore the diaries were a way to capture data this way. Alternatively, the text message questions enable real-time data collection to compare to the responses from the interviews and diaries. The methods chosen were deliberately more intensive than the traditional observations and questions from psychology methods that are usually utilised to understand domestic behaviours and practices. This was in an attempt to understand the complex formation of the social practices and allow them to be contrasted to those that are present post-occupancy in WGV (Keller et al., 2016; Schelly, 2016).

Interviewees self-selected through an open invitation sent to households who had purchased property in the LCD or were intending to become a tenant through SHAC ($n = 27$). Pre-occupancy data collection was conducted for a period of two week each household between April and June 2017 for SHAC residents and between December 2017 and March 2018 for Evermore and single house residents. Post-occupancy data collection was conducted once residents had moved into WGV, between December 2018 and March 2019. The long period of time for data collection pre-occupancy was intended to allow for a greater sample size of residents to self-select, however there is a bias towards those who post-occupancy are in SHAC or Evermore due to the requirement of the resident residing in the LCD during 2018 to allow for post-occupancy data collection to occur within the research time constraints. The period during which the households were studied was selected to be during a stable phase of their routines, not immediately before or after the residents had moved into WGV. This was to ensure the resident's systems of practice was represented at a 'normal' stage and not influenced by the process of moving to a new house.

3.4. Data analysis

The qualitative data was analysed through thematic analysis of interviews, short answer questions and text probes focusing on the elements of the practices and changes to them pre- and post-occupancy. In total, 43 overarching themes were identified, highlighting the different ways of performing practices and resident's lifestyle at WGV. The themes related to this paper include convenience, transport, waste, cleaning, food, shopping, habit, routine,

[1] Questions in the semi-structured interview ask residents how they keep warm and cool, the routines they go through each day and how their lives have changed since moving to the LCD.

[2] An example of a short answer question is: Where do you get your knowledge about recycling?

[3] 5-scale Likert question examples: How important is it to you to eat home cooked meals every day? Extremely important, very important, somewhat important, not so important, not at all important. How often do you buy from a local store (non-supermarket chain)? Very often, often, sometimes, rarely, very rarely.

Table 2
Travel modes for practices of 14 residents' pre- and post-occupancy in WGV. Question allowed for multiple answers for journey and travel option to capture the multiple ways residents may undertake the journey.

Travel mode	Study period	Purpose of journey and number of residents who use the travel mode for each journey type				
		Work	Shops	Local leisure journeys	Local social visits	Taking children to school
Car	Pre-occupancy	10	12	8	10	2
	Post-occupancy	9	13	7	9	2
Bus	Pre-occupancy	2	1	2	1	0
	Post-occupancy	2	0	0	1	0
Train	Pre-occupancy	4	1	2	1	0
	Post-occupancy	4	0	2	0	0
Walk	Pre-occupancy	3	7	5	4	1
	Post-occupancy	3	3	6	3	1
Bicycle	Pre-occupancy	3	1	5	5	0
	Post-occupancy	5	1	6	6	2

recycling, family, friends and local. The Likert scale data were analysed through tabulating and graphing the results to view trends, which were then compared with the qualitative data. The results are presented in this paper focusing on the performance of the practices and how these change post-occupancy in WGV. Analysis begins on the practices of the cohort as a whole and focuses on dwelling cohorts and individuals where relevant.

4. Results

4.1. Travel practices

The need for changes in transport practices to include those with less carbon emissions is well understood in the literature and the idea was supported by the residents in this study both pre-and post-occupancy, but is performed with varying success (Hickman and Vecia, 2016; Newman and Kenworthy, 2015). Table 2 shows the reported travel practices of residents pre- and post-occupancy. Residents across all the cohorts pre-occupancy anticipated change in their travel practices to reduce car use, with nine out of fourteen residents intending to alter their practice of getting to work, socialising or running errands. Five residents specifically identified that they wanted to ride bicycles to nearby amenities and activities more, despite the hilly landscape around the LCD, while others were not specific to how they wished to change their travel practices. The intention of changing a practice may be related to the meaning of the travel practice as people are living in a LCD and the desire to use the opportunity to make low-carbon choices in other practices. There is an electric vehicle on site that residents could book to use through a local share-car system, with three respondents indicating they would want to use this. This number may below because most residents already own a car and would not want to pay for using another one. Those who do not own a car were enthusiastic to have access to one if needed. For residents who already lived within 2 km of the WGV development (five out of 13 households), no change in their travel practices was anticipated because they are expecting to use the same local shops and parks and continue the same travel practices to work. However, the average distance residents lived from WGV pre-occupancy was 10km, ranging from 0.6km to 50km away, so travel practices were anticipated to change for most residents.

As shown in Table 2, the daily routine use of transport has not changed with the exception of Resident D who walks to work now instead of driving:

"Living here made it easy for me to not use my car and my work has moved to Fremantle in late last year. So instead of commuting 40 kilometres one way, twice a week…I walk or ride my bike"

Some residents have replaced some local trips to shops with walking or biking instead but otherwise shopping and work practices have remained the same. Those who reported using public transport (bus or train) in WGV are only those who were already using these forms of transport before they moved in.

Many of the residents reported being disappointed about the onsite electric vehicle at WGV. This was installed in partnership with the developer and a local car share company, with the residents of WGV receiving free membership. However, to use the electric vehicle a AU$500 deposit is held for up to one week on the resident's credit card as bond. This is too high a cost for many of the residents, particularly those in the low-income housing, SHAC. In addition, residents who reported expecting to use the electric vehicle have not used it either at all or regularly due to the flexibility in using their own car in not feeling restricted by the amount of time they spend outside of WGV. These residents all still own their own car, although some had plans to get sell their vehicle but have not done so yet. There was a suggestion by one resident that a community utility vehicle (as opposed to the current electric hatchback) may be more useful for residents to use to transport larger items from shops, to the recycling centre or people and luggage to the airport.

Three residents were expecting to either purchase or convert their current bicycles into an electric bike. At the time of the interviews post-occupancy, none of these residents had done this, citing being too busy settling in as the reason why. Two residents still want to make this conversion when they have time. Four residents wanted to cycle more once they moved into WGV. There has been an increase in the use of personal bicycles however the hills around WGV are a deterrent to the older residents who are more car dependent, especially for shopping trips, as Resident I and A stated:

Resident I: "Well, I'm 73 and I do have a few physical problems that kind of make it hard to walk long distances."

Resident A: "I just haven't got around to it and the hills here are actually quite steep. I've been a bit put off about "will I make it?""

The two apartment complexes, SHAC and Evermore have dedicated bicycle racks for residents to store their bicycles in. In Evermore, these are behind the gates to the complex, along with a bicycle repair station with tools, which is regularly used by residents who already own bicycles and with the inclusion of two communal bicycles, are now encouraging other residents to change their travel practises as highlighted by Resident C:

"I'm not a big bike rider, but…the complex has now got two communal bikes so I did actually have a bit of a trial run the other day…I can ride a bike, it's just that I haven't really done it very much – or certainly not in the recent years, so I am trying to build my confidence that I will use it to go in and out of Fremantle."

In SHAC however, the communal bicycle space is open to the public and there have been reports of some theft of bicycles. This has deterred members from storing their bicycles outside, which

Table 3
Pre- and post-occupancy recycling practices of 13 households.

Recycling practices	Number of household's pre-occupancy	Number of household's post-occupancy
Recycling	13	13
Soft plastics	0	9
Compost	6	11

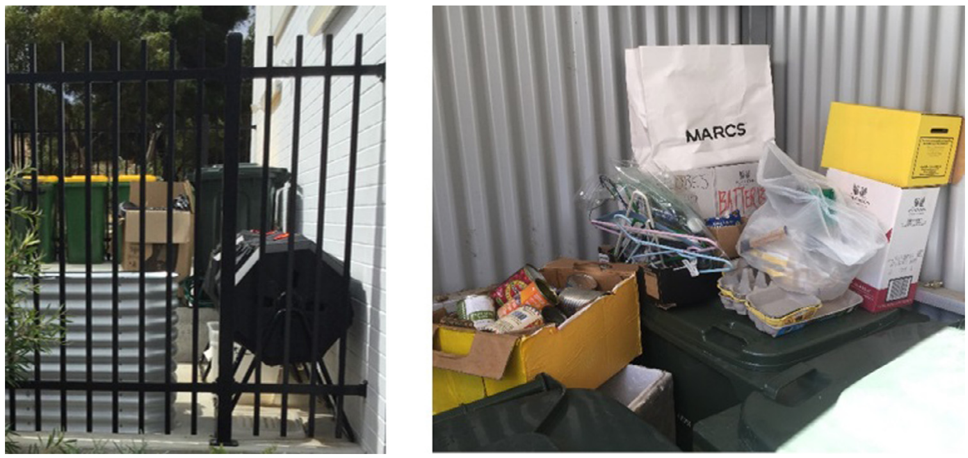

Fig. 1. Left photo: The waste management station at Evermore. Right photo: Part of the SHAC waste management station

results in them being moved inside the apartment or into the small storage shed adjacent to the car park.

4.2. Waste management practices

The waste management practices were studied, including recycling of aluminium, cardboard, glass, paper, steel and some plastics through the local council roadside recycling bins, soft plastics *via* dedicated disposal points and composting of food waste. The results are shown in Table 3. Pre-occupancy, all households recycled through the local council managed roadside recycling bins with either weekly or fortnight collections. This practice has continued post-occupancy in WGV. One detached house had multiple bin spaces installed in her kitchen cupboard to separate the waste and recycling at the source and cites this as assisting her to recycle. In regards to recycling of soft plastics which are unable to be placed in the roadside recycling bins, no households pre-occupancy reported recycling these. Post-occupancy, SHAC and Evermore residents independently implemented a soft plastics recycling system for each development that is then taken to a local drop off point by a volunteer. This resulted in all apartment households now recycling soft plastics. All apartments and semi-detached households also compost through a shared compost system in each apartment complex and shared between the two semi-detached houses. The remaining detached house resident had not implemented a compost system at the time of interviewing but was planning to in the future. Those who composted pre-occupancy are continuing this practice but appreciate the scheme set up, as highlighted by Resident I from Evermore who said that:

"It's been really great to have somewhere to put it and to know what to do with it."

Having a recycling system implemented by other residents who were more invested and motivated to do so has allowed residents who would not normally pursue this practice to participate, as Resident C reports:

"I'm not, you know, to be honest, I'm not as actively engaged with that [recycling] as a lot of the other people are, but I'm very happy to abide by…they know what they're doing, and as long as I know what to do, I'm happy to do it, you know?"

These results highlight that residents are willing to change their waste management practices if there is community support and adequate facilities in place for them to do so. Fig. 1 shows the waste management stations at Evermore and SHAC, with containers for soft plastics, composting, cardboard, aluminium and garden waste. The provision of the space for this to occur has enable the residents to participate in recycling these items post-occupancy, and they have been purposely thorough, as highlighted by Resident N:

"boxes for cartridges, batteries, tin lids, soft plastics. We're really quite militant about it, the sustainability aspects."

4.3. Food shopping practices

The practice of food shopping was examined to discover the frequency and location of where food was purchased for the household. Pre- and post-occupancy changes occurred to the shopping frequency and location. The frequency of shops increased for most household's post-occupancy. This is due to the households either decreasing in size with children not moving into WGV, therefore reducing the food required each week or by residents making a conscious effort to only buy what they need for a few days at each shop. This change in practice has been supported by an increase in the use of local stores and markets post-occupancy as shown in Table 4. The local stores are closer to WGV and residents report enjoying shopping there more and the convenience of the location and smaller stores. Residents who have lived further away from WGV pre-occupancy previously shopped at their local large supermarket but have now changed to the smaller supermarket or fresh food market due to the close proximity to WGV while still stocking the required items. A resident who shops at a local fresh food market 16km from WGV does so because it is close to her work and it is part of her weekly practice to do the shopping before or after work. This is a long-term practice she has performed and did not want to change when moving into WGV. Another long-term practice continued by 3 households in WGV is the delivery of food through weekly boxes. These residents enjoy the high quality food provided and this reduces the amount of time they spend shopping elsewhere during the week. Resident O from Evermore was

Table 4
Food shopping location pre- and post-occupancy of 13 households

Food shop (distance from WGV)	Number of households pre-occupancy	Number of households post-occupancy
Large supermarkets (3km)	6	4
Smaller supermarket (1.6km)	3	6
Local fresh food market (1.6km)	3	8
Local fresh food market (16km)	1	1
Local farmers markets (2.4km)	7	6
Speciality food shop in Fremantle (3km)	5	5
Speciality stores in surrounding area (2-5km)	1	3
Food delivery box	3	3

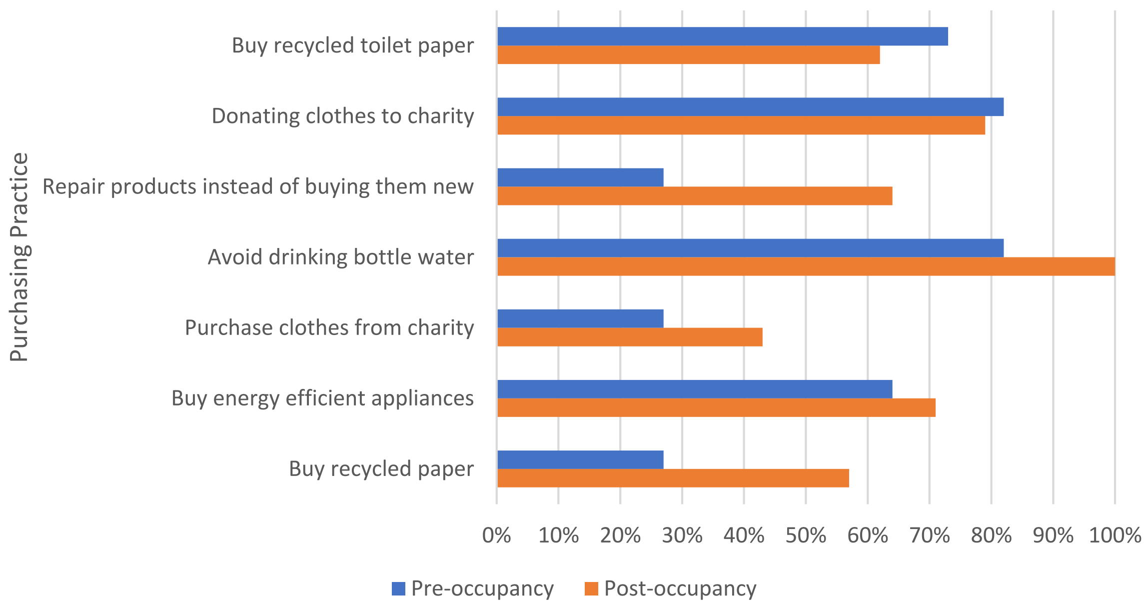

Fig. 2. Purchasing practice of resident's pre and post-occupancy per household. These results are shown as percentages due to the variance in the number of completed surveys by household's pre-occupancy (11 out of 14) and post-occupancy (14 out of 14).

also involved in bringing a local business into WGV to sell some speciality produce to the residents:

"…twice now, [we] have sold some goat's milk products from [a local] goat farm. And that's growing out of the fact that those products used to be sold at the farmer's market… [so we] contacted him and this arrangement was made. And it's happened twice so, it's involved contacting people throughout the whole eco village [WGV] and they could come in and buy things."

Residents in Households F and M are using the shared garden produce extensively and enjoy the seasonality of the produce. This has also reduced the amount of food they need to buy at the shops weekly. When they have excess, they are sharing it with others they know in the WGV precinct. The residents in Evermore have also started a produce garden with new plants and existing plants moved in pots to WGV. This allows residents to pick produce at their own leisure and have access to specialty plants that they did not have before in their gardens, as Residents B and O highlight:

Resident O: "Residents [of Evermore] have got a vegetable garden going and they just call everybody to harvest at will. And we've harvested lots of greens and zucchinis cucumbers and kale"

Resident B: "People giving grapes and we get mangoes"

4.4. Practice of purchasing household items

As Fig. 2 shows, post-occupancy practices of buying recycled toilet paper and donating clothes to charity decreased. The other practices reported all indicated an increase in performance post-occupancy. This includes an increase of over 50% for repairing products instead of buying new ones, as well as buying recycled paper when needed. An increase in purchasing energy efficient appliances and purchasing clothes from charity stores was also noted. Finally, all residents report that they have avoided purchasing drinking water in plastic bottles post-occupancy.

In the pre-occupancy interviews it was discussed with residents if they planned to purchase new furniture and appliances for their new homes and this was followed up on in the post-occupancy interviews. Most residents did not purchase large items for their households, although there were a few exceptions. Household B and O pre-occupancy lived in the same house pre-occupancy, so post-occupancy they purchased an additional fridge and washing machine for the second apartment. They were able to divide the rest of their household items for use between the two apartments post-occupancy to prevent buying anything else. A similar situation occurred in Household C, where the adult children moved into a different Evermore apartment post-occupancy (not included in this study) and purchased additional items for this. The residents from households B and O reported selling or bartering many household items pre-occupancy that they did not need including books, bikes, furniture and garden plants. Some other households purchased a new or second-hand couch or dining table to suit the aesthesis or size of the new household. Resident C was unsure in the pre-occupancy move what to do with her worm farm but found a solution before the move to WGV, while Resident N has sourced all of his furniture second-hand:

"Interviewer: What happened to your worm farm?
Resident C: I bequeathed it to my neighbour."

