Reconstructing low-energy housing using 'systems of practice'.

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Abstract

The residential sector accounts for a third of energy use in the UK (DECC, 2014b) and generates fifteen percent of greenhouse gas emissions (DECC, 2014c). Low-energy housing is therefore critical to meeting climate change mitigation targets (DECC, 2011). New homes are required to be carbon-neutral by 2016, presenting a considerable challenge to the housing industry (DCLG, 2006). Addressing this ambition remains shaped by the 'techno-rational paradigm', where energy savings rely on optimal design, technological diffusion and 'correct' use. In contrast, this thesis understands technologies and 'behaviours' as connected through social practices, which interrelate in dynamic 'systems of practice'.

Housing policy, newly built homes, and domestic practices are critical to governing low-energy housing transformations, yet initiatives consistently fail to account for inter-connections between these different practices. Whilst interventions are attempted, they frequently go awry, or operate in unexpected ways. Developing a systems of practice analysis, this thesis analyses implementation of the Code for Sustainable Homes (CSH) - a building energy performance standard introduced to drive 'a step-change in sustainable home building practice' (DCLG, 2006). A Norfolk-based affordable housing scheme, accredited as carbon-neutral, forms the focus of this mixed-methods case-study.

The research identifies that householders incorporate energy-efficient building materials and renewable technologies in ways that frequently fail to mesh with designers' assumptions. Housing professionals also struggle to modify ingrained 'ways of doing'. Importantly, these actors and their practices are enabled, or constrained, by connections within and across broader practice systems. This has important governance implications. Research and policy should therefore: (i) conceptually map the housing system delimiting the network of involved actors and agents, and identifying pivotal links for target practices or interventions, (ii) generate multi-actor and multi-pronged interventions and join up distributed sources of evidence, and (iii) attend to how interventions generate reactions, interactions and resistances across the practice system.

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Chapter 1. Introduction: Laying the foundations for low-energy housing

Climate change presents an urgent international challenge and opportunity to transform resource and energy governance. The latest Intergovernmental Panel on Climate Change (IPCC) assessment report unequivocally states that,

> 'Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems' (IPCC, 2014: 2).

It further states that,

> 'Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions, which together with adaptation, can limit climate change risks' (IPCC, 2014: 8).

To limit extensive and damaging societal, economic and environmental effects, sizeable and enduring reductions in greenhouse gas emissions are urgently required, alongside implementation of adaptive measures. Since the mid-1990s, the aim of limiting average global temperature rise to within 2°C (above pre-industrial levels) has been firmly entrenched in policy discourse, and since 2009 this goal has been central to international negotiations associated with climate change (Jordan *et al.*, 2013; Copenhagen Accord, 2009). Whilst debates about the level, speed, and viability of global carbon emission reductions required to achieve this target rages on (e.g. Smith *et al.*, 2009; Birol and Stern, 2011; Ghosh, 2012; Hulme, 2012; Rogelj *et al.*, 2012; Jordan *et al.*, 2013; Warren *et al.*, 2013; Tscharkert, 2015) most international governments, including the United Kingdom (UK), have recognised that global society needs to work towards mitigating climate change and radical decarbonisation (Anderson and Bows, 2008).

Perturbations to the global climate present a huge challenge to the way that the UK plans and builds housing, and to the way that homes are lived in, because the residential sector substantially contributes to this environmental, social, political and economic threat. Reducing greenhouse gas emissions resulting from the construction and operation of new homes is of paramount importance to the UK's climate change mitigation strategy. This challenge is critical especially given that housing architecture and infrastructure will shape how we live in years to come, contributing to future energy use and associated emissions (Macrorie *et al.*, 2014a). It is also essential that we address how homes are lived in, because greenhouse gas emissions, notably carbon dioxide emissions, arise from the supply, distribution and use of electricity and gas for heating, cooking, lighting, washing, work and entertainment purposes.

The challenge of addressing energy consumption and emissions reduction within the residential sector has been the focus of many policies, industry initiatives and academic studies since the 1970s, receiving particular attention within the last decade (e.g. Lovell, 2004; Banfill and Peacock, 2007; Boardman, 2007a; Reeves *et al.,* 2010; Monahan and Powell, 2011; Reid and Houston, 2013). Despite seeming progress however, this thesis contends that these interventions have continually failed to deliver the pace, scale and longevity of transformations required for low-energy homes to constitute the new norm for housing (Macrorie *et al.,* 2014a). Instead, adopting a UK focus, this research examines a radically different, sociologically informed and systems based approach for researching and planning low-energy housing policy and practice.

Throughout this thesis, I investigate and appraise how this alternative approach, informed by theories of social practice (Giddens, 1984, 1991; Boudieu, 1984, 1990; Reckwitz, 2002a; Schatzki, 1996, 2002; Schatzki *et al.*, 2001; Shove, 2003; Warde, 2005; Shove and Pantzar, 2005; Shove *et al.*, 2012), substantially contributes to tackling the challenge of energy consumption reduction and curbing greenhouse gas emissions associated with the residential sector. Whilst acknowledging the environmental implications of energy-inefficient existing housing stock within the UK (e.g. Karvonen, 2013; Judson and Maller, 2014), this thesis focuses on new build housing. In particular, attention is given to the design, construction and operation of a new social housing development in accordance with the trial of a particular building sustainability standard, the Code for Sustainable Homes (hereafter CSH or the Code).

1.1. Existing attempts to deliver a less energy-intensive residential sector

The global political response towards achieving long-term reductions in greenhouse gas emissions began with the United Nations Framework Convention on Climate Change in 1994 and the first legally binding protocol, The Kyoto Protocol, was adopted in 1997 (Monahan, 2013). Under this protocol the UK committed to reducing its emissions by 12.5 percent by 2012. This initial pledge was made more stringent when The Energy White Papers set out an assurance of making a 60 percent cut in emissions by 2050 (DTI, 2003; DTI, 2007). Consistent with limiting global temperature rise to 2°C, by ratifying the Climate Change Act in 2008, the UK took the unprecedented step of increasing this pledge to a legally binding commitment to reduce greenhouse gas emissions by 80 percent by 2050, with an interim emission reduction of at least 34 percent by 2020 (against a 1990 baseline) (Climate Change Act, 2008). The Act also provisioned for a carbon budgeting system that would cap emissions over five-year periods.

In accordance with this rationalist, science-led rationalist approach (Reid and Houston, 2013: 2; Abbott and Wilson, 2014), the UK Government recognises that to stay within these carbon budgets, and to create a low carbon economy (which is projected to reach £4 trillion by 2015 as economies around the world invest in low carbon technology, DECC, 2011: 12) - 'major structural changes to the way in which we work and live, including how we source, manage and use our energy' are required (*ibid.*: 15). These transformations are also necessary given that the nation faces three challenges to its energy security (*ibid.*: 14).These are: first, greater import levels of oil and gas, second, a reduction in electricity generation capacity due to the close of ageing coal and nuclear plants, and third, an increased reliance on renewable energy supplies (requiring intermittency in electricity supply and variable demand to be balanced). The Coalition Government's Carbon Plan outlines how such a profound transformation will be achieved,

> 'Energy-efficiency will have to increase dramatically across all sectors. The oil and gas used to drive cars, heat buildings and power industry will, in large part, need to be replaced by electricity, sustainable bioenergy, or hydrogen. Electricity will need to be decarbonised through renewable and nuclear power, and the use of carbon capture and storage (CCS). The electricity grid will be larger and smarter at balancing demand and supply' (DECC, 2011: 4).

A key sector required to deliver this transformation in energy supply and demand is the residential sector. In 2013 domestic energy consumption was responsible for just under one third of energy consumed in the UK - 29 percent of total UK final consumption of energy, compared to 24 percent in 1970 (DECC, 2014b: 5) (see Figure 1.1). This rise in overall energy consumption from housing is attributable to both demographic trends and a surge in the demand for energy. The number of households in the UK is growing due to net migration, an increasing life expectancy and a trend towards smaller households, and the UK population is projected to increase from 22.3 million in 2012 to 27.5 million in 2037 (DCLG, 2015). In addition, the continuing trend of small average household size and increasing single person households (*ibid.*; Palmer and Cooper, 2013) places further demand on energy resources.

The average UK home in 1970 would have been cold by contemporary standards; 12°C (Palmer and Cooper, 2013) compared to current expectations of central heating installed as standard, and temperatures being maintained at 21°C in the main living area and 18°C for the rest of the home (Boardman *et al.*, 2005; Boardman, 2007). In addition to the growth in heating energy demand, between 1970 and 2013 electricity consumption by household domestic appliances grew by 1.7 percent per year (DECC, 2014b:9). Indeed, during this period, demand for consumer electronics increased by 377 percent, demand for wet appliances increased by 154 percent and for cold appliances increased by 91 percent (*ibid.*).

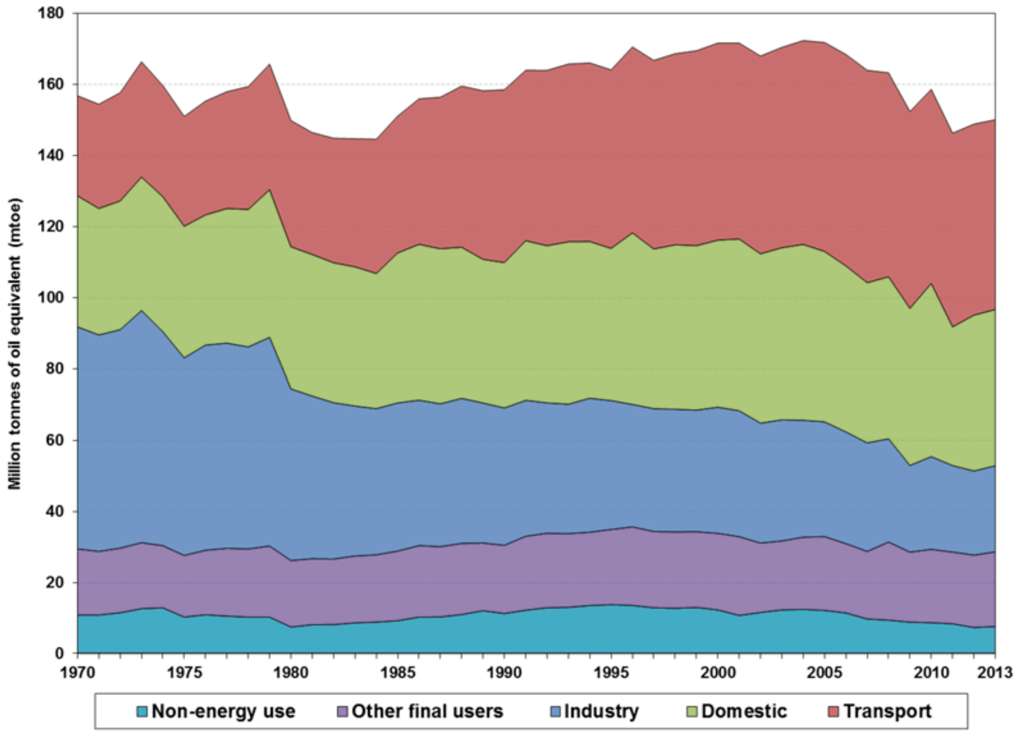


Figure 1.1 – Final energy consumption by sector, UK (1970 to 2013)

(Source: ECUK Table 1.05 – DECC, 2014)

Whilst household energy demand has risen, the number of houses constructed in the UK has been on a downward trend since the 1960s, decreasing housing availability and affordability (Barker, 2004; Calcutt, 2007). It has been estimated that 240,000 to 245,000 additional homes need to be built each year to 2031 in order to meet expanding demand and need in England (Schmuecker, 2011), and to this end, the Government has set a target of increasing the supply of housing to 240,000 additional homes per year by 2016 (Wilson, 2010). This ambitious growth programme is set against a growth in domestic electronic appliances, increasing expectations of home comfort and increasing levels of single occupancy. Given that in 2013 the residential sector contributed 14 percent of overall UK carbon emissions (DECC, 2015a), and taking this intended growth programme into consideration, in recent years, housing has come to the forefront of climate change mitigation and low carbon economy discussions.