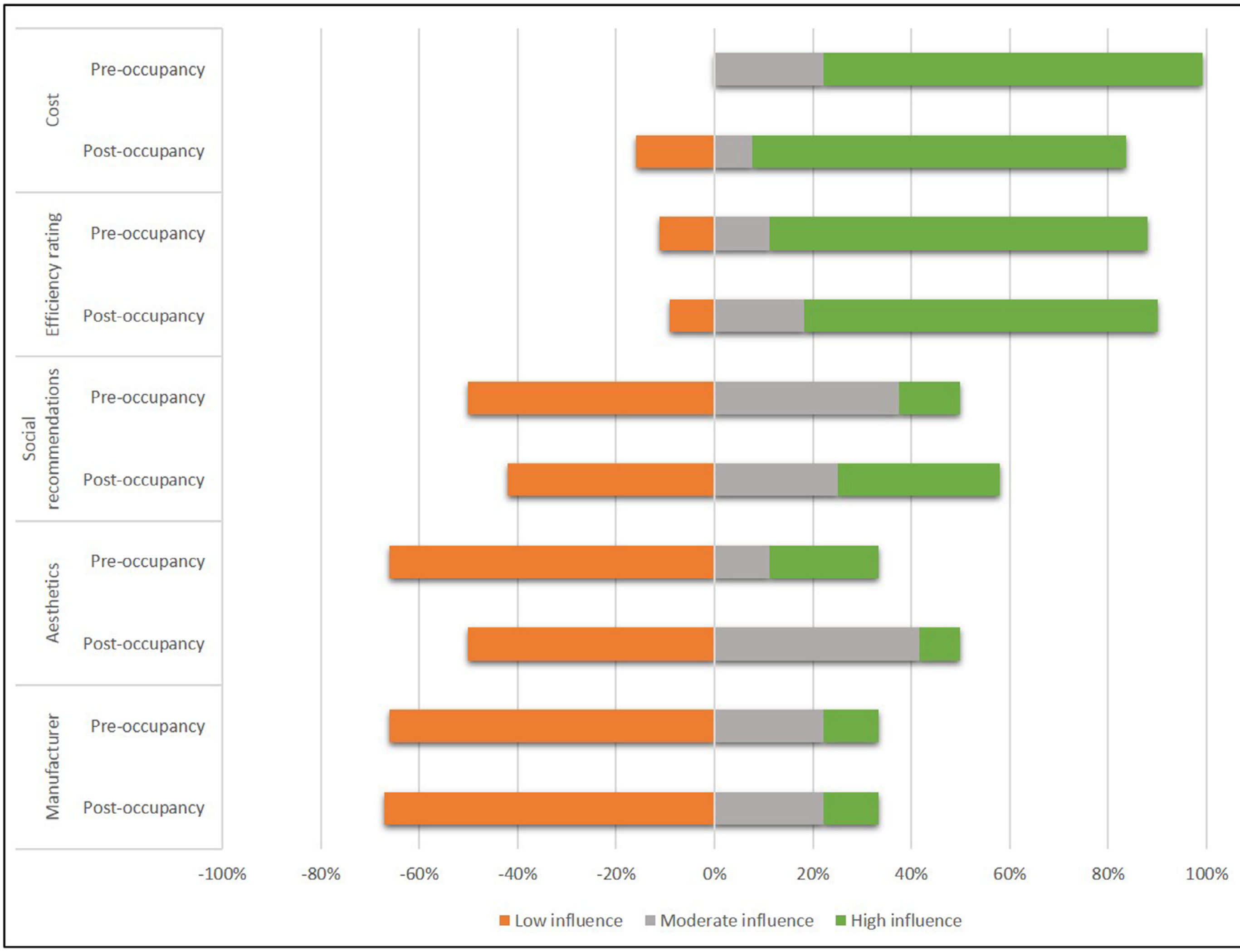

Fig. 3. Graph showing the influence of various factors on resident purchasing practices, These results are shown as percentages due to the variance in the number of completed surveys by household's pre-occupancy (nine responses out of nine), and post-occupancy (13 out of 14).

Resident N "A friend gave me a table. I got a second-hand fridge…everything is either given or second-hand or found at [WGV]. So I [have been] recycling furniture.

The influence of various factors on purchasing practices was also studied pre- and post-occupancy in the survey through a 5-point Likert scale. These results are summarised in Fig. 3 and show that pre-occupancy, the cost of energy and water efficiency of an item were the main influencing factors on item purchase. The manufacturer and aesthetics were of the least influence, while recommendations from friends and family were of moderate influence. Post-occupancy, these influences remained in that order, however the recommendations from friends and family increased from pre-occupancy, as did the aesthetics of the item. The efficiency of an item remained at a similar level of influence; however it overtook cost as the driving factor of item purchase.

4.5. Laundry practices

The study of laundry practices in this research highlights the influence of design and technology features on the performance of a practice. There were no changes to the meaning element of the practice, with residents reporting similar reasons for washing clothes as pre-occupancy, mostly around cleaning dirty clothes, the social expectation of having clean clothes and the comfort that comes with that, as highlighted by Resident J:

"I feel better about myself out in the world with clean clothes."

There were unexpected changes to resident's laundry practices in both the volume of laundry washed and the way the practice is performed that were not anticipated in the pre-occupancy interview. Most residents performed a similar number of loads of washing and drying as they had in their previous dwelling, with changes occurring only in households that had changes in the number of residents in the house, decreasing the volume of washing. The majority of residents pre-occupancy (12 out of 14) did not use a tumble drier to dry their clothes due to environmental or energy conscious preferences (Breadsell et al., 2019a). Post-occupancy, some residents have begun to use a tumble drier due to the reduction in clothesline space in WGV and for convenience, while others retain their previous practices, such as Resident A:

"I just don't [use a tumble drier]. I think I like the freshness the air on the clothes and sheets. I like that smell in preference to the hot tumble dry kind of smell. I guess if it was [raining heavily] for days on end and I couldn't dry anything, yes. Then I would use it but it came with the apartment and I prefer not to use it."

All the residents in Evermore had a tumble drier included in the apartment on purchase due to there being no permanent clothesline in the complex. Residents report only running the tumble drier

Fig. 4. SHAC communal clothesline with linen and towels drying.

Fig. 5. Use of heating pump space as a drying or freshening cupboard by SHAC resident J with a blanket in the cupboard to freshen up and improve the smell.

during the day to make use of the solar energy provided by the solar panels and battery to offset the additional energy usage. Other Evermore apartments have purchased small collapsible clotheslines that are positioned on balconies or inside. The residents have reported difficulty with drying bed linen and towels on these and the parents of children who have moved into other apartments in Evermore (that were residing with them pre-occupancy) have reported the children using their tumble drier for convenience. This is highlighted by Resident I's comment:

"There is no clothesline here [in Evermore] which would be nice to have a clothesline, but I don't think they want the visuals of hanging clothes."

In contrast to the apartment residents in Evermore, residents in SHAC do not own tumble driers and have a communal clothesline on the side of one of the apartment buildings (Fig. 4). Some residents are cautious of using this line due to the public nature and close proximity to the edge of the WGV precinct where passers-by can see the line. There have also been a few items stolen from the line, resulting in residents not putting valuable or emotionally important items on the line. The communal clothesline does serve as a social space for residents, with informal social networking when residents are handling their laundry.

An alternative drying practice has occurred in SHAC post-occupancy by resident J. She has used the space above the heating pump in the kitchen to leave items that need to be freshened up or quickly dried by the residual heat of the pump. This design (shown in Fig. 5), is present in all the SHAC apartments and the resident reported that she would tell her fellow residents of this new practice that they could incorporate.

Resident G in the detached house has also changed her drying practice from air dying to using a tumble drier post-occupancy. This is due to the installation of a heat pump drier that removes the water from the clothes and recycles the water on the garden. This appliance has a higher water and energy efficient rating than the standard tumble drier and so the resident is happy to use it regularly. She is also prevented from using a small outside drying court due to her neighbours still building their house next door and the dust contaminating the laundry.

4.6. Interlocking of practices

Practices interlock together into systems of practices, and when these exist in the space of the home they are termed the HSOP (Eon et al., 2018a; Macrorie, 2016). Practices interlock and influence other practices through their use of resources and the timing and space that they are performed in (Friis and Christensen, 2016). HSOP can be lightly or highly interlocked depending on how routine the performance of practices are and the constraining factors influencing when practices can be undertaken (Breadsell et al., 2019a). The resident's daily routines are generally similar, especially when influenced by work, despite the move, as Resident A states:

"It's pretty much the same. I mean, you know, if you're working, you're doing the same stuff, aren't you?"

Some practices though have become influenced by the design and technology of WGV. The presence of solar panels influences when residents put the dishwasher, washing machine and drier on, whether for economic reasons or environmentally conscious reasons. Many residents are conscious of putting these on during the day where they had not previously, shifting or displacing the interlocking of practices with others. Otherwise, the use of automatic systems is minimal, a few houses reported using the timer settings on the washing machine, dishwasher or air-conditioner unit but most will use these only when they are home. This has changed for residents using their washing machine and dishwasher during times they can use the solar power but has not changed for air-conditioner use. These changes in practices have required residents to learn a new skill (the setting of a timer). It has not changed the demand for the practice or the intention of the practice (having clean dishes and clothes).

Residents who had automatic reticulation post-occupancy have now all moved into apartments and now only hand water pot plants. Those in single houses all have reticulation on their gardens, which is set to automatic, different to their post-occupancy dwellings. This has dis-interlocked the performance of watering the garden for some residents who now do not have to actively engage in the performance of the practice each time (Eon et al., 2018a). This reduces the influence of other practices preventing or altering the practice of watering the garden. For instance, when the irrigation is on a timer, a resident does not have to remember to turn it on, this ensures the reticular will run at the scheduled time regardless of if the resident is home or not.

An example of a practice that is often highly dependent upon other practices are the times that residents eat meals (Molander, 2011; Yates and Warde, 2017). Table 5 shows the resident's pre- and post-occupancy mealtimes and the reasons for this. The degree of interlocking of HSOP did not change for most resident's post-occupancy. Table 5 shows the pre-occupancy interlocking status and mealtimes, and the post-occupancy interlocking status and mealtimes. Only two residents changed their interlocking status from light to high post-occupancy and no residents changed from high to light. This was due to resident L's son starting school with fixed hours that allowed for her work to become more consistent and washing and cooking routines to become interlocked. The other resident who changed was resident M who was moving between a number of different houses pre-occupancy and he now has a stable residence in WGV. This has allowed him to standardise his travel times between work, shopping and leisure times and has then flowed on to interlocking his cooking, washing and showering practices also.

Regarding mealtimes, those residents who are highly interlocked and work full-time have structured mealtimes. Those who are lightly interlocked eat at different times of the day. Those who live in houses with other occupants are influenced particularly in the evening by the other occupant's movements, this is the case for Households B and D. The residents will vary their evening mealtime based on each other's movements and work schedules. The exceptions to the lightly interlocked/variable mealtimes is for households I and M. The residents in these households have lightly interlocked practices but enjoy eating meals at a consistent time each day, this supports the findings found in a previous study whereby those who live alone (as it the case in household I) prefer to eat at similar meal times (Yates and Warde, 2017). Household M is highly interlocked post-occupancy and has continued the practice of consistent mealtimes. The timing of meals highlights how this is a stable practice that is linked with the HSOP and work and socialising practices, more than that of the home design or location.

Table 5
Relationship between mealtimes each day and WGV HSOP interlocking and occupation of households, pre and post-occupancy in WGV.

Dwelling	House	Pre-occupancy meal time same each day?	Pre-occupancy reason	Pre-occupancy HSOP interlocking status	Post-occupancy meal time same each day?	Post-occupancy reason	Post-occupancy HSOP interlocked status
Evermore Apartments	A	Yes	Work, eat simply	Highly	Yes	Work	Highly
	B	Mostly	Work, partner's movements	Highly	No	Work, evening activities, partner's movements	Highly
	C	Yes	Work and other household members	Highly	Yes	Work	Highly
	I	Yes	Hunger and convenience	Lightly	Yes	Hunger and habit	Lightly
	O	Yes	Work, evening activities and health	Highly	Yes	Work and evening activities	Highly
SHAC Apartments	D	Mostly	Work and other household members	Lightly	No	Work and other household members	Lightly
	H	No	Evening activities and hunger	Lightly	No	Depends on many factors	Lightly
	J	No	Depends on many factors	Lightly	No	Depends on many factors	Lightly
	L	No	Tries to have regular times with child when home	Lightly	Yes	Child	Highly
Semi-Detached House	N	No	Depends on many factors	Lightly	No	Depends on many factors	Lightly
	F	Mostly	Work and evening activities	Highly	Mostly	Work and evening activities	Highly
Semi-Detached House	M	Yes	Healthy to eat regularly	Lightly	Yes	Healthy to eat regularly	Highly
Detached House	G	No	Shift worker	Lightly	No	Shift worker	Lightly

5. Discussion

The purpose of this paper is to address the question: "What changes occur to individual domestic practices and the home system of practice (HSOP) when residents' move into a LCD?" It utilised a longitudinal study of resident's household and individual practices pre- and post-occupancy in WGV to track any changes that occurred as a result of the changing technology, social context or household composition changes.

The overall interlocking of a resident's system of practice has not changed due to resident's lifestyles not significantly altering post-occupancy, with household composition remaining the same for most residents. Resident's still work the same each week and undertake most household chores, with some changes happening to clothes washing, and socialising at similar times and places compared to pre-occupancy in WGV. These are the factors in this real-life study that influenced practices and their timing, with some changes occurring to the timing of practices when the desire was to utilise energy from the solar PV system to be used in certain practices. This aligns with the literature that states that when practices that are interlocked shift, they force a reconfiguration of the system (Shove and Walker, 2010). These results show that because there was not a major shift in residents transport practices, along with no shift in work practices, the interlocking of their HSOP has not shifted similarly. The timing of making and eating meals each day is influenced by resident's system of practice and how these interlock with others in their home. Those who have a highly interlocked HSOP are more likely to eat meals at the same time each day and do so due to work times, other household member's practices and habit. Those who are lightly interlocked are more likely to eat when hungry or depending on fluctuating work times.

Post-occupancy design features have affected laundry practices but not the timing of them being performed. The increase use of a clothes drier by some residents, as compared to air drying pre-occupancy, will increase the energy used in the performance of the entire laundry practice. This may be offset somewhat if the practice is performed during the day when there is sufficient energy provided by the solar PV panels on the dwelling or through energy stored in the communal battery. Where the household size has changed post-occupancy, residents are performing less loads of laundry than pre-occupancy. This will influence the overall consumption of energy and water in the household as a whole. A more detailed analysis of household energy and water consumption levels can be found in (Breadsell et al., 2019c).

The location of WGV close to food shops has resulted in local shops and markets being used more. Home grown fruit, vegetables and herbs are being used more in WGV also. The community has influenced recycling rates and increased self-reporting of other's recommendations influencing purchasing practices. This highlights the influence that community members have on resident practices, through providing the skills, technology or motivation (meaning) to change practices. The increased influence of family and friend recommendation on purchases post-occupancy could also be attributed to the sense of community developed in WGV. Less donation of clothes to charity may have been due to residents already donating enough before the move or wanting to purchase new items to fit the feel of a new house, or if they had additional money. The motivating factors, influencing the meaning behind the practice of purchasing, influenced product purchase and disposal should be explored further in future research, especially relating to a circular economy approach and the value that waste has in society (Van Vliet et al., 2005).

Pre-occupancy, residents expected their travel practices to change quite significantly, especially an increase in the use of bikes, the electric vehicle and walking. However, the use of transport post-occupancy did not change for the majority of residents with the exception of one resident who walks to work now instead of driving.

To have lasting change, previous studies have identified that influencing the routine use of resources has the largest benefit due to the long-lasting nature of the change (Eon et al., 2019, 2018b). Technological improvements also play a role, allowing practices to be performed easier or with less interlocking with other practices, or automatically negating the need for human interaction or decision making which may not be the more sustainable option (Eon et al., 2018a; Spurling et al., 2013; Van Vliet et al., 2005). Automation is useful for influencing highly interlocked practices as it reduces the influences of other practices and contextual factors on the timing and elements of the practice. For lightly interlocked practices, changing an individual element, technology, skill or meaning, is potentially more beneficial. In the absence of technology changes, cost-saving consumption choices have been observed to be subject to rebound effects when liberated income is used for additional consumption (Murray, 2013).

While individual consumption changes do little to drastically reduce the resource intensity of modern lifestyles (Connolly and Prothero, 2003), the results of this research show the influence that design, technology and community networks have in aiding daily household practices changes. The need to engage with the consumer and their daily actions has been acknowledged in the policy sphere for some time now (Shove, 2010; Spaargaren and Van Vliet, 2000). A social practice theory approach acknowledges that humans have certain contexts they consume resources in and their power to change these actions depends on the resources being used for the practice, the meaning the practice which is being undertaken and the skills they have to alter the practice (Macrorie et al., 2015; Spaargaren and Van Vliet, 2000; Spurling and McMeekin, 2015). This has been assessed in this study through the comparison of practices pre- and post-occupancy and discussing changes in these practices with residents who have had to alter their skills and technology used in the practice and the meaning behind the practice being performed. An approach of this measure also enables the context and design features of a practice to be studied alongside the traditional behavioural aspects of values and attitudes (Breadsell et al., 2019c; Whitmarsh et al., 2011). This adds depth to the understanding of the motivations and influences on a practice and hence resource use. This also allows for the refocusing of decision makers attention to different routes into these practices and practice bundles to explore other options to reframing them (Strengers et al., 2014). These include the reach and durability of existing practices and their elements and identifying what changes might have the greatest effect over time and space (Sahakian and Wilhite, 2014). For travel practices, policies that promote and enable non-car travel options to assist in promoting these and overcoming barriers to non-car travel options could be considered (Laakso, 2017). For recycling practices, creating supportive structures that can easily be incorporated into current practices will have more likelihood of creating lasting change (Cass and Faulconbridge, 2016). There is also a need to consider the other practices that are interlocked with each other such as bulk shopping trips, travelling with different ages and abilities of children and adults, location of schools, health care and entertainment centres to understand why and how people perform practices before they can be influenced (Cass and Faulconbridge, 2016).