The housing stock within the UK changes very slowly. Only around 160,000 new homes are built each year and far fewer homes are demolished (Palmer and Cooper, 2013). In addition the housing construction industry is frequently characterised as risk averse and conservative (Barker, 2003; Calcutt, 2007). Change within this sector has been described as occurring as an accumulation of tiny incremental modifications (Barlow, 1999; Ball, 1999), which, if the industry was left to operate without political intervention, would certainly be insufficient to bring about the scale of emission reductions required by the Government's low carbon plan (DECC, 2009; DECC, 2015b). Consequently, government policy and regulation has been the principal driver of energy-efficiency and emission reductions in the house-building industry.

The conservation and efficiency[1] of energy use in buildings was not explicitly discussed until 1976 (Monahan, 2013). Since this date, research, policy and industry activity on low-energy housing has been predominantly underpinned by a mode of problem framing labelled by Guy and Shove (2000) as the 'techno-rational paradigm'. This approach assumes that technological interventions alone will guarantee energy and carbon reductions. Once technical design has been optimised, according to this view, focus shifts to technology dissemination and ensuring the rapid uptake and 'correct' use of devices by individual consumers (Macrorie *et al.,* 2014a). However, because realised savings frequently fail to match predicted energy and carbon reductions (e.g. Bordass *et al.,* 2001; Branco *et al.,* 2004; Gill *et al.*, 2010; Menezes *et al.,* 2012), and persistent 'energy performance gaps' are often encountered (Shove, 1998), increasingly attention is placed on the activities of householders. Where occupants are considered however, the focus has remained fixed on removing 'barriers' to technology diffusion, or educating and incentivising users to encourage the 'correct' operation of technical devices and interaction with materials (see Leaman *et al.*, 2010; Whitmarsh *et al.,* 2011; DECC, 2013a). This approach has frequently failed to induce desired energy saving behaviours (e.g. Gram-Hanssen *et al.,* 2004; Firth *et al.,* 2008; Wingfield *et al.,* 2008; Stevenson and Leaman, 2010).

Recent years have seen the expansion of policy measures and initiatives designed to further the low-energy housing agenda (see Table 1.1). These interventions commenced in the 1970s when substantial technical energy-efficiency improvements were made by increasing levels of thermal insulation and enhancing the efficiency of space and water heating systems in residential properties. Arguably however, all of these interventions fall within the techno-rational paradigm in that they prioritise a technological-fix to address the problem of an environmentally unsustainable residential sector.

[1] Energy conservation refers to reducing energy consumption through using less of an energy service. Energy conservation differs from efficient energy use, which refers to using less energy for a constant service.

Year	Policy Intervention
1994	UN Framework Convention on Climate Change
1997	Kyoto Protocol
2003	UK Energy White Paper
2004	EU Energy Performance of Buildings Directive • UK Barker Review of Housing Supply
2006	Code for Sustainable Homes (CSH) launched in England, Wales and Northern Ireland
2007	UK Calcutt Review of House-building delivery • UK Housing Policy Statement: Zero Carbon Policy • UK Energy White Paper • Development of five eco-towns in England announced in New Growth Points programme • CSH becomes operational • Start of global economic downturn
2008	UK Climate Change Act • UK Energy Act • Zero Carbon Hub (ZCH) launched
2009	UK Low Carbon Transition Plan • Eco-towns Planning Policy Statement • Consultation on workability of zero carbon definition
2010	£60M made available for UK eco-town demonstration projects • UK Coalition Government elected: environmentally-friendly development by local communities • EU Energy Performance of Buildings Directive: new buildings to be 'nearly zero energy' by end 2020 • UK Building Regulations target emission rate 25% improvement on 2006 level • Technical guidance for CSH published: minimum Fabric Energy Efficiency Standard (FEES)
2011	New Homes Bonus scheme for local authorities in England • ZCH announce 'Closing the performance gap 2020 ambition' • Eco-towns 2010/11 grants halved • Definition of zero carbon housing revised • Homes and Communities Agency (HCA) set minimum CSH level four requirement • Review of Feed-in-Tariffs (FiTs) for small-scale solar photovoltaic schemes
2012	UK Eco-towns Planning Policy Statement dropped • UK National Planning Policy Framework
2013	UK Renewable Heat Incentive (domestic) sets tariff for renewable heat technologies • UK Housing Standards Review consultation announced
2014	'Next steps to zero carbon homes: allowable solutions' consultation published • Revised Part L (Conservation of Fuel and Power) UK Building Regulations strengthens Target Emissions Rate and emphasises fabric energy efficiency • Locally-led Garden Cities prospectus
2015	Zero carbon homes standard officially dropped
2016	Original target for all new homes in UK to be carbon zero
2050	UK Government committed to reducing carbon emissions by 80% from 2003 levels

Table 1.1 – Key low-energy policy developments applicable to UK housing sector

Where occupants are considered, they are framed as rational actors who act in their own economic self-interest. Key low-energy housing initiatives attempted during the last two decades have included: statutory regulations and targets (e.g. Building Regulations (The Building Regulations 2010 - SI 2010/2214), Zero Carbon Policy (DCLG, 2007a), Energy Performance Certificates (EPCs) (DECC, 2015c)), voluntary building energy performance standards and assessment methodologies (e.g. Passivhaus and BREEAM, see Glossary), and industry targets and consumer loan schemes aimed at increasing domestic energy-efficiency[2].

[2] For example, the former Carbon Emissions Reduction Target (CERT) required energy suppliers to achieve targets for reducing carbon emissions within residential properties (Watson and Bolton, 2013) whilst its replacement - the Green Deal - is a loan scheme aimed at retrofitting privately-owned properties (DECC, 2015d).

Low-energy housing policies have also taken the form of financial incentives aimed at promoting renewable technologies, for example Feed-in-Tariffs (FiTs)(DECC, 2015f) and the Renewable Heat Incentive (RHI)(DECC, 2015e).

The construction of new, low-energy buildings – such as those designed with high energy-efficiency, installed with 'smart' technologies and/or electricity generation capabilities – has formed a central plank of policy approaches intended to tackle emission reductions from the housing sector (Reid & Houston 2013; Macrorie *et al.*, 2014a). To aid this transformation in building construction, new institutions, such as the Zero Carbon Hub (ZCH, 2015) and the Passivhaus Institute (Passivhaus Institute, 2015), have been established and associated professional accreditation courses have been developed. Combining carbon emissions reduction at the household level with policy objectives of additional housing provision also resulted in endorsement of eco-towns by the Labour Government (DCLG, 2008a), a concept recently reformulated into garden cities by the Coalition Government (BBC News, 2014). Together, these developments have been made manifest in a burgeoning number of pilot projects around low-energy housing (Brown and Vergragt, 2008; Lovell 2004, 2007a, 2007b). Table 1.1 shows the complexity of this policy landscape, which has, the housing industry and consumer groups argue (NHBF, 2012), contributed to a failure to shift the residential sector in less energy-intensive directions.

These actions have contributed to energy use per household declining by 18 percent between 1970 and 2012 (Palmer, 2011; Palmer and Cooper, 2013), although the growth of new households and ever-increasing expectations around how energy is used at home largely offset these efficiency gains (*ibid.*). Whilst energy consumption and carbon emissions fluctuate on a year on year basis in the residential sector due in part to changing weather conditions and energy tariffs, between 2000 and 2013, collectively these techno-rational policy measures led to domestic energy consumption per household falling by 9 percent (DECC, 2014b: 5). This reduction was largely brought about by improvements in thermal efficiencies, which decreased the volume of natural gas used for domestic heating. Figure 1.2 illustrates the steady decline in household energy consumption that occurred between 2008 and 2013.

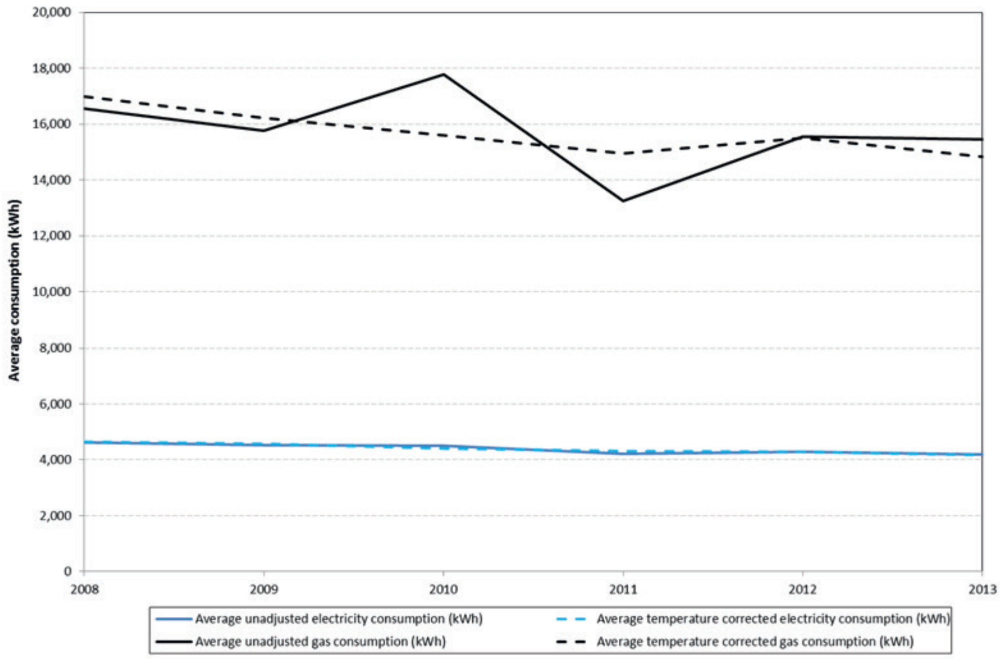


Figure 1.2 – Average domestic (unadjusted and temperature corrected) gas and electricity consumption, UK (2008 to 2013)

(Source: ECUK Tables 3.07 – DECC, 2014b)

Despite this welcome recent trend, the rate of decline in energy consumption is far from sufficient to bring about the substantial emission cuts demanded for the UK to meet its legally binding carbon budget targets for this sector (Oreszczyn and Lowe, 2010; CCC, 2014). Policies regulating the technical construction and energy performance of residential buildings in the UK have led to gradual changes in the structural composition of this sector. However, the persistent mismatch between architectural and engineering ambitions and the realised energy and carbon performance of lived-in homes, poses a substantial challenge for the UK government, housing industry and society as a whole. Furthermore, the plethora of different policies and initiatives trialled in recent decades, whether tackling how homes are technically constructed, incentivising the installation of renewables, or encouraging householders to cut back on their energy use, can all be understood as variations of the same linear techno-rational paradigmatic approach.

In low-energy housing initiatives, technological development and uptake is nearly always prioritised over understanding the energy consequences of domestic life. In designing a low-energy house, particularly using methods incorporating building performance simulation, standardised assumptions are commonly made about how the occupants will operate the building (Daniel *et al.*, 2015). However, the idea that materials and devices are socially neutral, and that they will be used exactly as intended (Brand, 2012), is technocratic, linear and reductive. Whilst there is growing recognition of the significance of household occupants, how users behave and how this contributes to building energy and carbon performance is poorly understood (Monahan, 2013).

When householders are considered, they are expected to act in a predictable way, using devices optimally and seeking to reduce their energy bills above all else (e.g. Strengers, 2013). This idea that people are rational individuals who act in their own self-interest, is partial and limited as it accounts insufficiently for the social, cultural and infrastructural arrangements that inherently shape what people do in their everyday lives. Indeed, a well-established critique of this techno-rational approach now exists, both as applied to the housing domain and to other areas of social life (e.g. Lutzenhiser, 1993; Guy and Shove, 2000; Wilhite *et al.*, 2000; Shove, 2003; Shove, 2010; Southerton *et al.,* 2004; Strengers, 2012; Ozaki and Shaw, 2013).

The rate of transformation towards a less energy intensive housing sector requires dramatic acceleration (e.g. CCC, 2014; DECC, 2011; ZCH, 2014). As such, there is an urgent need to critique and move away from the dominant, yet only partially effective, techno-rational paradigm. Sticking with this strategy, which arguably has a mutually reinforcing relationship with a large portion of academic research (Shove, 2010), will only continue to deliver variable and less than anticipated energy and carbon reductions in the residential sector. Instead, it is vital to investigate an alternative approach to enable environmentally sustainable, socially acceptable and politically and economically viable transformations in housing.

1.2. Ensuring firm foundations: Towards a new low-energy housing approach

In recent years social and cultural studies researchers have put forward alternative understandings of sustainability transformations that emphasise the irreducible multiplicity and non-linearity of our everyday lives and highlight how techno-rational interventions are unable to account for this complexity. Building on this research, this thesis highlights the limitations of the techno-rational approach to delivering low-energy housing, which is founded on: first, technological fixes and the social neutrality of technology; second, rational individualistic understandings of behaviour change (where householders are considered) and; third, linear and deterministic understandings of socio-technical change.

Instead, I argue that: first, building materials and technologies are inherently associated with cultural meanings and social expectations, and that their use and energy performance requires particular sets of tacit understandings and learnt skills. Technologies only have meaning through their being operated and used through practice. Furthermore they cannot be considered in isolation as they are not socially neutral, and they are inherently tied to wider infrastructural systems. Second, attention should turn away from individual consumers to the cultural, material, and economic structuring of consumption (e.g. Cohen and Murphy, 2001; Gronow and Warde, 2001; Shove, 2003; Southerton *et al.,* 2004; van Vliet *et al.,* 2005; Spaargaren, 2011). Rationalistic models of behaviour change are inappropriate for explaining everyday routines (*cf.* Halkier, 2001) and what people do is not simply a matter of cognitive decision-making (e.g. Macnaghten, 2003). In contrast, investigative attention should be placed on the social and cultural practices in which people engage, which make up social life (Schatzki, 2002), and that have critical implications for resource consumption (e.g. Warde, 2005).

Third, instead of understanding socio-technical change as a linear end-goal, I contend that there is a need to understand housing-related practices as connected within a broad and dynamically changing system. (Shove and Walker, 2007, 2010; Pantzar and Shove, 2010; Shove *et al.,* 2012; Watson, 2012; Spurling *et al.,* 2013; Macrorie *et al.,* 2014a&b (see Appendices O&P); Spurling and McMeekin, 2014). This 'system of practice' is sustained by the continuous performance of practices of which it is constituted (Watson, 2012). Changes in the residential sector can happen if the practices (and their interconnections) that determine how we design, build and live in our homes change. At the same time, because multiple, overlapping systems of practice make up social life, the housing sector can also change if indirectly connected practices change, such as how we work or shop. If practices and relations within the housing system of practice change, they will affect the configuration and overall energy performance of that system. I suggest then, that to reduce the energy and carbon implications of our homes, attention should be focussed on better understanding and attempting to reconfigure the housing 'system of practice', whilst paying attention to how it is related to overlapping practice systems.

To avoid the reductive shortcomings of conventional low-energy housing policy and research, this thesis adopts three original starting points. First, by adopting a social practice theory (SPT) approach, a focus on the social and collective organisation and *doing* of bundles of practice related to low-energy housing is advocated, as opposed to provision of techno-fixes or attempts to influence individuals' attitudes, values and behavioural choices. This research approach is unique in seeking to examine how different practices from across the housing sector (and beyond) overlap and relate, and exploring what these interconnections mean for reconfiguring housing practices in less energy-intensive directions. In conceptually developing and empirically applying a 'systems of practice' approach, this research extends traditional SPT analysis from isolated practices, charting new theoretical territory.

Second, this research focuses on appraising implementation of a particular building performance standard – the Code for Sustainable Homes (CSH) – as a policy initiative intended to embed a particular technical approach for delivering low-energy homes. The research assesses the design, construction and post-handover implications of building domestic properties to CSH level six (i.e. carbon neutral housing) at an exemplar site in the east of England.

Third, these two original starting points demand a particular research approach suitable for observing the situated performance, interrelations and dynamics occurring between multiple housing-related practices. As such, this research provides one of the first in-depth mixed-method investigations of carbon-neutral housing conducted to date. This novel approach revolutionises traditional methods for studying low-energy housing by taking into consideration a broad range of actors operating at diverse sites (including policy-makers, housing professionals and householders). It studies the energy and carbon implications of these actors' everyday practices, including both practices directly linked to housing and those seemingly indirectly connected but that are still highly relevant in configuring low-energy housing. Multiple methods, primarily qualitative in nature, are used to collect and analyse data over an extended eighteen-month period, providing an opportunity to develop a 'thick description' of low-energy housing (Geertz, 1973).

Given these starting points, and having identified relevant research gaps (see Chapter 2), I pose the following overarching research question and three sub-questions:

How can social practice theory inform the governance of low-energy housing?

1. Can the Code for Sustainable Homes (CSH) be conceptualised as an intervention in practice? If so, how?
2. What effects does CSH have as an intervention in practice?
3. What is the potential for applying 'systems of practice' to the governance of low-energy housing?

I use the term low-energy housing to describe newly built social housing properties that from their design, use of building products, installed technologies and tenant management use less energy (specifically electricity) than a contemporary new-build home built in accordance with statutory UK Building Regulations. Although the turnover rate of the UK housing stock is only approximately one percent *per annum*, a focus on new-build homes built to be carbon neutral in accordance with CSH level six addresses a small, but highly visible portion of the UK's overall carbon footprint (Karvonen *et al.*, n.d.). Furthermore, my focus on a unique social housing development is important given that social housing properties frequently act as a government test-bed for the trial of new building techniques, methods and approaches. Whilst contributing seemly modest numbers of new homes to the UK residential sector[3], social housing properties therefore have wider significance for the housing industry.

In these three ways, this thesis provides an examination of low-energy housing that differs theoretically, empirically and methodologically from most contemporary research, policy and practice in this field. It presents a new framing for tackling the low-energy housing challenge and aims to demonstrate the merit of its application for policy and industry interventions. My intention is that this research prompts new debates about the future of socio-technical systems and resource governance, applied housing practice, and implications for sustainability research. Whilst this thesis concentrates on the governance of energy and greenhouse gas emissions in the UK residential sector, I believe that it has wider international and sectoral relevance. The conclusions of this thesis can also be applied to the governance of alternative practices including food, mobility and working practices.

[3] Between 2011-2012, 27,170 Housing Association and 1,960 Local Authority social housing properties were constructed in England (DCLG, 2013c).

1.3. Thesis outline

In answering the question 'How can social practice theory inform the governance of low-energy housing?' and the three sub-questions set out in the previous section, I pursue six objectives throughout this thesis:

1. Identify the merits and limitations of existing approaches for the governance of low-energy housing using a qualitative case-study investigation.
2. Map and characterise a low-energy housing system of practice.
3. Trace the evolution of a low-energy housing system of practice and identify the main modes and dynamics of change.
4. Assess how and the extent to which housing-related practices, performed by different actors at different sites, are transformed in less-energy intensive directions for a CSH level six housing scheme.
5. Explore the theoretical and applied implications and opportunities provided by a 'systems of practice' understanding of low-energy housing.
6. Develop a mixed-methods qualitative research approach for analysing the low-energy housing challenge.
7. Develop a 'systems of practice' conceptual framework for understanding and analysing sustainability transformations in the housing sector and beyond.

Having provided a rationale for this thesis here, Chapter 2 goes on to situate these research questions and approach within the wider body of academic literature and current policy and industry context. It identifies the merits and limitations of existing dominant approaches to low-energy housing and warns that to date most progress made has been illusory given that the vast majority of initiatives attempted have conformed to the techno-rational paradigm. I argue that this dominant policy, industry and research approach is deeply flawed and is insufficient to meet UK carbon reduction targets. Instead, Chapter 2 puts forward an alternative systems of practice based approach for understanding low-energy housing. Having identified distinct research gaps, Chapter 2 concludes by revisiting the overarching research question (and three sub-questions) that underpin this investigation.