The need to engage with the consumer and their daily actions has been acknowledged in the policy sphere (Spaargaren and Van Vliet, 2000). A social practice theory approach acknowledges that humans have certain contexts in which they consume resources and their power to change these actions depends on the resources being used for the practice, the meaning of the practice which is being undertaken and the skills they have to alter the practice (Macrorie et al., 2015; Spaargaren and Van Vliet, 2000; Spurling and McMeekin, 2015). This also allows for the refocusing of decision-makers attention to different routes into these practices and practice bundles to explore other options to reframing them (Strengers et al., 2014). These include the reach and durability of existing practices and their elements and identifying what changes might have the greatest effect over space and time (Sahakian and Wilhite, 2014).

6. Conclusion

This paper has considered daily household of practices that involve resources outside of thermal comfort and personal hygiene to gain a more holistic understanding of resource use in the home. The opportunity to study resident's pre-and post-occupancy in a LCD has been a unique situation to examine how design, technology and community influence household practices. These results show that community influences recycling and purchasing practices, the location of a LCD is vital for influencing shopping practices as most people will shop locally in the area. The timing of meals is influenced by the activities of others in the home and work practices. Since these have not changed for most resident's since moving in, their timing of meals also has not changed. Resident's resource use is heavily influenced by their work and socialising routines and must take these into consideration when designing LCD and influencing resource use in the home.

Although this was a small cohort study of LCD residents, the detailed investigation of household practices has led to a richer understanding of their performance motivations and influences. This should continue to be scaled up to include more residents to broaden the understandings to various contexts (Hargreaves, 2011). A similar post-occupancy, longitudinal study could also be undertaken once residents have resided in the LCD for a longer period of time. This would be able to examine the long-term influence of the design, technology and community and assess the stability of practices that had altered post-occupancy. Residents may have returned to pre-occupancy practices or other influences may have resulted in changes to practices Further research could be undertaken on what people dispose of in the compost, recycle and general waste bins (Evans, 2012; Quested et al., 2011) to understand more about why people are disposing these items to inform policy on how to reduce this (Kaipia et al., 2013). Other research could also examine some of the household practices in more detail, such as the temperature or water level of washing loads to see if residents are using the technology in the most efficient way. Finally, continuing the research undertaken on the spatial and temporal aspects of social practices is important to understand how they connect to the home system and influence domestic resource use, enabling targeted approaches to reducing resource consumption to more sustainable levels (Friis and Christensen, 2016; Southerton, 2006; Torriti, 2017).

Declaration of Competing Interest

The authors have no conflict of interest to declare.

Acknowledgements

This research is funded by the CRC (Project number NP 2006 for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative. The authors would like to thank all the stakeholders involved in the WGV Precinct project, particularly DevelopmentWA and the City of Fremantle. The authors thank participants from WGV for their patience and involvement in this research and the anonymous reviewers for their thoughtful comments on this manuscript.

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Publication VIII

Breadsell, J., Morrison, G. M. & Byrne, J. (2019). Pre and post-occupancy evaluation of resident motivations for and experiences of establishing a home in a low carbon development. *Sustainability.* 11(14) 3970; https://doi.org/10.3390/su11143970

Status: published (peer-reviewed)

sustainability

MDPI

Article

Pre- and Post-Occupancy Evaluation of Resident Motivations for and Experiences of Establishing a Home in a Low-Carbon Development

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Received: 18 June 2019; Accepted: 20 July 2019; Published: 22 July 2019

Abstract: There is some understanding of how an individual's daily practices consume resources in the home, but the home as a space itself and peoples' relationships to it remain an interesting research area. In this paper, residents of an Australian low-carbon development (LCD) are studied in order to discover the expectations and motivations driving them to move to their new home, the emotional landscape of the home, and their subsequent experiences living in an LCD. This exploration through mixed methods and a post-occupancy evaluation enables a longitudinal empirical study of the motivations, perceptions, expectations and experiences of an LCD residence. This study aims to further conceptualize the social understanding of a home and what people consider when moving into an LCD, along with the post-occupancy experiences that are important for establishing LCDs in the future. The results show that a home is associated with being a place of community, sustainability, safety and comfort, as well as a place that incorporates aesthetically pleasing features. The motivation for residents moving into an LCD is to have housing stability, live the life they want (including performing sustainable practices) and enjoy the attractive design of the LCD. The user experiences of living in an LCD include unexpected design influences on daily practices and an appreciation of the community atmosphere created. The strong sense of community and the self-reported thermally comfortable homes met residents' expectations post-occupancy. This research is of interest to academics in the low-carbon and social science sectors, real-estate agents and property developers, as it provides insight into motivations and expectations of low-carbon dwelling residents.

Keywords: low carbon development; user experience; post-occupancy evaluation; home perceptions; Australia

1. Introduction

Given the surge of population towards 9 billion by 2050 and the concomitant rapid urbanization, cities around the world will have to accommodate additional dwellings while adapting to the climatic and spatial challenges facing them. The prevalence of low-carbon or zero energy homes is being driven by an international policy push to standardize these dwellings over the next few decades in the interests of climate and spatial issues [1]. Australia has one of the highest levels of greenhouse gas emissions per capita, with the main source being energy for electricity in homes [2,3]. This is being driven by high energy requirements in buildings and homes that are not thermally comfortable and have high mechanical heating and cooling uses by residents [4]. In Australia, building codes now require houses to meet minimum energy-efficiency requirements around orientation for natural ventilation and sunlight levels and building materials used [5], and there are ongoing efforts by both industry and government to see these regulations increased [6–8]. There are a number of projects around the country that showcase how (beyond compliance) energy efficiency and other sustainability initiatives can be incorporated into highly livable developments in Australia. Low- carbon developments (LCD) such as Christie Walk, the Commons, Bowden, Central Park and the WGV development provide working examples at different scales [9]. These developments have focused primarily on the physical design of the developments, but questions remain around how residents perceive LCDs, including whether the design of the home is a major concern for residents, what drives these perceptions and expectations and what levels of post-occupancy satisfaction exist. If Australia and the rest of the world continue building low-carbon houses, then the motivations behind people moving into these homes are important to understand. This paper will explore the resident attraction to a 2.2-ha medium-density residential LCD in Western Australia, called WGV, and residents' post occupancy experiences of their new homes. Perth, the capital of Western Australia, has one of the highest uptakes of solar PV systems in the country, with 25% of all residential homes possessing rooftop systems [10] and government policies continuing to promote higher densities. As such, Perth provides a good case study for assessing these changes in the housing market [11].

2. Relevant Literature

Previous studies examining housing preference in Perth, Australia generally and globally [12–15] have used a stated preference market-choices methodology [14,16], as distinct from what people have actually chosen when purchasing a home. There is often a large variation in what people would state they would buy versus what they actually do buy [16]. Therefore, less emphasis can be placed on findings from stated market preference studies [16,17] compared to studies with actual market-preference methods. Stated market preference was originally used to examine the difference between preferences revealed in surveys or experiments and those observed in actual behavior. Their use has evolved from economic theories in 1953, to the study of transportation preferences in the 1980s and 1990s to environmental preferences more recently [18]. Stated housing preference studies in Perth, Australia generally and globally have concluded that people are most influenced by the type of housing, as well as its affordability, location and size, when choosing where to live [12–15]. The Australian studies found that people prefer to own their own home, typically a large, detached house near a city center. This type of dwelling provides opportunities for self-expression, privacy and autonomy, as well as offering space to relax with less interaction with or interference from neighbors [14,16].

Literature examining housing preferences for low-energy or low-carbon homes has been less prevalent in Australia than in Europe. Post-occupancy evaluations of houses has centered on studies of Passive House residents, concluding that residents are generally more thermally comfortable in their dwellings in winter and appreciate the improved indoor air quality [19]. Post-occupancy studies of low-energy buildings in Australia have focused on occupant comfort and interaction with technologies in the dwellings [1,4,20,21]. These studies have found that many occupants of LCDs have little to no experience with the new technologies and how to effectively use them to remain comfortable in their homes [22]. However, individual user experiences are highly personal, and the many reasons that motivate people to move into an LCD, including health and well-being, lifestyle, environmental beliefs or simply price and location, should be acknowledged by builders, real-estate agents and policy makers [19,23–25]. Purpose-built low-energy houses in the UK were found to economically empower low-income residents through reducing energy bill stress and allowing income to be spent instead on family time together [25].

The absence of empirical evidence documenting residents' perceptions of these low-energy and low-carbon homes, particularly in regards to climate variability, limits the ability of policy makers and designers to understand residents' lives at home [20,21]. The work conducted by [26] highlighted this, and showed that a sustainable home is more than just an energy-efficient building—it must encompass a holistic view of the economic, environmental and social aspects of residents' lives. Evaluations by researchers should focus on users' reasons for choosing to live in energy-efficient buildings, to be able to give input on how to market energy-efficient buildings [23]. This paper contributes to addressing this knowledge gap.

This research also investigates the meanings and emotional landscapes attributed to homes by LCD residents. There are different perspectives of the home advocated through the literature that have provided succinct overviews of the research undertaken, and a selection of these aspects have been compiled in Table 1 [27–32]. As [33] states, a home is a feeling, a sense of comfort or belonging, and not necessarily a location. A person can live in a house and not feel at home [31]. The physical attributes a home provides (security, a place to raise a family, a place to perform activities and ownership) were the primary attributes a home was given in the literature pre-2000. In [29], a summary of the literature view on home perceptions was undertaken to clarify the inclusion of other aspects in the meaning of "home" to reflect the social and personal space it provides. This line of reasoning was continued in [34,35], concluding that people desire housing for its provision of both material security and an emotionally stable environment, especially individuals who have faced homelessness and housing instability. This paper investigates the aspects of a home that reflect the values of a person moving into an LCD, and uses this prior literature for context.

Table 1. A selection of aspects of the meaning of home identified in the research literature (author compiled).

Aspects of Home	References
Security and safety	[28,34–41]
A place to raise children and have relationships over generations	[28,29,32,34,36–38,40–44]
An asset, a place to own	[35–38,40]
A place to spend time and undertake activities	[32,37,40,41,43–45]
A place for privacy, a haven and being away from the world	[28,29,34,36–38,44,46]
A place to do what you like in, a sense of control	[28,32,34,36–40,42,43,45,46]
A reflection of one's ideas, values, identity and emotional landscape	[28,29,32,34,35,37,39,40,42,43,45–47]
A site of consistency and permanence	[28,29,32,35,37,38,40,41,45]
A site of engagement with community/neighbors	[29,34,39,41]

3. Methods

This research is based on a pre- and post-occupancy evaluation of an LCD. Post-occupancy evaluation is an established method of studying occupants of buildings for feedback and/or through measurements of building performance [19,24,48]. The occupants of low-carbon and similar homes (passive houses, low-energy houses, zero-energy houses) have been described as a special segment of the population with specific lifestyles, behaviors and practices and views. This is due to being early adopters of new technology, housing and community designs that are not standard for the rest of the population. The way these residents interact with these features can be studied to improve the uptake and acceptance of LCDs. With an increase in low-carbon homes around Australia, the study of these residents is vital in understanding how these buildings are integrated into society in the future. Therefore, this research will center on an LCD in Perth, Western Australia, called WGV [49].

In this paper, "LCD" refers to a group of households that form part of a development with design performance requirements beyond the Australian National Construction Code (e.g., 7+ star NatHERS thermal performance) and inclusion of a solar PV system. This standard can be met through natural ventilation, orientation of the dwelling to take advantage of the sun, shading through awnings and verandas and building materials used, including double glazing. The WGV development studied consists of multiple dwelling types and will comprise approximately 80 dwellings when completed, including multi-story dwellings flexibly connected to a broader energy system so that a home is no longer a single dwelling but part of a system (as discussed in [32]). The first residents began moving in to WGV in mid-2017. The homes were designed for a Mediterranean climate, with sustainability features including a passive solar design that allows airflow and sunlight levels (solar gain) to assist the regulation of international temperature. The average outdoor temperature is between 10 °C and 27.3 °C annually [50].

A cohort study of 14 residents inhabiting 13 homes (n = 14) was undertaken, with data collected both pre- and post-occupancy in the LCD. The residents studied had moved into a variety of dwelling typologies. One cohort (five residents studied) was Sustainable Housing for Artists and Creatives (SHAC), who were leasing apartments and two studio spaces from a local social housing provider, with rental payment concessions received from the Australian Government. Another cohort (six residents studied) were owner-occupiers of apartments sold at market rates in a commercial development called Evermore. The third cohort (three residents studied) were owner-occupiers of two semi-detached units, while the final resident studied was an owner-occupier of a stand-alone (detached) house. Three households across two cohorts had previously had sustainability features in their homes.

Mixed methods were employed pre- and post-occupancy for data collection [51,52]. The data collection methods focused on the themes of energy, water, waste, food, transport, social network practices and residents' expectations and motivations for moving into WGV. This paper focuses on concepts surrounding moving into WGV, such as the expectations and motivations for the move, definitions of home and how they changed, how the residents were experiencing living in WGV and community experience. The residents' practices concerning energy, water, recycling, shopping, transport and food will be discussed in forthcoming papers.

Residents self-selected through an open invitation sent to those who had already purchased property in the LCD or were intending to become a tenant through SHAC (n = 27). An original sample size of 16 individuals in 15 dwellings were part of the pre-occupancy data collection; however, one household decided to rent out their apartment in WGV, and another removed themselves from the study. Their results are not included in this paper. Pre-occupancy data collection was conducted between April and June 2017 for SHAC residents, and between December 2017 and March 2018 for Evermore and single-house residents. Post-occupancy data collection was conducted between December 2018 and March 2019 for all residents. The long period of time for data collection pre-occupancy was intended to allow for a greater sample size of residents to self-select. However, there was a post-occupancy bias towards those in SHAC or Evermore, due to the requirement that the resident reside in the LCD during 2018, to allow for post-occupancy data collection within the research time constraints.

A structured interview explored the occupants' motivations and experiences surrounding the move to the LCD, while text probes, hygiene and transport diaries provided contextual experience data. The interviews (questions in the semi-structured interview asked residents how they kept warm and cool, the routines they went through each day and how their lives had changed since moving to the LCD) were for approximately one hour and were undertaken in the residents' pre- and post-occupancy accommodations, except for one which was conducted at an independent venue. In households with multiple adults, only those moving into the LCD were interviewed. Children, including those over 18 and still living at home, were not interviewed due to uncertain circumstances surrounding their residency arrangements once their parents moved into the LCD.

A workbook was completed over two weeks, allowing residents to respond to short-answer questions about their resource uses and habits (an example of a short answer question is: Do you have difficulties in getting to places?) along with 5- (5-scale Likert question example: How comfortable are you finding the house in relation to temperature? Very comfortable, mostly comfortable, neutral, mostly uncomfortable or very uncomfortable?) and 7- (7-scale Likert question example: How often do you use the public outdoor areas in WGV? Every day, a few times a week, about once a week, a few times a month, once a month, less than once a month or never?) point Likert scale survey questions. Text probes were sent periodically through these two weeks to gain in situ qualitative contextual data on current practices, minimizing the impact of recall difficulties during interviews [53]. The text probe method is a combination of cultural probe methods developed over the past two decades that requires participants to take photos of objects during their daily life with a disposable camera [53–55]. The advent of mobile phones has allowed a significant advancement in this method. Text messages are a low-effort, quick and familiar method for the participant, increasing response rate. Examples of the questions used are, “Tell me how you have kept warm today?” or “In a picture or a few words, tell me what home means to you?”

Data analysis occurred after the first round of data collection and again after the second round. The Likert scale data was analyzed through tabular and graphical visualization of the results to identify trends, which were then compared with the qualitative data collected. A thematic analysis was performed using NVivo software to analyze the various data sources across 43 themes. (A short list of initial themes was drawn up before the thematic analysis based on the researchers’ notes from the interviews, and this was then added to the analysis. Themes included affordability, comfort, control, convenience, energy, health, ownership, privacy, stability, thermal comfort, time, employment, cooking, fresh air, routine, washing, animals, children and sense of community.) It was during this analysis that the themes of home, sense of place and the concerns around moving to an LCD were identified as noteworthy. This paper is based on the further thematic analysis of the data with these themes in mind, following the method set out in [56] as well as the post-occupancy evaluation of how residents are experiencing life in the LCD. Quantitative methods are not the focus in this paper, however some results from the Likert scale questionnaire are discussed due to their relevance.

4. Results

This research explores the pre- and post-occupancy factors surrounding residents’ motivations, perceptions and expectations of living in the LCD and how their emotional landscape of home is affected. These are important concepts to understand to further the acceptance of LCDs in cities of the future. These concepts were identified from the participants’ answers to question in the interviews about how they heard of WGV, their motivations for moving in and their expectations for how their life would change (or not). These themes were then revisited in the post-occupancy interviews.

4.1. Resident Awareness of the Possibility to Move to a Low-Carbon Development

There are multiple ways that the residents became aware of WGV. These are shown in Table 2. Most residents discovered the LCD through their friends, some of whom were from a community group they were in (such as the SHAC artists community). Other residents had friends involved in other LCD projects in Western Australia that they were considering moving into, but then chose WGV instead. One resident saw news stories on local television regarding the development, while another two attended a local council event where it was mentioned. A number of residents heard about the development through work associates, either those who were moving into the LCD, or those involved in the development of the LCD. The strong influence of social networks in distributing information throughout the community was shown through the majority of residents discovering the LCD through personal connections.

Table 2. Fourteen residents’ responses to how they originally heard about WGV.