Chapter 3 describes the methodology used in this research. It first sets out the research ontology and epistemology that framed data collection, analysis and the research write-up. It proceeds to introduce the case study of the Code for Sustainable Homes (CSH) and the east of England new-build social housing development studied. Based on the systems of practice conceptual framework discussed in the preceding chapter, I develop a mixed-method research approach for collecting data and analysing and understanding the low-energy housing challenge. I explain how the research questions are to be addressed using this conceptual framework and mixed methods approach.

Chapters 4, 5, and 6 present the findings of my empirical investigation. Chapter 4 first introduces the different sets of actors involved in the Trinity Close, Rackheath low-energy housing development. I describe the everyday housing-related practices of six emblematic actors, alongside their visions for change. In so doing, Chapter 4 responds to Research Question 1 in that it assesses whether, and if so how, the CSH can be conceptualised as an intervention in practice. Chapter 5 appraises the Trinity Close housing initiative as an intervention in practice by firstly reviewing building energy performance results for the case study. I then appraise how, if at all, the practices of housing professionals and householders were reconfigured in less energy-intensive directions.

Chapter 6 reframes the low-energy housing challenge using a far broader lens than dominant approaches used to date, and as such provides a more nuanced account that deals better with complexity. This challenge is uniquely presented as a matter of reconfiguring systems of housing-related practices and affecting how these practices relate and connect, as well as intervening in their composition and performance. In Chapter 6, I develop and apply a systems of practice conceptualisation of socio-technical change to the housing sector. This conceptualisation is used to map and characterise a low-energy housing system of practice, including the types of interconnections and dynamics occurring between practice complexes, bundles and elements. This conceptual lens is used to analyse implementation of the CSH building performance standard by tracing how the sample practice system evolves and by identifying the main modes and dynamics of change (and stability) demonstrated at the sample housing development.

Chapter 7 concludes by reviewing the major findings of this thesis and relating them to the research questions. It sets out the empirical, theoretical and methodological contributions provided by a systems of practice understanding of low-energy housing. I conclude this thesis by setting out a new research agenda, alongside recommendations for policy and practice.

Table 1.2 summarises how each chapter addresses the research questions (RQs) and objectives of this thesis.

Chapter	Title	Purpose	Research Question (RQ)	Objective
1	Introduction: Laying the foundations for low-energy housing.	Provides a rationale for the overarching RQ and sub-questions. Outlines the thesis.	Overarching RQ.	1
2	Governing low-energy housing: Assumptions, limitations and alternatives to conventional approaches.	Situates the overarching RQs and research approach within the existing body of academic literature and current policy/industry context. Highlights limitations of existing approaches for building and studying low-energy housing. Identifies research gap and derives RQs.	Situates RQs.	1, 6, 7
3	Researching low-energy housing-related practices.	Describes the research ontology and epistemology. Introduces the case study and sampling approach. Introduces data collection and analysis approach.	Explains how RQs will be addressed.	6
4	Governing housing practices: Planning the Trinity Close initiative.	Introduces case study actors, their housing-related practices and their visions for change.	RQ1	1,2,3,4
5	Appraising low-energy interventions in housing-related practices: Outcomes of the Trinity Close initiative.	Reviews building energy performance results for case study. Appraises how, and the extent to which, if at all, professional and household housing practices were reconfigured in less energy-intensive directions.	RQ2	1,2,3,4
6	A systems of practice approach to low-energy housing: Reframing Trinity Close.	Develops a systems of practice conceptualisation of socio-technical change in the housing sector. Applies this framework to the analysis of the case study building performance standard and sample housing development.	RQ3	1,2,3,4,5,6,7
7	Conclusion: Doing low-energy housing differently.	Reviews major research findings and relates them to the RQs. Sets out the empirical, theoretical and methodological contributions made. Provides recommendations for policy and practice as well as a new research agenda.	Addresses all RQs.	1,2,3,4,5,6,7

Table 1.2 – Thesis outline

Chapter 2. Governing low-energy housing: Assumptions, limitations and alternatives

This chapter provides a theoretical rationale for this thesis by situating it within the major bodies of literature associated with the governance of low-energy housing. In order to examine the challenge of reconfiguring the housing sector in less energy-intensive directions, this chapter adopts a dual focus. First, it compares different theoretical and applied approaches for the governance of sustainability transformations, highlighting the merits and limitations of each. Whilst the many different interpretations of governance are acknowledged (see Jordan, 2001; Kooiman, 2003; MacLeod and Goodwin, 1999; Pierre and Peters, 2000; Rhodes, 1996; Voß *et al.*, 2006), I take governance in its broadest sense to mean organising action and 'shaping society in desired directions' (Shove and Walker, 2010: 475). This understanding is applied in terms of encouraging transformation towards less energy-intensive modes of planning, building and living in new (social) housing. For each governance approach, where available, applied examples of initiatives undertaken as part of policy and practice are drawn upon. I also highlight the objects of governance, forms of knowledge, tools for intervention, and assessment approaches used.

Second, this chapter appraises the extent to which the governance of socio-technical change is considered in systemic terms by each governance approach. It is argued that in order to address the scale and urgency of the sustainability challenge facing society - particularly in relation to the way we plan, build and live in our homes – it is necessary to move beyond a dominant focus on isolated technical, behavioural and economic understandings of change. For systemic changes in housing to be encouraged, it is acknowledged that the mundane occurrences of contemporary life need to be studied, as opposed to 'periodic and inconsistent' happenings (Karvonen, 2013: 569). At the same time, this review highlights how an emphasis on the everyday-ness of life should also operate at the spatial and temporal scales demanded for widespread sustainability transformations.

Section 2.1 introduces and critiques technological approaches to the governance of low-energy housing, based on technical housing solutions. Focus is placed on energy-efficient domestic heating technologies as a potential techno-fix for the challenge of reducing carbon emissions from the residential sector. Sections 2.2 and 2.3 review and critique behavioural, contextual and socio-technical system approaches to the governance of low-energy housing. Section 2.4 considers recent research from a second generation of social practice theorists (Spaargaren, 2011). Social practice theory (SPT) is shown to be well situated for analysing socio-technical transformations (and stability) as it emphasises the interdependent relations between the everyday habits and personal choices of individuals, and broader socio-technical institutions and systems of provision (Hargreaves, 2011; Spaargaren and van Vliet, 2000). The chapter concludes with a set of research questions that underpin the rest of the thesis.

2.1 Technological approaches for the governance of low-energy housing

Political, industrial and research activity on low-energy housing is predominantly underpinned by the technology transfer model (Guy and Shove, 2000), which assumes that technological interventions alone will guarantee energy and carbon savings (see Figure 2.1). According to this paradigm, the effective governance of low-energy housing is achieved by developing and disseminating innovative energy-efficient building materials, installing new renewable and energy monitoring technologies, optimising the physical properties of a house, and ensuring the smooth operation of supporting infrastructural systems. Once technical design has been perfected and appropriate construction methods, and processes developed, focus shifts to ensuring the widespread transfer of these materials, technologies and protocols. Technological determinism is distinctly evident as 'the development and dissemination of certain technologies [and ways of building homes] is seen as inevitable' (Lovell, 2005: 817). This longstanding, dominant approach is therefore dependent on the concept of pure technical potential, and works to a linearly sequential process of research, development, demonstration, and dissemination (Shove, 1998).

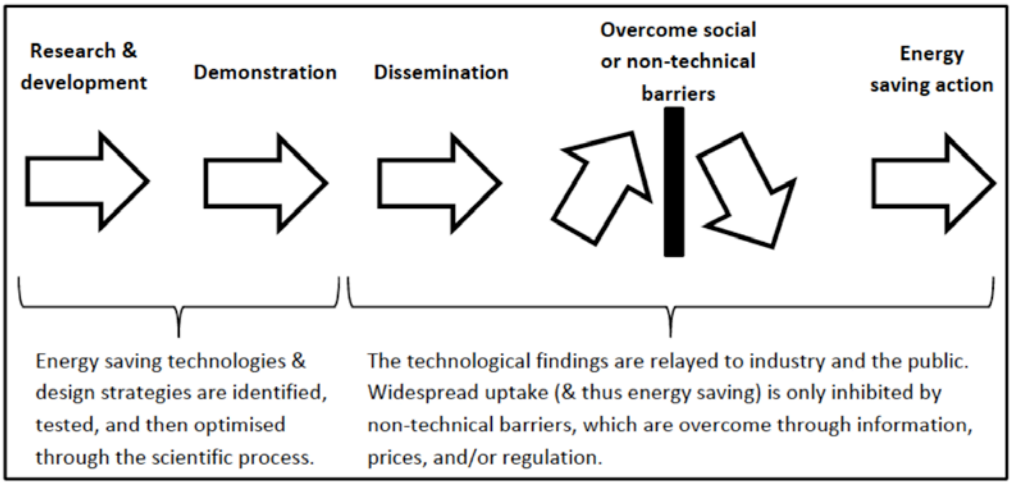


Figure 2.1 – The linear sequential model of technology transfer

(Source Guy and Shove, 2000: 62, adapted by Foulds, 2013)

In line with the technological paradigm, in recent years, recognition of the need to mitigate climate change has led to increasingly stringent regulatory requirements for the energy-efficiency and carbon performance of buildings. The housing industry has been forced to develop and use more innovative materials and technologies, trial new design strategies, and revise conventional house-building processes. Collectively, these activities 'embrace a traditional conception of innovation where new technologies and techniques are trialled, incentivised and regulated with the ultimate goal of making [carbon neutral] the new norm for house-building practices' (Karvonen *et al.*, n.d.). Section 1.1 outlined how recent years have seen the introduction of a wide-range of Government policies and initiatives within the housing sector. The vast majority of these interventions rest firmly on technological, but socially-neutral, understandings of change, which it was argued, have distinct limitations (explained further in this section). The UK Low Carbon Transition Plan (DECC, 2009) cites two key policies for delivering low-energy homes that it is claimed will enable the nation to meet the 2050 carbon emissions reduction target: Building Regulations and Zero Carbon Homes. These two strategies are founded on making technological improvements to the way that new homes are built, and are discussed below.

First, UK Building Regulations have formed the principal mechanism for regulating the energy performance of buildings since the introduction of the first minimum standards for heat loss in 1966 (Monahan, 2013). They set out minimum construction standards required in fourteen areas – parts A to P (The Building Regulations 2010

(SI 2010/2214)). Part L – the Conservation of Fuel and Power[1] – states minimum standards in relation to energy in housing, including: building fabric, heating, cooling and ventilation systems and renewable energy generation. Since their introduction, these minimum energy standards have been made progressively more stringent and their focus has shifted from energy conservation to energy-efficiency to the current focus on carbon emissions (Monahan, 2013). Focus has also shifted from a prescriptive approach based on defining elements of the building based on their thermal transmittance (measured in U-values[2]) to performance based on a whole house approach, where a 'household's energy needs and carbon dioxide impacts [are considered] as a whole' energy system (Hamza and Greenwood, 2009; DECC, 2009: 85).