How Residents Heard about the Low-Carbon Development	Residents
Friend	6
Workmate	2
Local council event	2
Advertisements at LCD	2
TV media	1
Friend living in the LCD	1

4.2. Motivation to Move to a Low-Carbon Development

Three main motivations for moving to an LCD have been identified through this research. These revolve around the design features of the LCD and the homes, the community aspects of the LCD and housing stability and control over space. As shown in Table 3, residents' motivations for moving to WGV were primarily due to the sustainability features of the homes and the development. This was followed by the attraction to living in a community of medium-density dwellings, as well as being able to interact with neighbors and engage in community events. For half of the studied residents, the LCD provided housing stability for them either by allowing them to purchase their own home or allowing them to lease an apartment belonging to SHAC, and the interviews uncovered a further aspect of this motivator: control over space. The final attractions of the LCD were the location, the design of the LCD and the dwelling design.

Table 3. Motivations of 14 residents for moving into the low-carbon development.

Motivation for Moving into the Low-Carbon Development	Residents
Sustainability features	10
Community focus	8
Housing stability	7
Location	3
Dwelling size and attributes	3
Ecology of the LCD	3

4.2.1. Attractiveness of Elements of the WGV Precinct

In a limited pre-purchase survey of some residents of WGV, 80% reported that the environmental sustainability features were a motivator to purchasing, while 100% reported the community attributes as a motivator. When asked how important these features were to them, all respondents reported them as very important or critical to their purchase decision. In the broader survey of the residents, as highlighted in the methodology, 10 out of 14 reported sustainability features as one of the motivations for moving to the LCD. The design of the dwellings and of the LCD were motivators also, at 3 out of 14 each. Residents believed that the system the LCD would create would enable them to perform the daily practices that they wanted to engage in and would bring satisfaction to their lives. This often revolved around the sustainable technology incorporated in the development, including the solar PV panels, rainwater tanks, community bore for garden irrigation and passive solar design features. For residents that previously had sustainability features in their homes, having these features in the LCD was an important motivator for the move. This highlights the acceptance and appreciation of sustainability features in housing, the economic and environmental benefits that were recognized by residents and the desire for these elements to be included in future homes.

The location of the LCD rated at 21% motivation for residents. For the residents of SHAC, the close urban center of Fremantle has traditionally been the artistic hub of the Perth metropolitan region and provided these individuals affordable and accessible housing and work spaces. Recently, local artists have been priced out of the housing market, and now have to travel long distances to reach their work spaces, exhibit their art or engage in the artistic community. The location was also popular with residents of other dwellings at WGV, due to the close proximity to farmers markets, preferred grocery shops, entertainment and social venues in Fremantle and, for some, proximity to work. Residents who purchased dwellings in Evermore and the single houses lived closer to the LCD pre-occupancy than those who moved into SHAC, as shown in Table 4. For residents moving into SHAC (the low-income subsidized housing for artists), they on average moved 16 km to live in WGV, with the greatest distance being 50 km. Those moving into Evermore and the houses were already closely located to the LCD and chose to stay in the same area, with distances of 8 and 1 km, respectively.

Table 4. Residents' pre-occupancy dwelling location distances from the LCD. Distances are in km and houses are grouped according to the development location post-occupancy in the LCD. House M has been left out due to the resident living between multiple houses each week, before moving to a stable house in WGV.

Dwelling in WGV	House	Pre-Occupancy Dwelling Location Distance from LCD (km)	Dwelling Average Distance from LCD (km)
Evermore Apartments	A	28	8.18
	B	1.8	
	C	4.3	
	I	5	
	O	1.8	
SHAC Apartments	D	0.6	16.32
	H	6	
	J	5	
	L	50	
	N	20	
Semi-Detached House	F	1.5	1.35
Detached House	G	1.2	

The design of the WGV precinct and the various dwellings was another motivator for residents to choose to live there. Residents of SHAC reported the industrial elements of the design as being reminiscent of the features along the port of Fremantle. The design also allowed them to make use of the multi-story steel walkways to showcase their artwork, and provided them with many spaces to congregate and socialize. For those who had lived in medium-density dwellings before, the return to this style of dwelling was an attraction (residents N and A). Other residents were attracted by the gardens and community space (resident I) that had been incorporated into the LCD.

4.2.2. Community Focus

Almost all residents discussed the community focus as part of their motivation for moving to WGV, either when specifically discussing why they moved to WGV or when discussing how they were expecting their lives to change. Residents discussed having more community connection with neighbors because of common interests, more community events or group projects between the groups (see quote below, Resident G) and more sharing of information (Resident O).

"The new lifestyle. Being part of something . . . being part of a community" (Resident G)

Residents were excited about living somewhere with a specific design focus on the ambiance of community and feeling free to walk out their door without being forced to talk to someone they do not want to talk with (Resident J). The mixed ages of the residents was also appealing, allowing retirees to interact with children and different backgrounds to come together (Resident C).

For the SHAC residents, the motivator of living with people working in the arts or creative industries was a primary reason for moving to WGV. The expectation was that they would work collaboratively, either in the dedicated studio workspace or in the common green space of the SHAC dwelling. A year after moving in, there were already a number of community functions in the studio space, with residents working on creative projects together and children frequently seen playing freely between the apartments.

4.2.3. Housing Stability and Control over Space

For the residents moving into the affordable housing provided by SHAC, one of the main motivators for moving to WGV was stable, affordable housing. All SHAC residents had been renting or living with family and receiving subsidized rental assistance from the federal government. Resident N was particularly excited about living in a stable house after being homeless and living with friends for many years, as highlighted by this quote:

" . . . there's this beautiful . . . exciting development happening . . . you could well end up with somewhere to live." (Comment made to Resident N about the LCD development.)

For most SHAC residents, the sustainability features of the LCD were not a primary motivator, although the financial benefits of sustainable housing design and the inclusion of energy- and water-efficient aspects were attractive to them. This reflects the results found in [34,35], where stable housing was found to be one of the most important characteristics of a home that residents look for. For residents of the other cohorts, most did not mention housing stability as a motivator for moving into WGV. These residents had a combination of previous dwellings that they rented or owned. For a resident (M) who had been staying between friends' houses for the past three years, having stable housing of their own and not needing to move around frequently was a motivator for moving to the LCD.

Along with housing stability, having control over their own space without the intervention of a landlord was motivating for many residents. These responses all featured in the residents' motivations for moving to WGV. Being able to craft their homes to support their personal identities while living a sustainable life and participating in activities with like-minded people was a common motivator (resident C). Managing the home to facilitate their work was particularly important to the residents of SHAC, who had an additional space in their apartments that was a dedicated office and art space where they could work. Resident J focused on being able to arrange her home so the light was maximized for her artistic activities. For resident C, whose two teenage children were not moving to WGV with her, downsizing to a more manageable space was an important motivator. She had a different spatial environment compared to other participants, as she does not have to accommodate other people as often in her home practices [57]. A few residents discussed changes to keeping thermally cool or warm in the LCD. One resident (M), who had been living with friends for the past three years, was relieved to finally have complete control over the thermal comfort of their home to optimize it for maximum efficiency when performing different tasks. This resident liked the home to be cooler when working and warmer when relaxing.

4.3. The Perception of Life and Home in a Low-Carbon Development

While attraction to the physical attributes of the LCD is important, the reflection of what a home is in an LCD is also important to attract people in the future. A home in this paper refers to the meaning that residents ascribe to the physical building they inhabit [32]. The residents surveyed highlighted many aspects of a home that are important to them. Table 5 shows that the most frequent features are a sense of community, social aspects and family interactions. Not surprisingly, and given that these residents committed to moving into an LCD, environmental sustainability was the second most important feature of a home. The aesthetics and design of the home is the next important feature for residents. Despite significant literature emphasizing the security and safety aspect of housing, these results show that only 5 out of 14 residents considered this to be a desirable feature in a home. This was reported primarily by the SHAC residents who had not had stable housing in the past. The security and safety aspect of housing was rated below the design and aesthetic features of a home, which half the residents stated were important. In this research, comfort was desired by 5 out of 14 residents as an important feature in a home; however, the topic was raised in regards to thermal comfort many times during the interviews. This indicates that comfort is of importance to residents when involved with their daily practices, and so should still be considered a desirable feature in a home. These results are similar to those shown in Table 3 (outlining the motivations for residents moving to the LCD), possibly indicating that they will feel satisfied with their move to WGV [16].

Table 5. The most important features of a home as reported by 14 residents.

Important Features of a Home Pre-occupancy	Residents
Pets	1
Enjoyment, haven, relaxation	1
Garden	3
Location	4
Comfort	5
Safe, security, secure housing	5
Aesthetics, design of home	7
Sustainability	7
Community, social, family	10

4.4. Expectations of Living in a Low-Carbon Development

Residents discussed their expectations of living in an LCD in the interviews structured around themes of sustainable living, sense of community and maintenance of their homes.

4.4.1. Living Sustainably

Many residents who had not previously lived in houses with sustainability features mentioned that they expected to be able to live more sustainability when they moved into the LCD. Residents used terms such as easier, normal and being supported when discussing the expectation that their daily practices would become more sustainable in their use of resources, including energy, water and transport. Resident H stated that the support from the community and the general focus throughout the LCD on sustainability would result in his daily practices changing to become more sustainable. Resident D made the statement that simply being in the LCD with a community of like-minded individuals would motivate her to change her practices and take environmental choices into consideration. She also stated that:

"Moving to a low carbon precinct I believe will improve my quality of life and motivate me to make better consumer and environmental choices." (Resident D)

Those residents who have already lived in a home with sustainability features did not expect many aspects of their life to change. They had expectations of travel practices changing, but discussions primarily revolved around the sense of community and opportunities to interact with their neighbors instead.

4.4.2. Low-Carbon Development Housing will be Easy to Maintain

A 2016 study investigated the ease of use of low-carbon technologies in the home [58]. It found that many residents had difficulty in using the technology, and recommend automation be considered to improve user perceptions. Other research has concluded that residents are concerned with the difficulty of maintaining their homes when sustainability features are employed [59]. The residents in this study, however, were confident in their abilities to maintain their LCDs, and believed that they would be able to perform the necessary practices required to maintain their LCDs (Table 6). There was a variety of answers from those residents who had sustainability features in their previous dwellings, and one responded neutrally, two were not concerned and one gave no response. Another resident (J) discussed having to change the way she warms the home, as she moved into a larger apartment in WGV with different design features and technology than she had pre-occupancy.

Table 6. Nine resident responses to the question "I am concerned about how easy it will be to maintain my low-carbon house" (five residents not included due to no response).

"I am Concerned about how Easy it will be to Maintain my Low-Carbon House"	**Resident Responses**
Agree	1
Neutral	2
Disagree	6

4.4.3. Concerns of Living in a Low-Carbon Development

Some concerns that are evident through interviews with residents have come from those who had not lived in a medium-density or LCD dwelling before. Individual residents were concerned with aspects outside of the dwelling design that they lacked influence over. This included neighbors' actions that may disturb them, the green space located within the LCD and how to incorporate it into their daily lives and the landscaping and management of the common garden areas. These concerns highlight the importance of communicating the benefits of living in an LCD effectively with residents, and clearly outlining policies and regulations before people decide to move in. Housing policies that are viewed as bureaucratic, or development regulations that are not well understood, may lead to conflict and produce a negative perception of the LCD as an attractive place to live.

4.5. Post-Occupancy Evaluation of Living in a Low-Carbon Development

In this longitudinal study, it is important to compare the experience of living in an LCD with a resident's expectations of life before they made the move. This will be discussed below, touching on the design aspects of the LCD, how the perception of the home changed and the community aspects.

4.5.1. Design Aspects

The design aspects and sustainability features of the LCD were major drawcards for residents choosing to make their home at WGV. Residents were attracted to the control they would have over their own space, the design of the apartments, the community space and the landscaping and green space.

The solar passive design features of the dwellings resulted in residents being more thermally comfortable in these dwellings than in their previous ones. Residents still have to engage in opening and closing doors and blinds, and putting on appropriate clothing; however, the space is reported to be more comfortable, and these actions are viewed as being more acceptable because the temperature remains in a more comfortable range. The design aspects also resulted in reduced energy usage by residents, adding to their attractiveness.

In terms of control over space, residents reported enjoying making their homes the way they wanted, and felt a sense of pride and ownership in their homes, with hope for future housing stability. This was particularly evident in the SHAC residents, who were motivated by this for the move. The community aspects will be discussed in a following section; however, one design aspect that was supposed to increase community interaction was the communal barbecues. These are placed in some green space in the north-west corner of the development. Their location was a deterrent for residents whose homes were located away from this area. The Evermore development also has their own communal barbecues inside their development, which were preferred by some residents due to their proximity. Other Evermore residents reported a preference for the WGV communal barbecues due to the surrounding landscape providing seating and shade and the communal atmosphere of interacting with other residents walking by.

A design aspect of Evermore that was criticized by all WGV residents was the extra lighting at night around the buildings and carpark. While this is intended for security reasons, and has been dimmed slightly in response to resident complaints, many WGV residents had to shut their curtains at night to be able to sleep, preventing them from having windows open to passively cool their homes. The lighting and security gates and fencing around the Evermore entrance ha residents reporting feeling uncomfortable entering the development, associating it with a jail, a medical institution or a sporting field, not a home. On the other hand, residents did appreciate the security aspect that this gating and lighting provides.

4.5.2. Perceptions of Home

As discussed in Section 4.3, establishing a new home was a primary motivation for residents moving to the LCD. Before moving into the LCD, the important features of a home included community aspects, sustainability features, design, security and comfort, and these aspects are compared to the post-occupancy responses in Figure 1. These features were mostly still expressed post-occupancy. The most common feature associated with home after the move was that it is a place that is a haven from the outside world, relaxing and soothing to be in. This was previously reported by only 7% of respondents, and now was reported by 57%. The next most important feature was the family and social aspects of the home, decreasing from 71% previously to 43% post-occupancy. This was rated at the same importance level as comfort aspects of the home, which were rated at 36% before the move. The safe and secure housing aspects were reported at 36% post-occupancy, the same as pre-occupancy. The design and aesthetics of the home decreased in importance from 50% reported before the move to 21% after. A new feature mentioned after the move was the ability for a home to be a place where the residents can be creative and express themselves. This was reported by one resident in each of the SHAC and Evermore developments. The garden and pets aspects of home both remained important features. Noticeably, the sustainability aspects of home were not mentioned since residents moved into the LCD, despite their importance before the move.

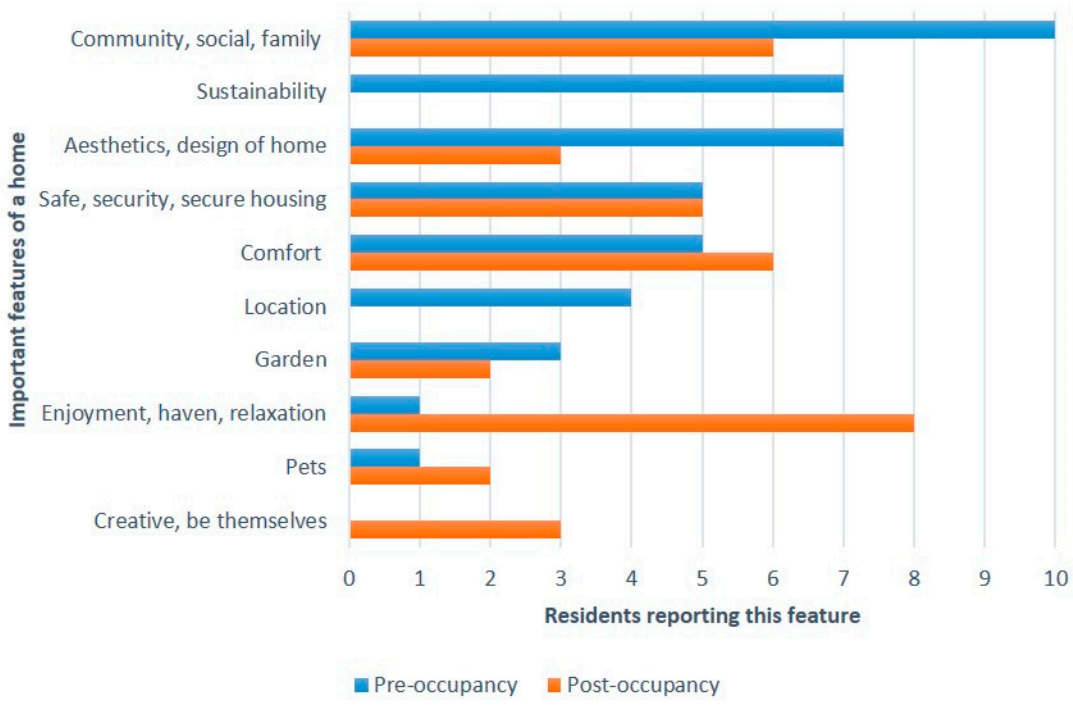

Figure 1. Important features of and associations with a home as reported by 14 residents pre- and post-occupancy in the LCD.

4.5.3. Community Aspects

The community focus was a driving force for many residents wanting to move into the LCD, with 57% of residents reporting it as being a motivating factor. Since moving in, all the residents reported enjoying the community atmosphere of the LCD. This included both those in the apartment buildings (SHAC and Evermore) and those in the semi-detached and stand-alone houses. Those in the apartments enjoyed the informal interactions with their neighbors as they walk about their development, while those in the houses enjoyed being in their garden and interacting with residents walking past as well as the more formal gatherings organized within the LCD. Residents have reported enjoying having younger children around the apartment areas and listening to them play. A SHAC resident with a young child reported enjoying the community atmosphere of hearing other families cooking breakfast at the same time each morning, and this encouraged the resident to have a cooked breakfast themselves, instead of cereal, and to engage in the practice of preparing breakfast more mindfully.

Whilst the community aspects were highly praised by the residents, there were some aspects raised by residents relating to areas that had influenced their experience of community in the LCD.