Building Regulations have undoubtedly been successful in driving the installation of better insulation, double-glazing and more efficient heating systems in new and existing homes (Palmer and Cooper, 2013). Since being introduced, this statutory regulation has significantly increased the thermal efficiency of newly constructed UK homes, improving the overall energy-efficiency and carbon footprint of the nation's housing stock (see Chapter 1). At the same time however, it has been suggested that such mandatory building performance standards have the potential to stifle innovation by setting requirements based on existing knowledge, practices and technologies (Gann *et al.*, 1998). Others argue that these regulations still require significant strengthening to be in line with best practice, for instance in terms of low heat requirements, electrical demand and the minimisation of embodied energy from the construction and use of buildings (for example CAT, 2013).

Second, in a landmark effort to ensure that all new homes are built to high environmental standards, in July 2007, the Government declared that all new-build domestic properties would be Zero Carbon by 2016 (and that all new non-residential buildings would be zero carbon by 2019)(DCLG, 2007a; Fischer and Guy, 2009). These measures were aimed at meeting the European Union's Energy Performance of Buildings Directive (2010/31/EU) requirement for Nearly Zero Energy Building. The route towards achieving Zero Carbon housing was to be met by tightening

[1] Part L of the Building Regulations has four parts: Part L1a New dwellings; L1b Existing dwellings; L2a New buildings other than dwellings; L2b Existing buildings other than dwellings. Only Part L1a is relevant to new build housing and therefore in this thesis reference to Part L refers to Part L1a.
[2] U-values are a measure of thermal transmittance expressed as units Watts per m^2 per degree of temperature difference (how much heat will pass through $1m^2$ of a structure when the air temperature on either side differs by 1°C). It has the units W/m^2K.

the Building Regulations in 2010, 2013 and 2016, to deliver a 25%, 44% and 100% (i.e. Zero Carbon) improvement on the 2006 Building Regulations Part L. It was estimated that increasing the stringency of the Building Regulations Part L in this way would deliver a carbon saving of 34.6MTCO_2eq by 2020 (DECC, 2009), almost half (45%) of the energy savings to be made by the UK housing sector by this date (NAO, 2008). In contrast to incremental changes characteristically made by the conservative housing sector, the ambitious 2016 zero carbon target was intended to engender a major shift towards use of green building materials and construction techniques. It was hoped that this target would 'mainstream' what had to date largely been isolated practices by small private developers (Greenwood, 2012; Monahan, 2013).

Increasingly stringent Building Regulations and anticipation of the Zero Carbon homes targets have led to a burgeoning number of low-energy housing technical demonstration projects (Lovell, 2004). For example, in 2008, commissioned under the Homes and Communities Agency (HCA) Carbon Challenge initiative (English Partnerships, 2007), 185 new homes were developed by Barratt Homes at Hanham Hall in Bristol. Hanham Hall has been billed as England's first large-scale commercial zero carbon development (Pearson, 2014). Whilst this demonstration scheme has been lauded for its technical innovation, it was originally designed to conform to level six of the Code for Sustainable Homes (CSH) building performance standard (introduced in Chapter 3) but, due to technical issues, was subsequently downgraded to CSH level five[3] (i.e. not carbon-neutral). These technical issues and change in scope led to unanticipated additional financial investment. Whilst marketed as a low-energy housing success story, the technical aspirations for this development were therefore not fully met.

The below anticipated energy performance outcomes at Hanham Hall epitomise persistent 'energy performance gaps' – where realised energy savings fall short of those predicted (Shove, 1998). Such outcomes have led to concern that energy performance gaps could undermine delivery of the national carbon reduction plan, present a reputational risk to the house-building industry and damage consumer confidence if energy bills are higher than expected (ZCH, 2014: 4). In response, the Government has stated an ambition that from 2020, 90% of all new homes should meet or perform

[3] Hanham Hall, Bristol was originally designed in 2008 to conform to level six of CSH. However following the government's 2011 definition of zero carbon, which does not include non-regulated emissions, the scheme targeted this definition, in effect downgrading the scheme to CSH level five.

better than their designed energy/carbon performance (*ibid.*: 3). Priority actions have been developed for industry and Government, which continue to reinforce the technological paradigm as they include: enhancing the accuracy of predictive models and quantitative measurement and assessment techniques, developing the skill-sets of housing professionals through information, feedback, and training provision, and regulating and assuring improved housing construction practices (*ibid.*). These recommendations also notably exclude consideration of energy performance post-handover to residents even though building energy performance crucially depends on how a home is used (e.g. Branco *et al.,* 2004; Juodis *et al.*, 2009).

The building energy performance gap is as much to do with how the home is lived in, as it is to do with modelling inaccuracies, technical faults, and a deficiency in construction skills (Wingfield *et al.*, 2008). Variations in domestic energy consumption are frequently observed between households occupying technically identical homes (e.g. Gram-Hanssen *et al.*, 2004; Firth *et al.*, 2008). Residents can use three or more times as much energy for heating as their neighbour while living in exactly the same type of home (Gram-Hanssen, 2010). This variation has been attributed to differences in personal heating routines and experiences of thermal comfort (Gram-Hanssen 2010; Guerra Santin *et al.*, 2009; Steemers and Yun, 2009). This suggests that even if a house is well insulated with suitable thermal mass[4] and an efficient energy heating source, the inhabitants ultimately determine the energy-efficiency of a home (Branco *et al.*, 2004; Guerra Santin *et al.*, 2009; Stevenson and Leaman, 2010). Furthermore, with increasing improvements to the building thermal envelope[5] and technological improvements in heat and power supply infrastructure, significance of 'the user' becomes more important (Papakostas and Sotiropoulos 1997; Haas *et al.*, 1998). Despite this, requirements for post occupancy evaluation (POE) do not form part of the Government's carbon reduction strategy (Stevenson and Leaman, 2010).

As such, a particular area of focus for technical research into building energy performance gaps is energy consumption associated with domestic thermal comfort. This is because how the domestic environment is heated accounts for sixty percent of energy used at home (DECC, 2012). In addition to the outdoor temperature,

[4] Thermal mass is the ability of a material to absorb and store heat energy.
[5] A building's thermal envelope is its outer shell that allows it to maintain a dry, heated or cooled indoor environment and facilitate its climate control.

heating system efficiency, extent of insulation, building air-tightness, and the indoor temperature set for a house during the heating season, are vital to determining the amount of energy used to heat a property. In addition, in recent years, the technological approach has led to a standardised understanding of thermal comfort, informed by the steady-state heat balance model of the human body (described by Fountain and Huizenga, 1997). This assumption suggests that people 'experience 'discomfort' when their bodies lose or gain 'too much' heat from the surroundings (Shove *et al.*, 2014: 117).

The steady-state heat balance model has had a hugely important influence on housing construction and product manufacture, as homes are 'routinely designed and engineered to deliver stable conditions optimised for physiological systems (i.e. people) the properties of which are uncomplicated by history or culture' (*ibid*: 117). There is a dominant assumption that it is preferable for residents and products to be 'encased in a bubble of carefully managed air' maintained at a temperature of around 22°C, which clearly has energy demand implications (Shove *et al.*, 2014: 118). This ambition of reproducing unchanging indoor environments has not been without criticism, not least for reinforcing expectations around the need for consistently heated buildings which has associated energy implications (Brager and De Dear, 2003; Shove, 2003; Shove *et al.*, 2008; Gram-Hanssen, 2011; Nicol *et al.*, 2012). It is clear then, that there is a definite requirement to think more broadly about why and how people use energy in the home, and to question the merit of standards that frequently reinforce energy demand requirements. Simply relying on (heating) technologies as impartial, instrumental tools 'fails to engage with the big questions of what our [energy] needs are and how they are constructed and reproduced' (Shove, 2004: 1053).

The technological paradigm consistently prioritises physical and technical characteristics over social and cultural aspects. In the residential sector, this approach has manifested as an expert-led technical approach that largely fails to involve householders (*cf.* Jackson, 2005; Darnton, 2008). Residential environmental governance is commonly organised 'behind the back of ordinary citizen-consumers' (Spaargaren, 2011: 814), with domestic energy-efficiency measures frequently installed using a highly discrete 'fit and forget' approach (Van Vliet *et al.*, 2005). But by failing to acknowledge that building energy performance is determined in part by how physical conditions, technologies, and infrastructures are experienced and interacted with, this approach is shown to be reductive and partial. Whilst disciplines such as Human Centered Design (e.g. Steen *et al.*, 2007) and initiatives such as Living Labs (e.g. Bakker *et al.*, 2010) have recently gained in popularity, technical performance and social life are predominantly treated as separate. The technology transfer model (Figure 2.1) assumes that any non-technical barriers to uptake can be overcome by greater uptake of technologies, but it fails to consider how technologies will be received when they 'go out to the real world' (e.g. Flyvbjerg, 2007). When below anticipated building energy performance results are received, emphasis is placed on optimising technical design, increasing the accuracy of modelling and assessment tools, training skilled operatives, and removing 'barriers' to technical diffusion.

Energy-efficient building materials and innovative technologies have certainly made major contributions to the recent reduction in carbon emissions from the residential sector. However, this thesis argues that to tackle the scale and urgency of sustainability challenges, both within the residential sector and in other areas of social life, it is necessary to go beyond the development and dissemination of new technologies and materials. By viewing 'technical change as following an almost pre-ordained pattern of design, development and diffusion' (Guy, 2006: 654), this governance approach has been shown to be linear, reductive and partial, often resulting in unexpected or below anticipated outcomes. Recognising how social aspects of building energy performance have been overlooked, the following section turns attention to the challenge of better understanding residents' 'behaviours' and their implications for low-energy housing. At the same time, Sections 2.3 and 2.4 argue that there is a need to look beyond simply focusing on householders, to consider the social and political context in which low-energy housing operates.

2.2 Behavioural approaches for the governance of low-energy housing

In recent years a re-scaling of the governance of environmental challenges, such as climate change and low-energy housing, has taken place, resulting in increased focus being placed on individuals as agents for change (Barr *et al.*, 2011). At the root of this shift in emphasis is the premise that environmental problems are fundamentally caused by 'maladaptive human behaviour' (Maloney and Ward, 1973). Much research on the operation of low-energy housing is underpinned by the belief that human behaviour results from linear and rational decision-making processes, and that individuals are 'self-interested, knowledgeable and economically calculative when considering energy measures' in the home (Guy, 2006: 647). Such behavioural approaches to understanding social change in this way have endured since the 1970s (e.g. Craik, 1973), but have recently gained in popularity with acknowledgement that technological solutions alone can not bring about lasting sustainability transformations.

Two distinct approaches to encouraging behaviour change have been developed and these are considered in the two following sections of this thesis. Section 2.2.1 emphasises the effects of individuals' attitudes on behaviour and explores their potential to be changed. It also examines whether, and if so how, individuals' behaviour is affected by societal values, and how interventions can promote more desirable values amongst the public, in turn bringing about preferred actions. Within low-energy housing, such approaches tend to be concerned with efforts to encourage householders to exhibit less-energy intensive domestic actions and/or to use installed energy-efficient materials and equipment correctly for optimal performance. Whilst making links between energy consumption and what people think, experience and do, these approaches are shown to be excessively individualistic and to provide a partial and de-contextualised view of social change.

In Section 2.2.2 individual behaviour is understood in terms of actors operating within the bounds of context-specific social settings. This 'contextual approach' to behavioural change (Burgess *et al.*, 2003) takes into account how individuals' decisions and actions are increasingly standardised across society. This approach acknowledges that even when individuals hold 'correct' attitudes or values, behavioural change is hard to accomplish (Hargreaves, 2009).

2.2.1 Individuals' attitudes and values towards low-energy housing

To minimise technical 'misuse' and optimise building energy performance, householders are often 'designed-out' of houses by making technologies and devices highly discrete (Macrorie *et al.*, 2014a). Where residents *are* considered, energy and housing policy asks that individuals simply change their behaviours in accordance with requirements for optimal technical operation (Lutzenhiser and Shove, 1999; Guy and Shove, 2000). Alternatively residents are asked to become more 'energy aware' and to curb their levels of energy consumption to save money on household energy bills. These actions tend to be encouraged by a focus on individual choice-making, which attempts to shape householders' perspectives, and to remove apparent barriers, so that 'correct' behavioural decisions are made (see Leaman *et al.*, 2010; Whitmarsh *et al.*, 2011; DECC 2013a). Shove (2010) terms this approach, which is dominant across policy, industry and research, the ABC model, describing it as, where '[for] the most part, social change is thought to depend upon values and attitudes (the A), which are believed to drive the kinds of behaviour (the B) that individuals choose (the C) to adopt'. Indeed most behavioural understandings of action, and of policies seeking to influence individuals' behaviour rest, either explicitly or implicitly, on 'models' of what behaviour is, what its antecedents are, and how it is influenced, shaped and constrained (Jackson, 2005). This section critiques four understandings of behavioural change commonly applied to understand how residents behave in low-energy housing: the Theory of Planned Behaviour (TPB) (Ajzen, 1991); the Technology Acceptance Model (TAM) (Davis, 1989); Behavioural economics and the 'nudge' approach (Thaler and Sunstein, 2008); and Value-Belief-Norm (VBN) theory (Stern, 2000).

2.2.1.1 The Theory of Planned Behaviour (TPB)

The best known, and most widely applied, of these models is Ajzen's (1991) Theory of Planned Behaviour (TPB) (Figure 2.2), which is an extension of Fishbein and Ajzen's (1975) Theory of Reasoned Action (TRA). As described by Davis *et al.* (2006), this model hypothesises that an individual's intention to perform (or not) a behaviour is influenced by three factors: 1) their attitudes towards performing the behaviour, 2) the subjective norm – perceived social pressure around performing the behaviour, and 3) their perceived control over performance of the behaviour. Part of the allure of TPB is the model's openness to the addition of different variables to increase its explanatory capacity. As such, factors including self-identity, belief salience, past behaviour/habit, perceived behavioural control versus self-efficacy, moral norms and affective beliefs have been incorporated to increase the model's accuracy (Jackson, 2005; Chatterton, 2011).

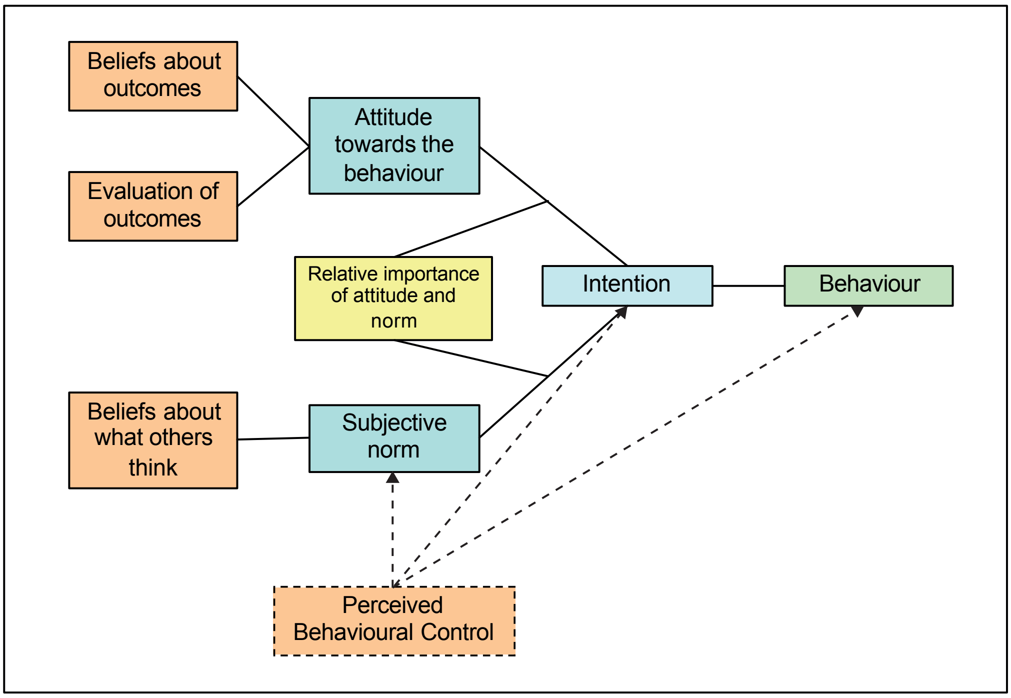


Figure 2.2 – Ajzen's Theory of Planned Behaviour

(Source: Jackson 2005: 49)

Within low-energy housing research, several researchers have drawn upon the TPB to examine whether household energy use and intentions to reduce it could be informed by, or predicted from, variables from the TBP (e.g. Scott *et al.*, 2014; Yearley *et al.*, 2014; Kriek *et al.*, 2013; Abrahamse and Steg, 2009; Gill *et al.*, 2010; Faiers *et al.*, 2007). To establish an occupant's intention to reduce household energy use, informants might be asked what energy-saving actions they take, and this would be correlated with their attitudes towards climate change and energy tariffs, their perception of social norms towards thermal comfort and/or being green, and their perceived ability to make changes to domestic services requiring electricity and gas.

Where the TPB has been applied to inform policy interventions, the social psychologist Paul Stern suggests that initiatives should be based on the understanding that 'behaviour (B) is an interactive product of personal-sphere attitudinal variables (A) and contextual factors (C)' (2000: 415). This understanding is used to segment a broad population into specific groups, making it easier for government or businesses to tailor their interventions. For example, in 2012 research was conducted by GfK NOP, based on a survey of 2,050 owner-occupiers and private rented tenants in Britain, in order to understand the potential for households to take up the Green Deal package of technical domestic energy-efficiency improvements (DECC, 2012b). The research identified the percentage contribution of six Green Deal segments it was suggested made-up the UK population: 'money savers', 'carbon savers', 'convertibles', 'not on the radar', 'disengaged rejectors' and 'overstretched' (see Figure 2.3). For each of these specific groups motivations and barriers to the uptake of Green Deal measures were identified. Subsequently, a range of tailored policy initiatives were developed aimed at removing barriers hindering Green Deal uptake and encouraging those members of the population already interested in the initiative.

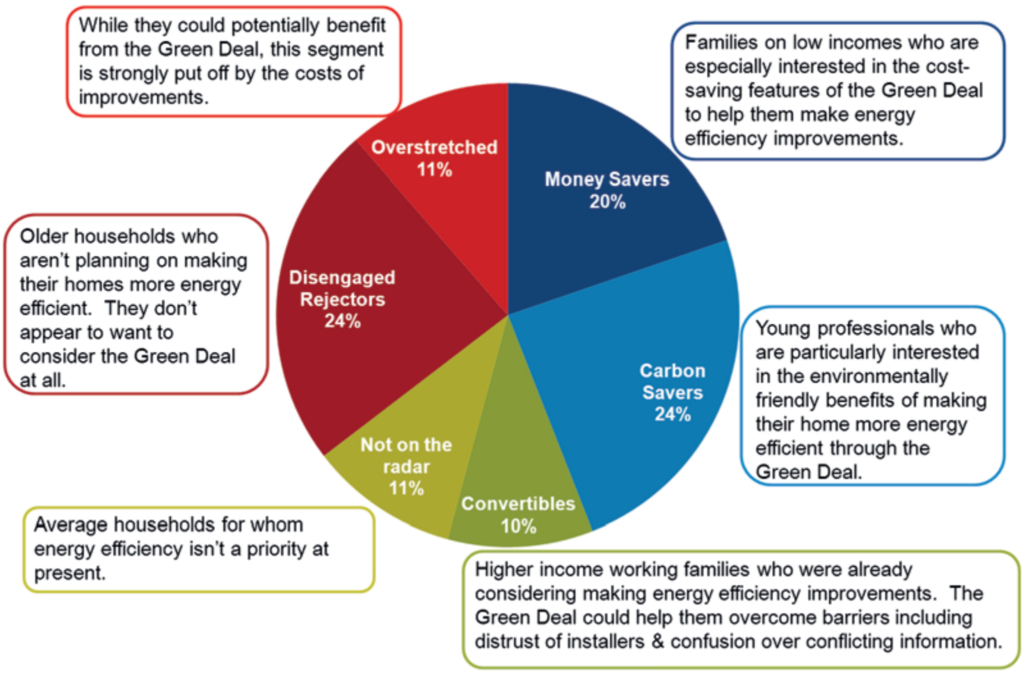


Figure 2.3 – Green Deal population segments

(Source: DECC, 2012b: 4)

2.2.1.2 The Technology Acceptance Model (TAM)

A variation on the TPB is the Technology Acceptance Model (TAM), developed by Davis (1989). This model is based on ascertaining the perceived usefulness of a technology, measuring how its ease of use affects individual attitudes, and determining how these factors shape an individual's intentions, and subsequent technical use (see Figure 2.4). This model has been used in domestic energy research to investigate, the uptake of smart meters (e.g. Guerreiro *et al.*, 2015), advanced electricity metering services (e.g. Park *et al.*, 2014), and renewable energy technologies (e.g. Alam *et al.*, 2014). For example, using the TAM, Guerreiro *et al.* (2015) found that domestic smart meter use was influenced by subjective norms, the perceived utility of the device, health-related risk perception, procedural justice, and time of usage.