The SHAC residents were some of the first to move in to the LCD, and some reported feeling like they had a responsibility to present a profile of a good community to the surrounding community outside of the LCD, even when their pets or kids did something that others did not believe to be socially acceptable. SHAC holds regular community events and workshops, and encourages the broader WGV community and residents of surrounding areas to attend these.

One resident of a single house felt that a greater effort to have had the residents of the single houses move in at a similar time would have allowed for more of a community to develop, and would have resulted in less construction noise impacting residents. Currently, that resident is waiting for both her neighbors to complete their homes before she completes her outside landscaping, and this is affecting her association with and comfort at home.

A community hub was mentioned by residents as a gathering space for those who do not otherwise have a space (such as the Evermore and SHAC common areas), or simply as a space for all WGV residents to interact regardless of their dwelling location. There is a building on site that could be used for this purpose when not being used for other community events such as workshops and dance classes; however, the organization of the hub or events would need to be done by either a resident or an external actor.

Finally, there was the realization by some residents that not everyone moving into WGV was embracing the community living or sustainability aspects of the site, and some residents just wanted to live as they would in more traditional housing developments, without engaging in these features or events. As the community and sustainability aspects were reported by the residents studied to be major motivating factors for the move to the LCD, this is not surprising; however, some residents stated that this was a surprise, and they had to respect the decisions of other residents.

5. Discussion and Conclusions

This paper set out to explore residents' motivations and expectations for how their life would change when they moved into an LCD, and the post-occupancy evaluation of this. The concept of home in the literature revolves around technical perspectives (technology features), social perspectives (comfort, social place, physical use) and sustainable practice (sustainable housing) perspectives of home [30]. The aspect of comfort in social housing policy generally relates to thermal or physical comfort, something that can be measured, predicted and changed through design adaptations [31]. Previous research has found that the future of comfort remains fluid and controversial [60]. Some of the results in this paper support this view, where the traditional notions of home design only focus on thermal comfort. In taking a social view of home perceptions and expectations of a move to an LCD, however, this research highlights the varying results that occur when non-technical aspects of an LCD are considered [30]. Home in this paper has been outlined to be primarily a place for community, sustainability, aesthetic features, safety and comfort, although the sustainability aspect reduced in importance once residents moved into the LCD. This could be due to residents easily integrating their practices and technology in the new environment and focusing more on the community aspects of their lifestyles. The different meanings of home revealed through this research point to various opportunities and obstacles for reducing resource consumption in homes [61]. Future research should focus on how the meaning of home influences individual and household resource consumption, and investigate how living in an LCD impacts these. This could then inform more appropriate policy making related to homes and resource use that does not solely focus on the built environment.

In the literature, a primary aspect of the meaning of home is the importance of control over space, whether in relation to personal identity, security, comfort, privacy or activities [32,39,40,46]. These results are the same even for households with sustainability features [62,63]. This is supported in this research, as residents were particularly motivated by housing stability and having control over their own space [34,35]. Other motivation results also reflect the conclusions made by previous research [34], that the external environment of the community is important to people in a home along with housing stability. Location and design are common factors in purchasing a home anywhere, let alone in an LCD, and are replicated in this study as common features people look for in a potential home [16].

Previous studies have shown a strong desire from residents to have sustainability features in their homes, and the WGV precinct provides them with this opportunity [64]. The sustainability features of the LCD in this research were rated as a strong motivator for residents, followed by the community aspects being fostered at WGV. Residents believed that living in the LCD would enable them to develop practices that require less resources, increase their interaction with the community and change their travel practices. Residents of the LCD primarily found out about the opportunity to move into the LCD through their social networks of friends and workmates. Social networks are a trusted and familiar source of information for people in society, and hence might be used by real-estate agents to increase awareness of, and interest in, LCDs. LCDs feature design aspects and technology that require resident interaction to ensure their optimal performance. These can be of concern for prospective residents, as shown previously [20], although the residents in this study were not concerned about these features pre-occupancy. Designers, planners, real-estate agents and strata managers need to explain these clearly to prospective residents to ensure the technology is maintained in good working order to achieve the sustainability outcomes of the development.

The expectation of a strong sense of community pre-occupancy concurs with the findings from many studies on the important features of a home including the community aspects [34,35,41]. The strong sense of community and the self-reported thermally comfortable homes met residents' expectations post-occupancy, and are a positive selling point for future LCDs. Some design and community aspects were met with surprise in this research. The lighting and security aspects of the Evermore development received mostly negative views from the residents as influencing the ease at which they could move about the LCD precinct and interact with other residents. The communal barbecues also had mixed reactions, engaging some residents but not all. Other options for community interaction and meeting places should be explored to accommodate other preferences.

Research focusing on questions of the home often examines only the physical and techno-economic aspects of the built environment of the dwelling that people reside in. Those studies that focus on the home tend to include social and emotional connotations along with the built environment [20]. If policy is only focused on the built environment, then human social and emotional connections with their home may be neglected [24]. As these are important elements of social practices, any programs designed to influence resource use in the home are unlikely to result in long-term change. The emotional landscape of a home is increasingly being recognized as significant to residents, including in this study, and its relevance should be advocated for in housing policy, along with the physical structure of the dwelling [33,37,48].

For housing policy to lead to attractive homes in the future, it is important to understand which elements of the design of a home are desired by residents post-occupancy, and how these features influence daily practices. In terms of a policy approach towards housing, the WA Housing Authority acknowledges the desire for residents to have a safe, secure, stable house, and provide various dwelling types to meet residents' needs [62]. It is clear from this review that the term "home" is a complex system of physical and emotional elements [63], and the various ways of categorizing it provide opportunities to change resource consumption in related practices. It is with this open policy direction in mind that this paper explored how residents perceive their homes and what they expect out of the LCDs that are being built to withstand future environmental climate change.

The authors acknowledge that this paper features results from a small cohort of LCD residents; however, it is unique in tracking them both pre- and post-occupancy. This was mostly due to the low uptake in residents who fit the time limit criteria for moving into the LCD in 2018. Some residents were also reluctant to participate, due to not having stable housing pre-occupancy, as this influenced the energy and water aspects of the research not discussed in this paper. However, with a small cohort study, particular themes could be examined in greater detail with the residents, such as how the different methods of hearing about the LCD influenced their decision to move in. Future research should examine a larger sample size of residents from different locations to assess whether other themes and concerns arise. A second post-occupancy study could also be completed once residents have resided in the LCD for a longer period of time. For most of the residents in the stand-alone and semi-detached houses and Evermore, they began living at WGV less than six months from when this data was collected. The SHAC residents had been residing at WGV for more than a year. This may have influenced their perceptions of their experiences.

Further research areas should continue to investigate LCD housing in a variety of climatic and design landscapes outside of the Australian and European regions to broaden the lessons learnt, the residents engaged with and the policies that affect LCDs. Mixed method research focusing on a longitudinal view of LCD residents is vital for understanding how residents access an LCD, move in and settle over the years with new technology and communities. Post-occupancy evaluation studies will contribute to this understanding.

Author Contributions: Conceptualization, J.K.B.; Formal analysis, J.K.B.; Funding acquisition, J.J.B. and G.M.M.; Investigation, J.K.B.; Methodology, J.K.B. and G.M.M.; Project administration, J.J.B. and G.M.M.; Resources, J.J.B. and G.M.M.; Supervision, J.J.B. and G.M.M.; Visualization, J.K.B.; Writing—original draft, J.K.B.; Writing—review & editing, J.K.B., J.J.B. and G.M.M.

Funding: This research is funded by the CRC for Low Carbon Living Ltd. supported by the Cooperative Research Centres program, an Australian Government initiative, NP2006.

Acknowledgments: The authors wish to especially thank the research participants from the WGV precinct for participating in this research and all the stakeholders involved, particularly LandCorp and the City of Fremantle.

Conflicts of Interest: The authors declare no conflict of interest.

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Appendix A: WGV dwelling details for participating post-occupancy residents

Building type	Apartment- SHAC					Apartment- Evermore					Semi-detached house		House
House code	L	D	H	N	J	A	O	I	B	C	F	M	G
Floor area (m^2)	65.9	96.7	67.7	47.5	73.5	78.1	78.1	46	119.5	117.8	80	57	160
Balcony size (m^2)	5.2	11.9	5.2	5.7	5.3	4	4	7.7	3.8	8.6	5	6	59.5
NatHERS rating	9	8.5	7	5.5	5.5	7.1	7.6	7.2	5.8	5.9	7.7	7.3	7.4
# of bedrooms	2	3	2	1	2	2	2	1	3	3	1	2	3
# of bathrooms	1	2	1	1	1	2	2	1	2	2	1.5	1.5	2
Solar PV system (kW)	20					53.6					5		3.5
Battery system (kWh)	40					150					NA	NA	NA
Rainwater tank (kL)	NA					NA					7		3
Private irrigation	Mains					Mains					Community bore		Mains
Communal irrigation	Community bore					Community bore					Community bore		Community bore
Windows	Standard laminate glass	Standard laminate glass	Standard laminate glass	Standard laminate glass	Standard laminate glass	High solar gain Low-E	High solar gain Low-E	High solar gain Low-E	High solar gain Low-E	High solar gain Low-E	Double glazed	Double glazed	Double glazed low E

Building type	Apartment- SHAC					Apartment- Evermore					Semi-detached house		House
House code	L	D	H	N	J	A	O	I	B	C	F	M	G
Hot water system	Electric storage	Electric storage	Electric storage	Electric storage	Electric storage	Electric storage	Electric storage	Electric storage	Electric storage	Electric storage	Heat Pump		Solar Hot Water System with electric boost
Cooking type	Resistance electric	Resistance electric	Resistance electric	Resistance electric	Resistance electric	Induction electric	Induction electric	Induction electric	Induction electric	Inducti on electric	Induction electric	Induction electric	Induction electric
Lighting	LED	LED	LED	LED	LED	LED	LED	LED	LED	LED	LED	LED	LED
Shower head	3 star WELS rated shower head	3 star WELS rated shower head	3 star WELS rated shower head	3 star WELS rated shower head	3 star WELS rated shower head	3 star WELS rated shower head	3 star WELS rated shower head	3 star WELS rated shower head	3 star WELS rated shower head	3 star WELS rated shower head	Low flow shower head 5.5L/min	Low flow shower head 5.5L/min	3 star WELS rated shower head
General appliances													
Fridge/freezer	1	1	1	1	1	1	1	1	1	1	1	1	1
Tumble drier	0	0	0	0	0	1	1	1	1	1	0	0	1
Washing machine	1	1	1	1	1	1	1	1	1	1	1	1	1
Dishwasher	0	1	0	0	0	1	1	1	1	1	1	1	1

Appendix B: Structured interview questions

Interview questions SHAC pre-occupancy

General

Tell me about yourself... e.g. occupation, age, interests, like to host?, like to cook?,

How did they start doing the hobbies or work they do?

How heard of energy efficient or low carbon and got involved with SHAC

Household size (number of people)

Household type

Currently in social housing or privately rented or owned?

Insulation in house

Any PV or greywater systems?

Car/no car

Lounge/living area

Type of heating and cooling in the house- portable vs in wall, fan, fireplaces,

Do you like the fresh air?

Ventilation, opening windows, curtains,

Where does it get particularly hot/cold in the house?

What do you do if it is too (1) hot, (2) cold, (3) stuffy/humid/smelly, (4) dry air?

How are your heating controls typically set? How are these decided upon?

Use any additional heating/cooling equipment?

Energy saving – heating, bulbs, lights off, standby.

Turning off lights when leaving room

Appliances on standby mode

Are you on any different pricing plans with Synergy? Time of day pricing? If so, how do you manage your usage?

How do the users fix the technologies if something goes wrong, maintenance, sourcing replacement materials, extent to which providers are willing to delegate responsibility to consumers?

Who does the domestic work?

Kitchen

Who do you cook for?

Fresh vs frozen?

How do you use the freezer in daily life (planning, or avoiding meal planning, saving money, individual snacking)

Where do you buy your food?

When do you put the dishwasher on? Fully loaded or as needed?

Recycling- do you? How?

Do you get things from curbside recycling or from a reuse centre or op shop?

Purchasing new appliances- when, why, where

Sharing appliances or things with other people?

How do household's resource use change when people are over?

Bathroom

Bushing teeth turning off the tap?

How often do you shower?

Do you have any water efficient shower heads, taps or toilets?

Laundry

How often do you do the laundry?

Do you do the laundry at the same time of day?

Sheets/towels frequency

Full loads or as needed?

Why do you wash clothes? dirty? Smell?

What laundry setting do you use?

Do they have a drier or air dry?

What type of clothes do you own and how does this influence laundry habits (uniforms? Type of work influences the cleanliness of clothes)

Do you recycle water?

Garden

Hand water frequency

Retic frequency

Who looks after the garden?

Animal cleaning

Car cleaning

Other uses of water

Moving to SHAC

What attracts you to the SHAC development?

Are you a part of the WGV precinct group or any other groups in the area?

What parts of your life do you think will change when you move to SHAC?

Expectations of moving in? Looking forward to anything specific? Unsure of anything?

Who will be living in the new home?

Interview questions- Evermore and houses pre-occupancy

Talk about concepts of cleanliness, comfort and convenience and look for products in their house that are involved in multiple core practices

Information sheet & consent form, confidentiality, ask about recording, check again on the record. No right or wrong answers- I want to listen, not talk- you are the expert here. Today we'll be talking about your energy and water use and the types of appliances you have in your home. I'm interested in how you use them in your everyday life

Current house info

Household size & type of house

people & age, education, occupation

Currently in social housing or privately rented or owned? How long in this house for?

Insulation in house?

PV or greywater systems?

General

How heard of and got involved with Evermore? *Motivation*

What does home mean to you? What do you associate home with? What is important in a home? *Privacy, space, community, location, comfort. Look & feel like*

How familiar are you with the term sustainability? *Very aware to not very aware, in what sectors (housing, transport, energy, water, purchasing)*

Tell me about a typical weekday and weekend day in your house

What are inflexible practices in their lives? Cooking times, watching TV, showering, meal times? Routines & habits

Do you have any automatic systems or appliances in your home? Why do you use/not use them? Timers *Comfort, convenience*

Talking about your transport: How do you get around? Is it always the same? Car/bike/walk/PT/taxi/uber *Routines/habits, # of each in household*

Lounge/living area

Type of heating and cooling in the house- portable vs in wall, fan, fireplaces

Do you like the fresh air?

Ventilation, opening windows, curtains,

Where does it get particularly hot/cold in the house?

What do you do if it is too (1) hot, (2) cold, (3) stuffy/humid/smelly, (4) dry air? keeping doors shut between rooms

How are your heating controls typically set? How are these decided upon?

Use any additional heating/cooling equipment?

Energy saving – heating, bulbs, lights off, standby.

Turning off lights when leaving room

Appliances on standby mode

Are you on any different pricing plans with Synergy? Time of day pricing?

If so, how do you manage your usage

How do the users fix the technologies if something goes wrong, maintenance, sourcing replacement materials

Who does the domestic work?

Kitchen

Who do you cook for?

Fresh vs frozen? How do you use the freezer in daily life (planning, or avoiding meal planning, saving money, individual snacking)

Where do you buy your food? WHO does this?

When do you put the dishwasher on? Fully loaded or as needed?

Recycling- do you? *Daily, weekly, monthly*

Bulk waste collection?

Do you get things from curbside recycling or from a reuse centre or op shop

Describe what you recycle- bottles, cardboard, why wouldn't you recycle something?

How full are your bins usually?

Do you use your own jars or bags when shopping for food?

Purchasing new appliances- when, why, where

Sharing appliances or things with other people?

How do household's resource use change when people are over?

Garden

Hand water vs retic frequency

Who looks after the garden?

Animal cleaning

Car cleaning

Other uses of water eg. *Getting leaks fixed*

Social sustainability: overlooking/noise problems with neighbours

Laundry

How often do you do the laundry? *Why*

Do you do the laundry at the same time of day? *Why*

Sheets/towels frequency

Full loads or as needed? *Why*

Why do you wash clothes?- *dirty? Smell*?

Laundry setting?

Drier or air dry?

What type of clothes do you own & how does this influence laundry habits *(uniforms? Type of work influences the cleanliness of clothes)*

Do you recycle water?

Water saving fixtures?

Bathroom

Brushing teeth turning off the tap?

How often do you shower? *WHY*

Timer in the shower?

Moving to Evermore

What attracts you to the Evermore development?

What info have you been provided re Evermore & sustainability? What are your thoughts on this? Any worries?

Are you a part of the Evermore precinct group or any other groups in the area?

What parts of your life do you think will change when you move to Evermore?

Expectations of moving in? Looking forward to anything specific? Unsure of anything?

Are there any practices or routines you'd like to change in relation to sustainability? Why? Why don't you act this way already?

Who will be living in the new home?

Is there anything I've not asked that you think I may be interested in?

End

- Probe packs will focus on your food, waste, transport, a bit on water & energy but we've covered most of that today- *what night is bin night for recycling? What is the best time to send pictures?*
- Do you have any questions for me?
- Business card if need contact

Interview questions- all participants post-occupancy

Household size (number of people, changes from previous dwelling)
Profession (any changes)
Is living in WGV different from what you thought it would be?

What are the things you like the most about your current home?

Best and worst aspects about living in the homes?

Cost of living changes

Changes to daily routines since moving *work shifts time you spend at home/working from home*

Changes to lifestyle or routines as a direct result of the house technologies *energy/water real-time display, the solar panels, batteries, standby switch, etc.*

Do you try to save energy or water on a daily basis?
How; Who tends to be the most energy/water conscious in the family?; do you remind each other?