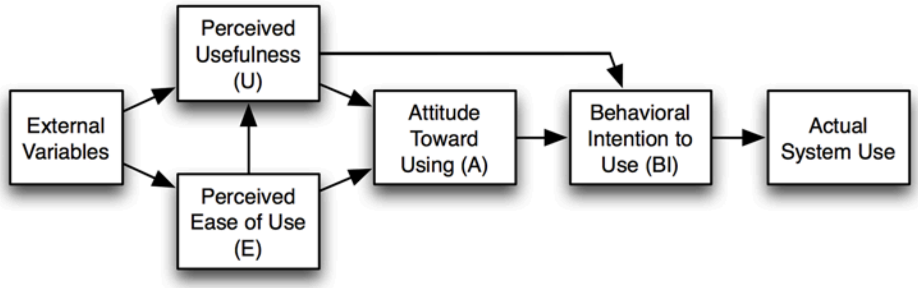


Figure 2.4 – The Technology Acceptance Model, version 1.

(Source: Davis, 1989)

The most commonly addressed barrier is an assumed information deficit amongst the public (*cf.* Burgess *et al.*, 1998; Owens, 2000). It is suggested that if only accurate and accessible information was available on how to live 'correctly' in low-energy housing, peoples' awareness would increase and they would act in the ways intended, i.e. reduce their domestic energy demand (Dobbyn and Thomas, 2005; Bahaj and James, 2007). Over the years, a variety of information campaigns have aimed to help householders gain knowledge about how they can reduce their energy-use by taking practical actions (e.g. Citizens Advice, 2015; EST, 2012). Similarly, various channels are available for housing professionals to obtain updates on regulatory changes, funding and training, not least via communications from the Zero Carbon Hub (ZCH, 2015).

Another commonly addressed barrier to low-energy housing is perceived to be the cost of installing technical measures or developing a carbon-neutral home. Economic rationalism assumes that correct pricing (coupled with provision of information) is sufficient for people to make politically desirable decisions (Chatterton, 2011). This perspective is based on the assumption of rational maximisation of self-interest; people will choose to behave in a certain way because it is economically advantageous for them to do so. Incentive schemes developed to overcome the cost barrier to low-energy housing include: loan schemes (e.g. Green Deal: DECC, 2015d); grants (e.g. Renewable Heat Incentive; DECC, 2015e); reduced tax rates (e.g. VAT exemption: HMRC, 2013); subsidised installation capital costs (e.g. Energy Companies Obligation: OFGEM, 2014); and payments to households for installing renewable technologies (e.g. Feed-in-Tariffs: DECC, 2015f). Other interventions have adopted a motivational approach (Chatterton, 2010; Shove, 2010). For example, DEFRA's 4Es model depicts an approach based on encouraging, enabling and engaging individuals, and exemplifying desired behaviours to encourage their uptake (DEFRA, 2008).

The TPB and TAM extend understandings of human behaviour from pure economic rationalisation to consider a wider range of factors that affect the actions that people take, and as such can be considered as extended-rationality approaches. Despite this, these approaches focus on how individuals make choices about low-energy housing technologies – i.e. they have a cognitive and/or technical focus. Research based on these frameworks often relies on modeling influences on individual decision-making processes using large-scale questionnaire surveys, perpetuating methodological individualism. In terms of policy application, these frameworks for understanding behaviour have been applied in, public information campaigns, the development of financial (dis)incentives, and through tailored attempts to remove barriers preventing the adoption of desirable behaviours for specific groups of the population. These intervention approaches have however been subject to fervent criticism both theoretically and at an applied level.

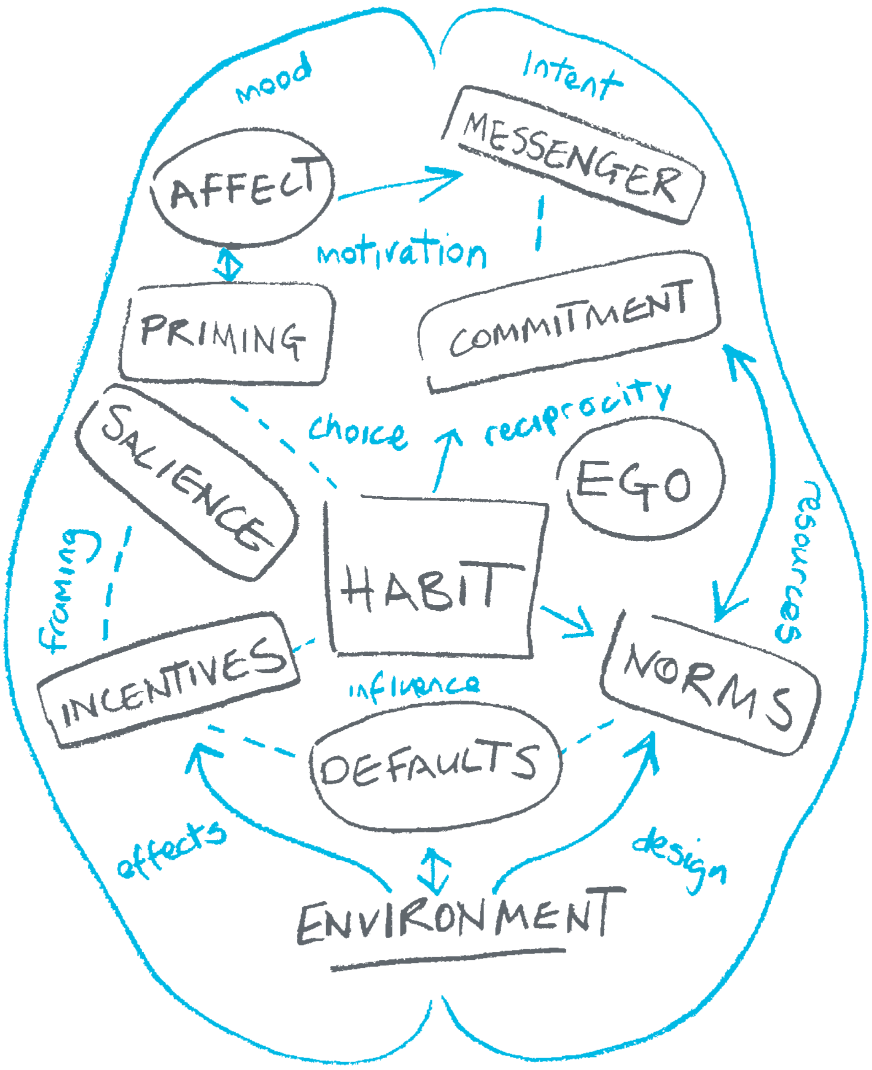
At a theoretical level, Barr (2003) points out that antecedents can diverge widely even in behaviours with very similar outcomes, (for example, turning down the thermostat and insulating the loft) and individuals that perform one behaviour are unlikely to perform the other. Shove draws on DEFRA's Framework for pro-environmental behaviour to identify an extensive list of external constraints often raised as barriers to behaviour change: 'infrastructure, cost, working patterns, demand on time, habit, scepticism, disempowerment…' (DEFRA, 2008: 7). She suggests that on this basis, 'pretty much anything can qualify as a driver or a barrier [to individual behaviour change], and it is in any case not always easy to tell which is which' (Shove, 2010: 1275). Importantly then, models such as TPB and TAM becomes less usable with the increasing addition of attitudinal determinants of behaviour and the identification of more and more variables to explain human action (Hargreaves *et al.*, 2008; Hargreaves, 2009; Shove, 2010). Further, when segmentation and targeted social marketing strategies are undertaken (Kotler and Zaltman, 1971; McKenzie-Mohr, 2000), they often prove insufficient to build support for ambitious policy changes (Corner and Randall, 2011). Recent work on behavioural spillovers has extended this debate by suggesting that 'no behaviour sits in a vacuum' and that policy interventions need to consider the possible spillover effects from one behavioural response to the next (e.g. Dolan and Galizzi, 2015:1).

2.2.1.3 Behavioural economics and the 'nudge' approach

Behavioural economics presents numerous principles to account for less rational behavioural choices (e.g. Dawnay and Shah, 2005). This discipline has become popularised in recent years through books such as 'Nudge: Improving Decisions about Health, Wealth and Happiness' (Thaler and Sunstein, 2008). Behavioural economics was embraced by Government in the formation of the Behavioural Insights Team, which had the remit of 'designing policies or interventions that can encourage, support and enable people to make better choices for themselves and society' (BIT, 2014). The premise of this approach is that rather than individuals working out seemingly endless cost/benefit calculations prior to taking an action, people make a range of mental shortcuts or heuristics. Behavioural economists contend that actions result from two distinct systems within the human brain; the reflective system – the rational part of the brain, and the automatic system – a range of sub-conscious processes that allow fast responses to environmental circumstances (e.g. fight-or-flight response[6]) and that enable routine behaviours requiring minimal mental effort (e.g. adjusting to changing room temperatures).

Work by the Institute for Government summarises this body of knowledge, and provides a tool-kit for policy makers. The work is based around the MINDSPACE mnemonic (Figure 2.5) - Messenger; Incentives; Norms; Defaults; Salience; Priming; Affect; Commitments; and Ego – which stands for factors leading to the formation of Intention and is intended as a quick checklist for the design of behavioural change interventions (Dolan *et al.*, 2010). Tim Chatterton (2011: 35, 36) applies MINDSPACE to low-energy housing by considering the Green Deal policy (DECC, 2010). For example, he explains that this approach would understand householders as heavily influenced by who communicates information to them (i.e. the Messenger) because 50 percent of customers reportedly changed their mind about which measures to install in their home following a visit from an expert assessor on DECC's 'pay as you save' pilot scheme (DECC and EST, 2011).

[6] Fight-or-flight response: a physiological reaction that occurs in response to a perceived harmful event, attack, or threat to survival, which primes the animal/ human for fighting or fleeing.



Messenger	we are heavily influenced by who communicates information
Incentives	our responses to incentives are shaped by predictable mental shortcuts such as strongly avoiding losses
Norms	we are strongly influenced by what others do
Defaults	we 'go with the flow' of pre -set options
Salience	our attention is drawn to what is novel and seems relevant to us
Priming	our acts are often influenced by sub-conscious cues
Affect	our emotional associations can powerfully shape our actions
Commitments	we seek to be consistent with our public promises, and reciprocate acts
Ego	we act in ways that make us feel better about ourselves

Figure 2.5 – MINDSPACE checklist for behavioural change policy interventions

(Source: Dolan *et al.*, 2010: 18)

In focusing on the point of individual decision-making and failing to account for 'the complex array of factors which influence our choices' (Prendergast *et al.*, 2008: 47), behavioural economics applied through 'nudge', or 'soft paternalism' interventions are also shown as a reductive and individualistic way to achieve domestic energy demand reductions. Nudge's focus on the automatic decision making and choice-architecture of individuals fails to sufficiently account for social structures and situated contexts. In addition, it is arguably morally questionable as paternalistic interventions often attempt to covertly 'nudge' individuals by restricting their choices or making them unavoidable, for instance in the way that energy tariffs are set. Such limitations are increasingly outlined (e.g. Sugden, 2009; French, 2011; Avineri, 2012 and Croson and Treich, 2014).