What has been your experience of using the technology in WGV? EV & dashboarad
Did you like this/dislike this?
What was easy or hard and why?
What would you change?
What sort of discussions have you had in your family/friends about WGV and the experience of living here?
Do you think you are more aware of sustainability issues now and how to live sustainably?
Rebound effect- do they not think about sustainability?
common sense of purpose, positive influence from peers, sense of obligation etc

How has home changed for you? *What does home mean now? Did you expect this?*

Comfort & convenience: When you think about comfort, what comes to mind? Do you like this?

Change in sense of community: *How you go about interacting with people?; Accessing services?; Precinct groups?*

<u>Handover</u>

what worked, what didn't work, suggested improvements

Complicated? What was hardest to understand? Still apprehensive about anything?

How useful did you find the instruction manuals and guides?

What did you do when you didn't know what to do?

Have the landlords been quick to problems? (have there been many?)

<u>Design</u>:

Was being able to help design SHAC/The Fish a good thing? Were you able to incorporate your own wants into the design and have these been used in practice?

Transport- how, when, who with, why

Thermal comfort- Warm/cool

<u>Cooking</u> (fresh vs frozen; appliances; freezer use; time of day to cook)

<u>Shopping</u> (where, when, transport)

<u>Lighting</u>

<u>Technology fixing</u>

<u>Appliances</u>:

What did you get rid of and what did you keep and why?

Anything that you didn't have a need for before, but do now?

Automatic?

Sharing appliances

<u>Recycling</u>- how/when

<u>Washing dishes</u>- Dishwasher- how often per week, full loads?

<u>Bathroom</u>: # in house

Brushing teeth/shaving tap off?

Shower timer?

Do you shower places other than home?

Resources change when people over:

Heating/cooling; cooking; lighting

<u>Laundry</u>

When? Full loads/as needed? How many cycles per week, what temperature?

Different wash cycle lengths?

Drying- how often use tumble dryer/week?, why

Recycling water at all?

<u>Garden</u>: Hand water vs retic; whose responsibility

Grow food?

Animal cleaning

Car cleaning

Privacy concerns

Have you given any thought to the monitoring while you've been living here?

Health impacts – positive/negative?

Shared spaces

1. Has the sump park meet your expectations as a green urban space? If not, what would you change about it?
2. In what way and how often do you use the sump garden?
3. Can you describe your feelings about that space? Do you experience emotional connectedness to the sump garden?

Anything else you'd like to tell me?

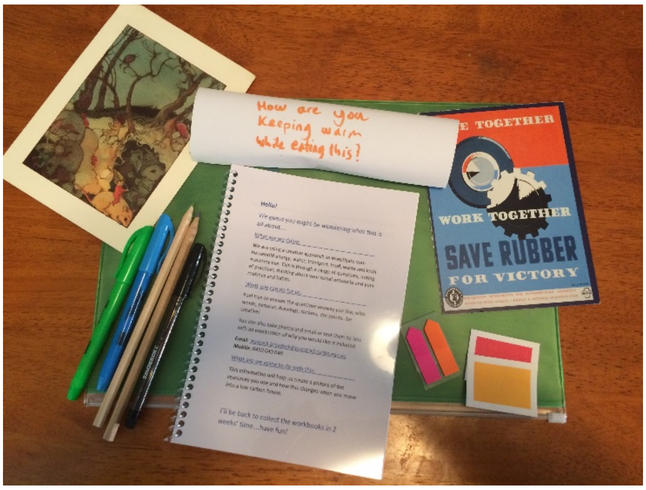
Appliance and time audit used in round 1 and 2 completed by interviewer during interview

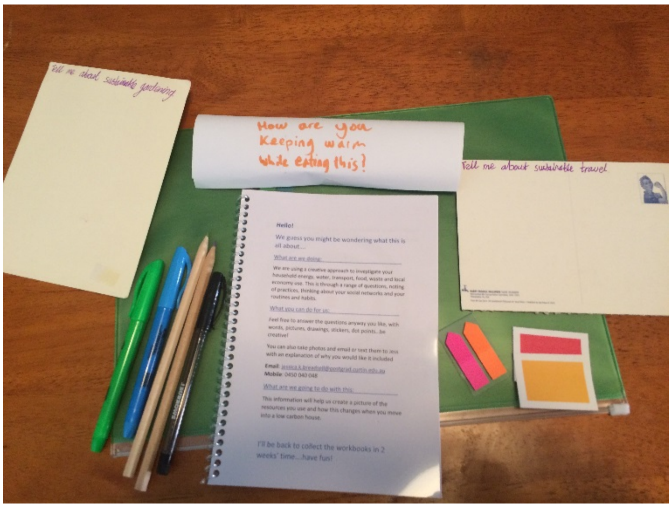
Time audit	**Activity**
5am	
6am	
7am	
8am	
9am	
10am	
11am	
12am	
1pm	
2pm	
3pm	
4pm	
5pm	
6pm	
7pm	
8pm	
9pm	
10pm	
11pm	

Appliance audit	**Y/N**	**WGV New**
Fridge/freezer		
Fridge		
Freezer		
Microwave		
Dishwasher		
LCD TV		
DVD player		
CD player or radio		
Washing machine		
Tumble drier		
Gas heater		
Electric heater		
Patio heater		
PC		
Tablet		
Printer/scanner		
Lawnmower		
BBQ		

Appendix C: Pre-occupancy workbooks containing the survey and cultural probes

Workbook SHAC pre-occupancy





Hello!

We guess you might be wondering what this is all about….

What are we doing:

We are using a creative approach to investigate your household energy, water, transport, food, waste and local economy use. This is through a range of questions, noting of practices, thinking about your social networks and your routines and habits.

What you can do for us:

Feel free to answer the questions anyway you like, with words, pictures, drawings, stickers, dot points…be creative!

You can also take photos and email or text them to Jess with an explanation of why you would like it included

Email: jessica.k.breadsell@postgrad.curtin.edu.au
Mobile: 0450 040 048

What are we going to do with this:

This information will help us create a picture of the resources you use and how this changes when you move into a low carbon house.

I'll be back to collect the workbooks in 2 weeks' time….have fun!

Tell me about your social networks around energy or water or sustainable ideas on food, transport, waste- who do you talk to, get information from, trust? You can use the diagram or draw your own.

Food

Do you use your own jars or bags when shopping for food?

Do you make your meals at the same time each day?

Waste

How do you get rid of food waste?

What do you recycle? How?

Where do you get your knowledge about recycling?

Do you do any of the following?	*How often?*
Check the cupboard/fridge before shop	
Make a shopping list	
Plan meals for the week	

Local economy

Do you use any local services such as babysitting, cleaners, Uber or delivery services?

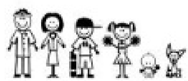
Do you consider Fair Trade products when purchasing?

Do you use online shopping to purchase anything?

Travel

How do you usually get around?

Do you ever travel with other people?



What is your annual car mileage?

Do you structure your transport around other events? Peak hour, school times?

What activities do you do when you are commuting? *Listen to ebooks, read the news, write?*

Who do you go on holidays with?

How often do you fly? Where to?

Do you purchase carbon offset when travelling?

How do you get to your holiday destinations?

Do you have difficulties in getting to places?

If you could change how you travel around would you? What would you change?

Water

Have you discussed your water use with anyone recently? Who was this?

Did they influence the way you used water?

What appliance do you think uses the most water in your house? Do you use it much?

How often do you contact your water provider? What about?

Energy

Have you discussed your energy or gas use with anyone recently? Who was this? *Did they influence the way you use energy?*

Do you use electricity or gas differently when people are around?

What appliance do you think uses the most energy in your house? Do you use it much?

How often do you contact your energy or gas provider? What about?

My personal hygiene

Date, time	How?	Length	Reason
1/5/17 7:15am	Shower	4 min	Wake up before work, get clean
1/5/17 6pm	Wash face with cloth	1 min	Freshen up before going out to dinner

My personal hygiene cont…

Date, time	How?	Length	Reason

My personal hygiene cont…

Date, time	How?	Length	Reason

My personal hygiene cont…

Date, time	How?	Length	Reason

My transport diary

Date & time	Method	Length	Distance approx	Travel with anyone?	Reason
1/5/17, 7:35am	Walk, bus & train	45min	20km	Alone	Going to work

My transport diary cont…

Date & time	Method	Length	Distance approx	Travel with anyone?	Reason

My transport diary cont…

Date & time	Method	Length	Distance approx	Travel with anyone?	Reason

My transport diary cont…

Date & time	Method	Length	Distance approx	Travel with anyone?	Reason

Send me a picture of…

Over the two weeks I will text you to ask you to send me a picture of the following….

A piece of technology that saves you time

Something you won’t be taking with you to SHAC

How you kept warm today

How you kept cool today

An appliance you use to make a meal with regularly

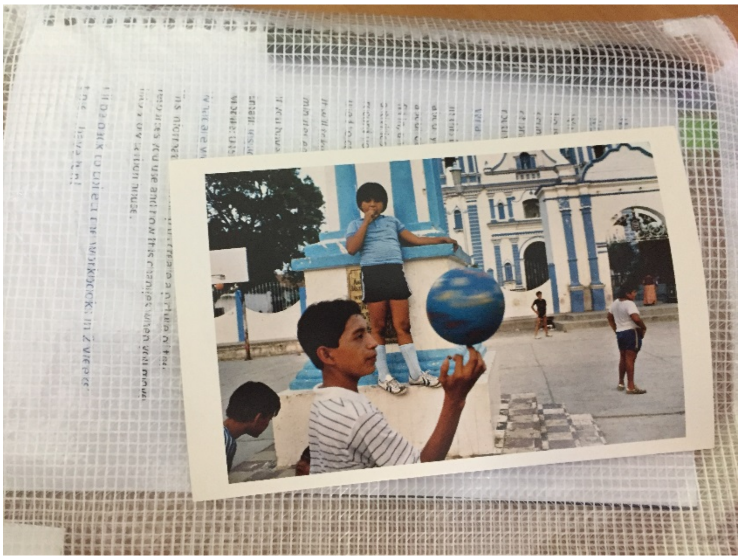
What is in your recycling bin before you put it out

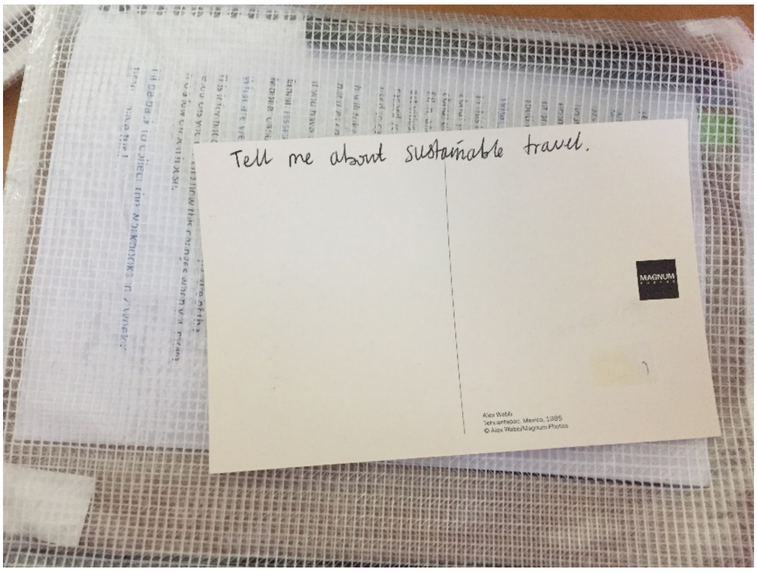
Something that is good for the environment

How you keep in contact with people

How you got around today

Workbook for Evermore and houses pre-occupancy





Hello!

What are we doing:

We are using a creative approach to investigate your household energy, water, transport, food, waste and local economy use. This is through a range of questions, noting of practices, thinking about your social networks and your routines and habits.

What you can do for us:

In this booklet there are some questionnaires to answer about your resource use, some short answer questions about different daily practices, a social network table to fill in, and a transport and hygiene diary to record your activities over a 2 week period. Finally there is a space to record your recent water and energy bills that will be used to calculate your carbon footprint.

It will take approximately half an hour to fill in and a few minutes each day noting your showering and transport

If you have any questions, please contact Jessica on:

Email: jessica.k.breadsell@postgrad.curtin.edu.au
Mobile: 0450 040 048

What are we going to do with this:

This information will help us create a picture of the resources you use and how this changes when you move into a low carbon house.

I'll be back to collect the workbooks in 2 weeks' time….have fun!

Food

Do you make your meals at the same time each day?

Why/why not? What influences this?

How often do you:	**Very often**	**Often**	**Sometimes**	**Rarely**	**Very rarely**
Buy food with less packaging instead of food with more packaging	○	○	○	○	○
Buy a product with a fair trade symbol	○	○	○	○	○
Eat a meal without meat	○	○	○	○	○
Eat organically grown food	○	○	○	○	○
Compost or recycle garden waste	○	○	○	○	○
Compost kitchen waste	○	○	○	○	○
Check the cupboard/fridge before you shop	○	○	○	○	○
Make a shopping list	○	○	○	○	○
Plan meals for the week	○	○	○	○	○

Do you think there is a pattern between your use of food and convenience in your life? *Saving time*, *reducing stress*, *preference for food types*, *cooking skills*

Waste

Where do you get your knowledge about recycling?

How often do you:	**Very often**	**Often**	**Sometimes**	**Rarely**	**Very rarely**
Separate paper and cardboard from the rest of the waste	○	○	○	○	○
Separate plastics, cans, and cartons from the rest of the waste	○	○	○	○	○
Reuse paper	○	○	○	○	○
Reuse glass	○	○	○	○	○

Local economy

Do you use any local services such as babysitting, cleaners, Uber or delivery services? Why/why not?

Do you use online shopping to purchase anything?

Why/why not?

When purchasing a new appliance, rate the following for influence	1- greatest influence to 5- least influence
Cost	
Energy rating	
Aesthetics	
Manufacturer	
Friends and family recommendation	

Purchasing habits

These questions are referring to your actions when you need to make a purchase for your household:

How often do you:	**Very often**	**Often**	**Sometimes**	**Rarely**	**Very rarely**
Purchase high efficiency bulbs	○	○	○	○	○
Purchase energy efficient appliances	○	○	○	○	○
Buy recycled paper	○	○	○	○	○
Buy recycled toilet paper	○	○	○	○	○
Buy locally produced foods	○	○	○	○	○
Buy from a local store (non-supermarket chain)	○	○	○	○	○
Use own bags/containers when shopping	○	○	○	○	○
Refuse plastic bags or wrappings offered by shopkeepers	○	○	○	○	○
Repair products or have them repaired instead of buying them new	○	○	○	○	○
Donate furniture to charity	○	○	○	○	○
Donate clothes to charity	○	○	○	○	○
Purchase furniture from charity	○	○	○	○	○
Purchase clothes from charity	○	○	○	○	○
Avoid drinking bottled water	○	○	○	○	○

Travel

Do you structure your transport around other events? *Peak hour, school times?*

What activities do you do when you are commuting? *Listen to ebooks, read the news, write?*

Do you have difficulties in getting to places?

What is your annual car mileage?

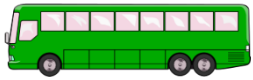
____

Travel

How would you get to the following places in a normal day?	Car/ motorbike	Bus	Train	Walk	Bicycle
Work	○	○	○	○	○
Shops	○	○	○	○	○
Traveling whilst at work	○	○	○	○	○
Local leisure journeys	○	○	○	○	○
Visiting friends/relatives locally	○	○	○	○	○
Taking children to school	○	○	○	○	○

How often do you:	Very often	Often	Sometimes	Rarely	Very rarely
Choose to extend the walking portion of my trip to my final destination	○	○	○	○	○
Use public transport as my main mode of travel	○	○	○	○	○
Stop at facilities (such as cafes/shops) as part of my journey to work or home	○	○	○	○	○
Not use the car for short trips	○	○	○	○	○
Walk to close facilities if possible (shops/markets, parks, cafes)	○	○	○	○	○
Use public transport or walking/bike options when visiting friends/family	○	○	○	○	○
Engage in carpooling	○	○	○	○	○

Travel



What are your views of the following statements:	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I try to end my journey by motorised transport as close to my destination as possible to minimise walking	○	○	○	○	○
There is a clear maximum distance I am willing to walk from any bus stop/station to my final destination	○	○	○	○	○
A poor link in a journey means I tend to drive my car	○	○	○	○	○
I would consider changing my main mode of travel if a poor link in the journey was made more attractive	○	○	○	○	○
My home to work journey changes significantly with daily weather conditions	○	○	○	○	○
Most of my friends and relatives do not use public transport regularly	○	○	○	○	○
Using the car is something that belongs to my everyday routine	○	○	○	○	○
Not using the car is something I would find hard	○	○	○	○	○
Walking and/or cycling is convenient for me	○	○	○	○	○

Holiday travel

Number of holidays in the past year (over 4 nights)

____

Number of short breaks in the past year (3 nights or under)

____

Considering you recent holidays:

Who do you go on holidays with?

How do you get to your holiday destinations?

Do you own a holiday home? If so, how often do you use it and how do you travel to get to it?

Holiday travel

When on holiday, how often do you:	**Very often**	**Often**	**Sometimes**	**Rarely**	**Very rarely**
Travel overland instead of flying	○	○	○	○	○
Offset carbon emissions	○	○	○	○	○
Choose environmentally friendly accommodation	○	○	○	○	○
Visit non-touristic towns	○	○	○	○	○
Shop at supermarkets to cook at accommodation	○	○	○	○	○
Buy locally made souvenirs	○	○	○	○	○
Shop at markets	○	○	○	○	○



When on holidays, what is your view of the following statements:	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
Walking and/or cycling is hard for me	○	○	○	○	○
Taking public transport is convenient for me	○	○	○	○	○
Holidays are a time when I don’t have to think about the environment	○	○	○	○	○
I try to save water when I’m on holiday	○	○	○	○	○
I don’t try to save energy when I’m on holiday	○	○	○	○	○
I try to use the fastest mode of transport to get there quickly	○	○	○	○	○
I don’t think about how I can reduce environmental damage when I go on holiday	○	○	○	○	○

General

The following statements are about your household practices relating to comfort, energy and water use:

What are your view of the following statements:	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
I am concerned about how easy it will be to maintain my low carbon house	○	○	○	○	○
Comfort at home in summer is important to me even if it means spending more each month for energy	○	○	○	○	○
Comfort in winter is important to me but I won’t spend more money each month for energy	○	○	○	○	○
It is not important for me to find ways to control my energy costs	○	○	○	○	○
It is important for me to find ways to control my water costs	○	○	○	○	○
Cost is the most influential factor that influences my energy usage	○	○	○	○	○
Cost is the not the most influential factor that influences my water usage	○	○	○	○	○



How often do you:	**Very often**	**Often**	**Sometimes**	**Rarely**	**Very rarely**
Volunteer for an environmental cause	○	○	○	○	○
Learn about indigenous cultures	○	○	○	○	○
Volunteer for a social cause	○	○	○	○	○

General

The following statements are about thoughts and behaviours in the household and personal travel, please tell us to what extent you agree or disagree with them:

What are your views on the following statements:	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Living in a comfortable and attractive home is an important goal for me.	○	○	○	○	○
I work hard to reduce my greenhouse gas emissions whenever possible.	○	○	○	○	○
I feel very good when I am successful in reducing my greenhouse gas emissions.	○	○	○	○	○
I would feel very bad if I failed to reduce my greenhouse gas emissions.	○	○	○	○	○
Most people work hard to reduce their greenhouse gas emissions whenever possible.	○	○	○	○	○
Most people think it is very important to reduce their greenhouse gas emissions.	○	○	○	○	○

What are your views on the following statements:	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
I have friends and family outside the home who can give me advice about, or practical support for doing things that reduce greenhouse gas emissions.	○	○	○	○	○
Members of my household keep track of what is happening in the household to make sure the goal of reducing greenhouse gas emissions in the household is achieved *(Think about how your household generally operates 'on average' in terms of this goal. If you are the only member of your household, just answer in terms of yourself).*	○	○	○	○	○
Members of my household remind each other to behave in a way that helps achieve this goal of reducing greenhouse gas emissions in the household *(Think about how your household generally operates 'on average' in terms of this goal. If you are the only member of your household, just answer in terms of yourself).*	○	○	○	○	○
Our household income is high enough to satisfy nearly all our important desires.	○	○	○	○	○

Water

How often do you contact your water provider? What about?

Do you think there is a pattern between your water use and feeling clean or comfortable? *Showering, washing clothes or dishes*

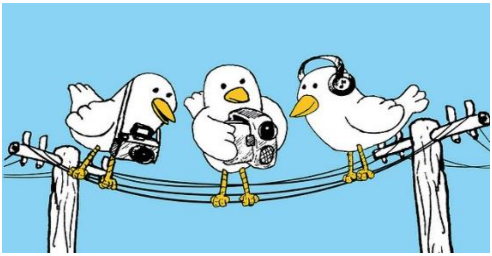
Water

How often do you:	**Very often**	**Often**	**Sometimes**	**Rarely**	**Very rarely**
Wait until I have a full load for washing before I do my laundry	○	○	○	○	○
Use a washing machine for clothes because it fits my schedule, even though I do not have a full load	○	○	○	○	○
Do my laundry with a lower temperature than 60 degrees	○	○	○	○	○
Turn off the tap when washing dishes	○	○	○	○	○
Only turn on the dishwasher when it is full	○	○	○	○	○
Turn tap off when soaping up	○	○	○	○	○
Turn tap off when cleaning teeth	○	○	○	○	○
Use a shower rather than bath	○	○	○	○	○
Dry clothes without using a tumble drier	○	○	○	○	○
Choose plants that need less water	○	○	○	○	○
Avoid hosing down decks, walkways, driveways	○	○	○	○	○

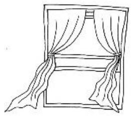
Energy

How often do you contact your energy or gas provider? What about?

Do you think there is a relationship between your energy consumption and your feeling of comfort at home? *Are you only comfortable when the room is a certain temperature?*



Energy


How often do you:	**Very often**	**Often**	**Sometimes**	**Rarely**	**Very rarely**
Wear more clothes instead of more heating					
Turn lights off in unused rooms					
Turn off unused computer and monitor					
Reduce heating in unused rooms					
Reduce cooling in unused rooms					
Turn off heating before opening windows					
Turn off cooling before opening windows					
Unplug unused appliances					
Use a power stript to turn off electronic equipment when it is not in use					
Unplug battery rechargers when they are not being used					
Perform annual maintenance on heating, ventilation, or AC equipment1					

Social Networks

Please fill in the following information, names may be repeated:

Most important people in your present life

This will not be used for identification purposes

First name	Suburb	Live in same house?	How often do you communicate? Daily, weekly, once a month, quarterly, once a year	Did they influence your move to WGV?

People you talk to about living sustainably
ie. Water use, energy use, transport use, food use, waste disposal, purchasing habits
This will not be used for identification purposes

First name	**Suburb**	**Live in same house?**	**How often do you communicate? Daily, weekly, once a month, quarterly, once a year**	**Did they influence your move to WGV?**	**What sustainability topics do you discuss?**

My personal hygiene

Date	Time	How?	Length	Reason
Eg: 1/5/17	7am	Shower	4 min	Wake up before work, get clean
Eg: 1/5/17	6pm	Wash face with cloth	1 min	Freshen up before going out to dinner

My personal hygiene cont…

Date	Time	How?	Length	Reason

My personal hygiene cont…

Date	Time	How?	Length	Reason

My personal hygiene cont…

Date	Time	How?	Length	Reason

My transport diary

Date	Time	Method	Duration	Distance approx	Travel with anyone?	Reason
Eg: 1/5/17	7:35am	Walk, bus & train	45min	20km	Alone	Going to work
Eg: 1/5/17	5:009m	Walk, bus & train	45min	20km	Alone	Returning home

My transport diary cont…

Date	Time	Method	Duration	Distance approx	Travel with anyone?	Reason

My transport diary cont…

Date	Time	Method	Duration	Distance approx	Travel with anyone?	Reason

My transport diary cont…

Date	Time	Method	Duration	Distance approx	Travel with anyone?	Reason

Electricity

Please fill in your electricity bill details from the previous 12 months if you have them available.

Plan: ___________________________________

Bill period (dates and # of days)	Total units used (kWh)	Total cost ($)

This information can be found on the front of your bill:

New charges

Business Plan (L1) tariff
Charge period: 06 Aug 2016 - 03 Oct 2016

	Units	Unit of measure	Unit price (cents)	Amount
Business Anytime consumption	3461.0000	kWh	26.7523	$925.91
Supply charge	59	days	40.7048	$24.02
Plus GST @ 10.00%				$94.99
Total new charges				**$1,044.90**

If you're having problems paying your account, assistance is available. Please contact us before the due date.

A $5.50 fee may apply for additional reminder notices sent regarding overdue payment of this account.

Overdue balances may incur an interest charge equal to the Reserve Bank of Australia's cash rate plus 6.00% and will appear on your bill when applied.

Water

Please fill in your water bill details from the previous 12 months if you have them available.

Bill period (dates and # of days)	Total units used (kL)	Total cost ($)

This information can be found on the back of your bill:

Meter reading details

Meter number	This reading		Last reading		Use (kL)
[redacted]	14 Aug 2017	1450	13 Jun 2017	1444	6

Total water used in 62 days was 6 kilolitres (6000 litres)

How your water use charges have been calculated

Water use 6 kL at $1.5860 $9.52

Water use charges **$9.52**

YOUR NEXT USAGE PRICED AT	
next 132 kL	$1.6810/kL
next 350 kL	$2.2410/kL
over 482 kL	$3.1730/kL

Your average daily use was 97 Litres at $0.15 per day.

How your service charges have been calculated

Water residential	1 Jul 2017 to 31 Aug 2017 Service charge for 1 residence	$42.53
Sewerage residential	1 Jul 2017 to 31 Aug 2017 Based on the rateable value of $20020	$142.76
Drainage residential	1 Jul 2017 to 31 Aug 2017 Minimum charge for 1 residence	$19.35
State Senior concession		$16.99CR
	Service charges	**$187.65**
	Total charges	**$197.17**

Gas

Please fill in your gas bill details from the previous 12 months if you have them available.

Plan: ____

Bill period (dates and # of days)	Total units used (kWh)	Total cost ($)

This information can be found on the front and back of your bill, placement varies according to provider but follows a similar formate to water and electricity bills.

Send me a picture of…

Over the two weeks I will text you to ask you to send me a picture of the following….

A piece of technology that saves you time

Something you won't be taking with you to WGV

How you kept warm today

How you kept cool today

An appliance that you use for convenience

What is in your recycling bin before you put it out

How you keep in contact with people

How you got around today

How you kept comfortable today

What 'home' means to you

What 'sustainability' means to you

Postcard questions pre-occupancy

Resident	Questions	Response?
A	Tell me what sustainable travel means to you?	N
B	Tell me what eating sustainably means to you	Y
C	Tell me about your travel habits and if you think they are sustainable?	N
D	Tell me about being social and sustainable Tell me about food and low carbon housing	Y Y
E	Tell me about using water sustainably	N
F/f	Tell me what sustainable travel means to you?	Y
F/m	What does it mean to live sustainably to you?	Y
G	Tell me what sustainable travel means to you?	Y
H	Tell me about the social aspect of housing Tell me about sustainable water use	Y Y
I	Tell me about sustainable travel	N
J	Tell about living sustainably with a pet Tell me about sustainable gardening	Y Y
K	Tell me about your favourite way to communicate with people	Y
L	Tell me about sustainable food Tell me about sustainable technology	Y Y
M	What does it mean to live sustainability?	Y
N	Tell me about sustainable gardening Tell me about sustainable travel	Y Y
O	What does it mean to live sustainability?	N

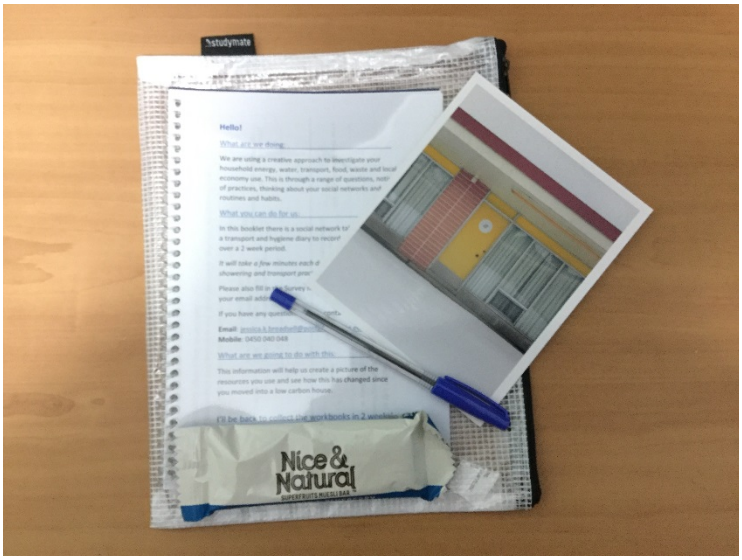
Text probe questions pre-occupancy

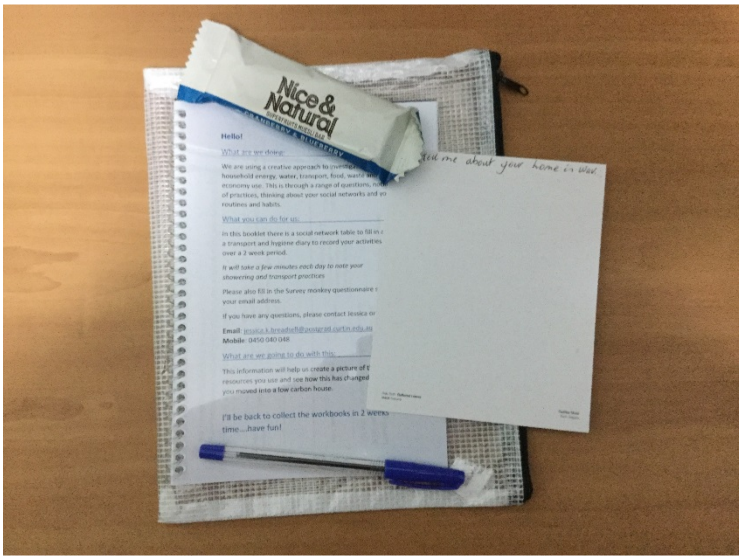
NA indicates that the question was not sent

Text/ response	A	B	C	D	E	F/f	F/m	G	H	I	J	K	L	M	N	O
A piece of technology that saves you time	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	NA	Y	Y
Something you won’t be taking with you to WGV	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	Y	Y
How you got around today	NA	Y	Y	Y	Y	NA	NA	N	Y	Y	Y	Y	Y	NA	Y	Y
An appliance that you use for convenience	Y	Y	N	Y	Y	NA	NA	Y	Y	Y	Y	Y	Y	NA	Y	Y
How you kept comfortable today	Y	N	Y	NA	Y	NA	NA	Y	NA	Y	NA	N	NA	NA	NA	Y
What is in your recycling bin before you put it out	Y	Y	Y	NA	NA	Y	Y	Y	NA	Y	NA	NA	Y	NA	NA	Y
What ‘home’ means to you	Y	Y	Y	NA	Y	Y	Y	Y	NA	N	NA	N	NA	NA	NA	Y
How you kept warm today	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	NA	N	Y
How you kept cool today	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	NA	NA	Y	Y
How you keep in contact with people	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	NA	Y	Y
What ‘sustainability’ means to you	Y	Y	Y	NA	Y	Y	Y	Y	NA	Y	NA	Y	NA	NA	NA	Y

Appendix D: Post-occupancy workbook, survey and cultural probes

Workbook post-occupancy all participants





Hello!

What are we doing:

We are using a creative approach to investigate your household energy, water, transport, food, waste and local economy use. This is through a range of questions, noting of practices, thinking about your social networks and your routines and habits.

What you can do for us:

In this booklet there is a social network table to fill in and a transport and hygiene diary to record your activities over a 2 week period.

It will take a few minutes each day to note your showering and transport practices

Please also fill in the Survey monkey questionnaire sent to your email address.

If you have any questions, please contact Jessica on:

Email: jessica.k.breadsell@postgrad.curtin.edu.au
Mobile: 0450 040 048

What are we going to do with this:

This information will help us create a picture of the resources you use and see how this has changed since you moved into a low carbon house.

I'll be back to collect the workbooks in 2 weeks' time....have fun!

Social Networks

Please fill in the following information, names may be repeated:

Most important people in your present life

This will not be used for identification purposes

First name	Suburb	Live in same house?	How often do you communicate? Daily, weekly, once a month, quarterly, once a year	Did they influence your move to WGV?

People you talk to about living sustainably
ie. Water use, energy use, transport use, food use, waste disposal, purchasing habits
This will not be used for identification purposes

First name	**Suburb**	**Live in same house?**	**How often do you communicate? Daily, weekly, once a month, quarterly, once a year**	**Did they influence your move to WGV?**	**What sustainability topics do you discuss?**

My personal hygiene

Date	Time	Length	How?	Reason
Eg: 1/5/17	7am	4 min	Shower	Wake up before work, get clean
Eg: 1/5/17	6pm	1 min	Wash face with cloth	Freshen up before going out to dinner

My personal hygiene cont…

Date	Time	Length	How?	Reason

My personal hygiene cont…

Date	Time	Length	How?	Reason

My personal hygiene cont…

Date	Time	Length	How?	Reason

My transport diary

Date	Time	Duration	Method	Distance approx	Travel with anyone?	Reason
Eg: 1/5/17	7:35am	45min	Walk, bus & train	20km	Alone	Going to work
Eg: 2/5/17	5:00pm	15mins	Bus	10km	With partner	Shopping

My transport diary cont…

Date	Time	Duration	Method	Distance approx	Travel with anyone?	Reason

My transport diary cont…

Date	Time	Duration	Method	Distance approx	Travel with anyone?	Reason

My transport diary cont…

Date	Time	Duration	Method	Distance approx	Travel with anyone?	Reason

General comments

Please enter any additional comment or feedback you would like to provide below:

Send me a picture of…

Over the two weeks I will text you to ask you to send me a picture of the following….

A piece of technology that saves you time

How you kept warm today

How you kept cool today

An appliance that you use for convenience

What is in your recycling bin before you put it out

What 'home' means to you

What 'sustainability' means to you

How you keep in contact with people today

How you got around today

How you kept comfortable today

Online survey post-occupancy

Welcome to the WGV data collection survey

What are we doing:
We are using a creative approach to investigate your household energy, water, transport, food, waste and local economy use. This is through a range of questions, noting of practices, thinking about your social networks and your routines and habits.

What you can do for us:
This survey is about your resource use with some short answer questions and questionnaires about different daily practices.
It will take approximately 30 minutes to complete.

You will need to use the physical booklet provided to track your personal hygiene and transport practices and your social networks.

What are we going to do with this:
This information will help us create a picture of the resources you use and see how this has changed since you moved into a low carbon house.

Household information

* 1. What is your name?

2. To which gender identity do you most identify?

- Female
- Male
- Transgender Female
- Transgender Male
- Gender Variant/non-conforming
- Prefer not to answer
- Other (please specify)

3. What is your age?

- 18 - 29
- 30 - 44
- 45 - 59
- 60 - 79
- 80 +

4. How many adults (over 18) live in your household usually?

5. How many children usually live in your household?

6. What is the highest level of education you have completed?

7. What was your total household income?

- ◯ $0 to $9,999
- ◯ $10,000 to $24,999
- ◯ $25,000 to $49,999
- ◯ $50,000 to $74,999
- ◯ $75,000 to $99,999
- ◯ $100,000 to $124,999
- ◯ $125,000 to $149,999
- ◯ $150,000 to $174,999
- ◯ $175,000 to $199,999
- ◯ $200,000 and up
- ◯ Prefer not to answer

8. What does a normal weekday look like for you and other members of your household? Please check the boxes that apply for you and each of your household members.

	Full-time worker	Part-time worker	Work from home	Shift worker including weekends	Work varying hours each weekday	At home	Pre-schooler at home	Full-time student/day care	Part-time at day care
You	◯	◯	◯	◯	◯	◯	◯	◯	◯
Member 1	◯	◯	◯	◯	◯	◯	◯	◯	◯
Member 2	◯	◯	◯	◯	◯	◯	◯	◯	◯
Member 3	◯	◯	◯	◯	◯	◯	◯	◯	◯
Member 4	◯	◯	◯	◯	◯	◯	◯	◯	◯
Member 5	◯	◯	◯	◯	◯	◯	◯	◯	◯

General questions

9. The biggest proportion of energy consumed in an Australia household is for heating and cooling purposes

- [ ] True
- [ ] False
- [ ] Do not know

10. Coal is a renewable energy resource

- [ ] True
- [ ] False
- [ ] Do not know

11. Solar energy accounts for 10% of the total Australian electricity production

- [ ] True
- [ ] False
- [ ] Do not know

12. CO_2 emissions play a crucial role in global warming

- [ ] True
- [ ] False
- [ ] Do not know

13. What are your view of the following statements:

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Comfort at home in summer is important to me even if it means spending more each month for energy	○	○	○	○	○
Comfort in winter is important to me but I won't spend more money each month for energy	○	○	○	○	○
It is not important for me to find ways to control my energy costs	○	○	○	○	○

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
It is important for me to find ways to control my water costs	◯	◯	◯	◯	◯
Living in a comfortable and attractive home is an important goal for me.	◯	◯	◯	◯	◯
I work hard to reduce my greenhouse gas emissions whenever possible.	◯	◯	◯	◯	◯
I feel very good when I am successful in reducing my greenhouse gas emissions.	◯	◯	◯	◯	◯
I would feel very bad if I failed to reduce my greenhouse gas emissions.	◯	◯	◯	◯	◯
Most people work hard to reduce their greenhouse gas emissions whenever possible.	◯	◯	◯	◯	◯
Most people think it is very important to reduce their greenhouse gas emissions.	◯	◯	◯	◯	◯
I believe most of my acquaintances save energy whenever possible	◯	◯	◯	◯	◯
I believe most of my acquaintances save water whenever possible	◯	◯	◯	◯	◯
I know how to behave in an environmentally friendly way	◯	◯	◯	◯	◯
I have friends and family outside the home who can give me advice about, or practical support for doing things that reduce greenhouse gas emissions.	◯	◯	◯	◯	◯

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Members of my household keep track of what is happening in the household to make sure the goal of reducing greenhouse gas emissions in the household is achieved (Think about how your household generally operates 'on average' in terms of this goal. If you are the only member of your household, just answer in terms of yourself).	○	○	○	○	○
Members of my household remind each other to behave in a way that helps achieve this goal of reducing greenhouse gas emissions in the household (Think about how your household generally operates 'on average' in terms of this goal. If you are the only member of your household, just answer in terms of yourself).	○	○	○	○	○
Our household income is high enough to satisfy nearly all our important desires.	○	○	○	○	○

14. Rate the importance of the following values as guiding principles in your life:

	Extremely important	Very important	Moderately important	Slightly important	Not at all important
Pleasure: joy, gratification of desires					
Enjoying life: enjoying food, sex, leisure					
Self-indulgent: doing pleasant things					
Equality: equal opportunity for all					
A world at peace: free of war and conflict					
Social justice: correcting injustice, care for the weak					
Helpful: working for the welfare of others					
Respecting the earth: harmony with other species					
Unity with nature: fitting into nature					
Protecting the environment: preserving nature					
Preventing pollution: protecting natural resources					
Social power: control over others, dominance					
Ambitious: hard-working, aspiring					
Authority: the right to lead or command					
Influential: having an impact on people and events					
Wealth: material possessions, money					

Energy

15. How often has your family used a heater since moving in to WGV?

- ○ Every day
- ○ A few times a week
- ○ About once a week
- ○ A few times a month
- ○ Once a month
- ○ Less than once a month
- ○ Never

16. When you use the heater, what time of the day do you usually have it on?

- ☐ Mornings
- ☐ Afternoons
- ☐ Evenings
- ☐ Over night
- ☐ All day

17. How often has your family used the air conditioning since moving in?

- ○ Every day
- ○ A few times a week
- ○ About once a week
- ○ A few times a month
- ○ Once a month
- ○ Less than once a month
- ○ Never

18. When you use the air conditioning, what time of the day do you usually have it on?

- ☐ Mornings
- ☐ Afternoons
- ☐ Evenings
- ☐ Over night
- ☐ All day

19. How often has your family used a fan since moving in?

- ○ Every day
- ○ A few times a week
- ○ About once a week
- ○ A few times a month
- ○ Once a month
- ○ Less than once a month
- ○ Never

20. When you use the fan, what time of the day do you usually have it on?

- [ ] Mornings
- [ ] Afternoons
- [ ] Evenings
- [ ] Over night
- [ ] All day

21. How often do you

	Very often	Often	Sometimes	Rarely	Very rarely
Wear more clothes instead of more heating	○	○	○	○	○
Turn lights off in unused rooms	○	○	○	○	○
Turn off unused computer and monitor	○	○	○	○	○
Reduce heating in unused rooms	○	○	○	○	○
Reduce cooling in unused rooms	○	○	○	○	○
Turn off heating before opening windows	○	○	○	○	○
Turn off cooling before opening windows	○	○	○	○	○
Unplug unused appliances	○	○	○	○	○
Use a power strip to turn off electronic equipment when it is not in use	○	○	○	○	○
Unplug battery rechargers when they are not being used	○	○	○	○	○
Perform annual maintenance on heating, ventilation, or AC equipment	○	○	○	○	○

22. Do you think there is a relationship between your energy consumption and your feeling of comfort at home? *Are you only comfortable when the room is a certain temperature?*

Water

23. How important to you is it to

	Very important	Important	Moderately important	Slightly important	Not at all important
Take long showers (over 4 mins)	○	○	○	○	○
Wear fresh clothes every day	○	○	○	○	○

24. How often do you

	Very often	Often	Sometimes	Rarely	Very rarely
Wait until I have a full load for washing before I do my laundry	○	○	○	○	○
Use a washing machine for clothes because it fits my schedule, even though I do not have a full load	○	○	○	○	○
Do my laundry with a lower temperature than 60 degrees	○	○	○	○	○
Turn off the tap when washing dishes	○	○	○	○	○
Only turn on the dishwasher when it is full	○	○	○	○	○
Turn tap off when soaping up	○	○	○	○	○
Turn tap off when cleaning teeth	○	○	○	○	○
Use a shower rather than bath	○	○	○	○	○
Dry clothes without using a tumble drier	○	○	○	○	○
Choose plants that need less water	○	○	○	○	○
Avoid hosing down decks, walkways, driveways	○	○	○	○	○

25. Do you think there is a pattern between your water use and feeling clean or comfortable?

Showering, washing clothes or dishes

Life at WGV

26. Have you accessed the WGV dashboard energy/water real-time display?

- Yes
- No

27. How often do you access the WGV dashboard energy/water display?

- Every day
- A few times a week
- About once a week
- A few times a month
- Once a month
- Less than once a month

28. How do you use the information about your electricity and water consumption provided by the WGV data dashboard?

- I keep an eye on it out of curiosity
- I try to change habits to reduce my consumption
- I try to identify where the electricity/water is coming from as an educational tool
- Other (please specify)

29. How comfortable are you finding the house in relation to

	Very comfortable	Mostly comfortable	Neutral	Mostly uncomfortable	Very uncomfortable
Temperature					
Natural lighting					
Space setup					
Noise					
Air quality					

30. If you answered ‘very uncomfortable’, ‘mostly uncomfortable’ or ‘neutral’ for any of these, could you please explain why?

31. How often have you felt very cold in your accommodation at WGV?

- ◯ Every day
- ◯ A few times a week
- ◯ About once a week
- ◯ A few times a month
- ◯ Once a month
- ◯ Less than once a month

32. How often have you felt very hot in your accomodation at WGV?

- ◯ Every day
- ◯ A few times a week
- ◯ About once a week
- ◯ A few times a month
- ◯ Once a month
- ◯ Less than once a month

33. How often do you use your private outdoor area in your accommodation at WGV?

- ◯ Every day
- ◯ A few times a week
- ◯ About once a week
- ◯ A few times a month
- ◯ Once a month
- ◯ Less than once a month

34. How often do you use the public outdoor areas in WGV?

- ◯ Every day
- ◯ A few times a week
- ◯ About once a week
- ◯ A few times a month
- ◯ Once a month
- ◯ Less than once a month

Food

35. Do you make your meals at the same time each day?

- ◯ Yes
- ◯ No

36. Why/why not? What influences this?

37. How important to you is it to

	Extremely important	Very important	Somewhat important	Not so important	Not at all important
Eat freshly prepared food every day	◯	◯	◯	◯	◯
Eat home cooked meals every day	◯	◯	◯	◯	◯

38. How often do you

	Very often	Often	Sometimes	Rarely	Very rarely
Buy food with less packaging instead of food with more packaging	◯	◯	◯	◯	◯
Buy a product with a fair trade symbol	◯	◯	◯	◯	◯
Eat a meal without meat	◯	◯	◯	◯	◯
Eat organically grown food	◯	◯	◯	◯	◯
Compost or recycle garden waste	◯	◯	◯	◯	◯
Compost kitchen waste	◯	◯	◯	◯	◯
Check the cupboard/fridge before you shop	◯	◯	◯	◯	◯
Make a shopping list	◯	◯	◯	◯	◯
Plan meals for the week	◯	◯	◯	◯	◯

39. Do you think there is a pattern between your use of food and convenience in your life? *Saving time, reducing stress, preference for food types, cooking skills*

Waste

40. How often do you

	Very often	Often	Sometimes	Rarely	Very rarely
Separate paper and cardboard from the rest of the waste	○	○	○	○	○
Separate plastics, cans, and cartons from the rest of the waste	○	○	○	○	○
Reuse paper	○	○	○	○	○
Reuse glass	○	○	○	○	○

41. Where do you get your knowledge about recycling?

Local economy

42. Do you use any local services such as babysitting, cleaners, Uber or delivery services?

- ◯ Yes
- ◯ No

43. Why/why not?

44. Do you use online shopping to purchase anything?

- ◯ Yes
- ◯ No

45. Why/why not?

46. When purchasing a new appliance, rank the following for influence from least influential to the greatest influence, with one answer per option.

	Least influence				Greatest influence
Cost	◯	◯	◯	◯	◯
Energy/water rating	◯	◯	◯	◯	◯
Aesthetics	◯	◯	◯	◯	◯
Manufacturer	◯	◯	◯	◯	◯
Friends and family recommendation	◯	◯	◯	◯	◯

Purchasing habits

These questions are referring to your actions when you need to make a purchase for your household.

47. How often do you

	Very often	Often	Sometimes	Rarely	Very rarely
Purchase high efficiency bulbs	○	○	○	○	○
Purchase energy efficient appliances	○	○	○	○	○
Buy recycled paper	○	○	○	○	○
Buy recycled toilet paper	○	○	○	○	○
Buy locally produced foods	○	○	○	○	○
Buy from a local store (non-supermarket chain)	○	○	○	○	○
Use own bags/containers when shopping	○	○	○	○	○
Refuse plastic bags or wrappings offered by shopkeepers	○	○	○	○	○
Repair products or have them repaired instead of buying them new	○	○	○	○	○
Donate furniture to charity	○	○	○	○	○
Donate clothes to charity	○	○	○	○	○
Purchase furniture from charity	○	○	○	○	○
Purchase clothes from charity	○	○	○	○	○
Avoid drinking bottled water	○	○	○	○	○

Travel

48. How would you get to the following places in a normal day?

	Car/motorbike	Bus	Train	Walk	Bicycle
Work	☐	☐	☐	☐	☐
Shops	☐	☐	☐	☐	☐
Traveling whilst at work	☐	☐	☐	☐	☐
Local leisure journeys	☐	☐	☐	☐	☐
Visiting friends/relatives locally	☐	☐	☐	☐	☐
Taking children to school	☐	☐	☐	☐	☐

49. What is your annual car mileage? Including car share, taxi, uber kms

- ◯ Less than 10,000km
- ◯ 10,000 - 15,000 km
- ◯ 15,000 - 20,000 km
- ◯ 20,000 - 30,000km
- ◯ Over 30,000km

50. Do you structure your transport around other events?*Peak hour, school times?*

51. What activities do you do when you are commuting?*Listen to ebooks, read the news, write?*

52. Do you have difficulties in getting to places?

53. How often do you

	Very often	Often	Sometimes	Rarely	Very rarely
Choose to extend the walking portion of my trip to my final destination	◯	◯	◯	◯	◯
Use public transport as my main mode of travel	◯	◯	◯	◯	◯
Stop at facilities (such as cafes/shops) as part of my journey to work or home	◯	◯	◯	◯	◯
Not use the car for short trips	◯	◯	◯	◯	◯
Walk to close facilities if possible (shops/markets, parks, cafes)	◯	◯	◯	◯	◯
Use public transport or walking/bike options when visiting friends/family	◯	◯	◯	◯	◯
Engage in carpooling	◯	◯	◯	◯	◯

54. What are your views on the following statements

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I try to end my journey by motorised transport as close to my destination as possible to minimise walking	○	○	○	○	○
There is a clear maximum distance I am willing to walk from any bus stop/station to my final destination	○	○	○	○	○
A poor link in a journey means I tend to drive my car	○	○	○	○	○
I would consider changing my main mode of travel if a poor link in the journey was made more attractive	○	○	○	○	○
My home to work journey changes significantly with daily weather conditions	○	○	○	○	○
Most of my friends and relatives do not use public transport regularly	○	○	○	○	○
Using the car is something that belongs to my everyday routine	○	○	○	○	○
Not using the car is something I would find hard	○	○	○	○	○
Walking and/or cycling is convenient for me	○	○	○	○	○

Holiday travel

55. Number of holidays in the past year (over 4 nights)

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5+

56. Number of short breaks in the past year (3 nights or under)

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5+

57. Considering your recent holidays, who do you go on holidays with?

58. Considering your recent holidays, how do you get to your destination?

59. Do you own a holiday home?

- ○ Yes
- ○ No

60. If so, how often do you use it and how do you travel to get to it?

61. When on holiday, how often do you

	Very often	Often	Sometimes	Rarely	Very rarely
Travel overland instead of flying	○	○	○	○	○
Offset carbon emissions	○	○	○	○	○
Choose environmentally friendly accommodation	○	○	○	○	○
Visit non-touristic towns	○	○	○	○	○
Shop at supermarkets to cook at accommodation	○	○	○	○	○
Buy locally made souvenirs	○	○	○	○	○
Shop at markets	○	○	○	○	○

62. When on holidays, what is your view of the following statements

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Walking and/or cycling is hard for me	○	○	○	○	○
Taking public transport is convenient for me	○	○	○	○	○
Holidays are a time when I don’t have to think about the environment	○	○	○	○	○
I try to save water when I’m on holiday	○	○	○	○	○
I don’t try to save energy when I’m on holiday	○	○	○	○	○
I try to use the fastest mode of transport to get there quickly	○	○	○	○	○
I don’t think about how I can reduce environmental damage when I go on holiday	○	○	○	○	○

Final comments

63. Please enter any additional comment or feedback you would like to provide on this study

Postcard questions post-occupancy

Code	Questions	Response?
A	Tell me about your home in WGV	N
B	Tell me about living in WGV with your family	N
C	Tell me about your home in WGV	N
D	Yell me about living in WGV with your family	N
F/f	Tell me about your home in WGV	Y
F/m	Tell me about communicating with people in WGV	Y
G	Tell me about communicating with people in WGV	N
H	Tell me about your home in WGV	Y
I	Tell me about the gardens at WGV	Y
J	Tell me about living with a pet in WGV	Y
M	Tell me about gardening in WGV	Y
N	Tell me about communicating with people in WGV	Y
O	Tell me about your life in WGV	N

Text probe questions post-occupancy.

NA indicates that the question was not sent

Text/ response	A	B	C	D	F/f	F/m	G	H	I	J	M	N	O
A piece of technology that saves you time	Y	Y	N	NA	Y	Y	Y	NA	NA	Y	Y	Y	Y
How you kept warm today	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
How you kept cool today	Y	NA	Y	N	Y	Y	Y	Y	NA	Y	Y	N	NA
An appliance that you use for convenience	Y	NA	Y	Y	Y	Y	Y	N	NA	Y	Y	Y	NA
What are some things you recycle?	NA	NA	NA	NA	NA	NA	NA	NA	NA	Y	NA	Y	NA
What ‘home’ means to you	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y
What ‘sustainability’ means to you	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
How you keep in contact with people today	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
How you got around today	Y	Y	Y	N	NA	NA	Y	NA	NA	Y	Y	Y	Y
How you kept comfortable today	Y	Y	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	NA

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Title: The home as a system of practice and its implications for energy and water metabolism

Author: Christine Eon, Jessica K. Breadsell, Gregory M. Morrison, Joshua Byrne

Publication: Sustainable Production and Consumption

Publisher: Elsevier

Date: January 2018

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Changes to household practices pre- and post-occupancy in an Australian low-carbon development

Author: Jessica K. Breadsell,Gregory M. Morrison

Publication: Sustainable Production and Consumption

Publisher: Elsevier

Date: April 2020

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