2.2.1.4 Value-Belief-Norm theory (VBN)

The Value-Belief-Norm (VBN) theory of pro-environmental behaviour (Stern, 2000) rests on the premise that 'pro-social attitudes and personal moral norms are significant predictors of pro-environmental behaviour' (Jackson, 2005: 56). This model describes how values form the basis for beliefs, and they in turn underlie norms, which dictate behaviour (see Figure 2.6). Dependent on a person's values (e.g. altruistic, biospheric, egoistic), they are more or less likely to accept that their behaviour impacts on the environment. Based on these beliefs, a personal norm is formed (e.g. they will conserve electricity as part of their domestic activities) that ultimately determines how the individual acts (e.g. whether they insulate their home, or reduce their expectations of heat comfort).

The VBN model understands cognitive structures as social structures as opposed to individualised, ahistorical constructs (Hargreaves, 2009: 35). It has been applied in low-energy housing policy by attempts to make information more personally-relevant to resonate with individuals' values, and to reinforce the connection between personal action and impact on the climate. For example, Boardman and Darby (2000) indicate that immediate provision of energy use feedback via household energy meters can effectively reduce householders' resource consumption. Researchers, such as Poortinga *et al.* (2012), have applied the VBN to understand the acceptability of low-carbon behaviours and renewable energy technologies to householders' value sets.

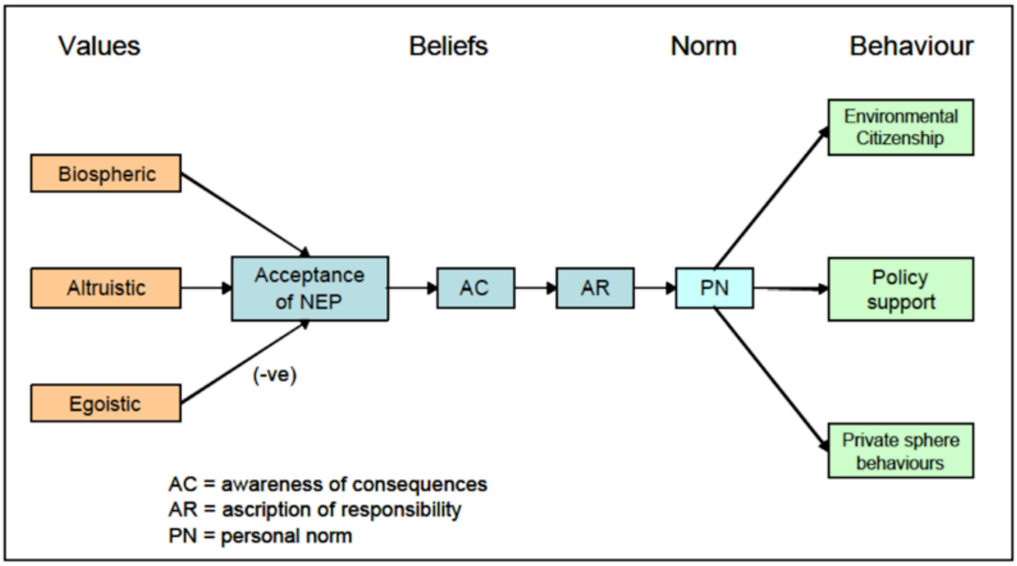


Figure 2.6 – Value-Belief-Norm (VBN) theory

(Source: Jackson, 2005: 57)[7]

Engaging with peoples' ethics and morals may spread pro-environmental attitudes, values and beliefs amongst the public but often fails to result in sustained behavioural change at a domestic level. This 'value-action' gap has been widely reported (e.g. Blake, 1999; Kollmus and Agyeman, 2002; Frederiks *et al.*, 2015). For example, many people advocating reductions in personal carbon emissions (e.g. living in low-energy homes) may carry out a range of high-carbon activities (e.g. taking international flights). In response, some have argued that greater emphasis needs to be placed on 'activating' pre-established values by engaging with 'deeper frames' held by the public (Chatterton, 2011: 21).

Section 2.2.1 has considered behaviour in terms of individual decision-making and actions and highlighted how ABC-based models of behaviour (Shove, 2010) have been critiqued for adopting an individualistic approach, which largely overlook the role of different contexts in shaping social life. In Section 2.2.2 behaviour is understood in terms of actors acting within the bounds of context-specific social settings.

[7] NEP: The New Ecological Paradigm (NEP) scale, devised by Dunlap and Van Liere (1978). It puts forward a range of beliefs that science, technology and neo-liberal economics will solve all of humanity's problems.

2.2.2 Contextual low-energy housing solutions

The contextual approach, suggests that behaviours are:

> 'fundamentally *social*, undertaken by social actors acting and interacting within wider social discourses and settings; fundamentally *contextual*, unfolding according to different dynamics, rules, logics and socio-technical networks in different contexts; and fundamentally *political*, embodying particular assumptions about individual agency and responsibility and liable to be contested, resisted, disparaged and even to cause offence' (Hargreaves, 2009: 52, emphasis added).

In order to understand behaviours and the potential for them to change, contextual researchers argue that research needs to observe what people actually do and importantly the context in which things are done. Whilst Nudge researchers (see Section 2.2.1.3) contend that this approach considers peoples' available choices, economic incentives, social norms, technologies and infrastructures, contextual approaches place greater emphasis on the wider social, political and infrastructural settings that affect human behaviour, and move further away from individual cognitive decision making. The contextual approach instead seeks to take account of both socio-demographic and situational variables that either motivate or act as barriers to decision-making processes (e.g. Moezzi and Janda, 2014; Murtagh *et al.*, 2014).

The contextual approach adopts the position that the Information Deficit Model, constructs individuals as passive agents, reliant on clear communiqués from experts (Hobson, 2002; Heiskanen, 2005). Illustrating deficiencies in this model, Wilhite and Ling describe how feeding back energy consumption data to residents incorrectly assumes that a linear sequence of cognitive processing and decision-making will culminate in a decrease in domestic energy demand: 'Increased feedback > Increase in awareness or knowledge > changes in energy-use behaviour > decrease in consumption' (1995: 150). Instead, it is suggested that disseminated 'facts' may be contested, framed and re-interpreted in diverse ways to different effects (Owens and Driffill, 2008). Furthermore, information is never neutral or value-free, as knowledge is socially constructed (Berger and Luckman, 1967) and different environmental knowledges can be interact and evolve (e.g. Faulconbridge, 2012).

In relation to domestic energy demand, contextual research has brought awareness to the fact that home energy use is shaped by a diverse array of things, conditions, communications, habits and lifestyle preferences, and as such there is no 'standard' household (e.g. Lutzenhiser, 1993; Wilhite *et al.*, 1996). For example, according to the contextual approach, it is commonly reported that older residents, spending long periods at home and heating their homes to high temperatures, consume more energy for space heating than younger householders (e.g. Liao and Chang, 2002; Lenzen *et al.*, 2006). Similarly, high-income householders with a greater number of appliances, tend to use more energy than lower earning households (e.g. Benders *et al.*, 2006; Vassileva *et al.*, 2012).

This chapter continues by briefly critiquing three contextual approaches to socio-technical change commonly applied to understand low-energy housing and domestic energy demand. First, the role of discourses in 'telling the story' of low-energy housing and leading to particular forms of doing. Second, the ways in which spatial and temporal contexts affect individuals' lifestyles and routines, with implications for domestic energy consumption. Third, the role of socio-technical arrangements in enabling and constraining how low-energy homes are designed, built and lived in.

2.2.2.1 The discursive contexts of low-energy housing

Discursive framing is defined as '… a way of selecting, organising, interpreting, and making sense of a complex reality to provide guideposts for knowing, analysing, persuading and acting' (Rein and Schon, 1993: 146). As such, discourses can be evaluated,

> '…not only for their truth and falsity but also for their partiality, their selective framing of the issues at hand, their elegance or crudeness of presentation, their political timeliness, their symbolic significance, and more. [These arguments] are practical productions' (Fischer and Forester, 1993; 2-3).

The discursive perspective holds that arguments and forms of communication construct environments that variously appeal to people in different situations. This approach contrasts with the top-down, expert-led models of communication put forward by the cognitive perspective (Hargreaves, 2009: 40). Discourse analysts argue that discourses are critical to socio-technical change as they 'set… boundaries around an issue, or technology, and allow ownership of it by certain actors' (Lovell, 2008: 616). For example, Lovell explores how different framings of sustainable housing (emphasising the poor quality of existing housing stock, the need for innovation in the construction sector, and the need to meet renewable energy generation targets) have variously been suggested as a solution to different UK housing problems, leading to different engagement responses and outcomes (Lovell, 2004). Similarly, Hommells (2005) reviews how discursive frames can prevent people from bringing about changes that fall outside of particular ways of thinking and interacting, leading to technological 'obduracy in the [design and development of a] city'.

In relation to encouraging less-energy intensive housing, discursive research would seek to understand how to 'reconfigure the normative basis of society' (Hargreaves, 2009: 40). Policy interventions and communications would be analysed according to how (if at all) they resonate with public understandings of sustainable development, and suggestions made would be made as to what this might mean for action (Macnaghten and Jacobs, 1997). Whilst the discursive approach explores how different societal discourses construct environments and affect people differently in different contexts, this approach fails to acknowledge the influence that materials, technologies and infrastructures have on, and are affected by, what people do.

2.2.2.2 Temporally and spatially situated low-energy lifestyles

The second strand of contextual research situates behaviour in a temporal and spatial context. This approach assumes that lifestyles are increasingly standardised across society, making it hard for individuals to depart from accepted social conventions (for example: levels of comfort, cleanliness and convenience (Shove, 2003)). Consequently, even when individuals develop 'correct' attitudes or values, pro-environmental behaviour (such as curbing energy use for domestic activities) is hard to accomplish (Hargreaves, 2009). Instead of encouraging individuals to change from making particular resource-intensive choices and actions, this approach contends that attention should be placed on affecting the routines and conventions in which householders (housing professionals and policy decision-makers) are involved.

With spiralling pressures to work and spend, contemporary affluent societies are operating at an ever-increasing pace, and time allocated for particular tasks is often 'squeezed' (Southerton, 2003; Aldrich, 2005; Ehn and Löfgren, 2009; Southerton, 2009). In this 'harried and hurried' world (Southerton *et al.*, 2001), the notion of lifestyle describes how behaviours are grouped, and everyday life is organised to allow life to be practically lived out in specific contexts (Giddens, 1991). This ordering of actions forms 'interwoven timespaces' – 'a kind of infrastructure through which human activities co-ordinate and aggregate' (Schatzki, 2010: 39). Such routines overcome the need to reflect on every single act (for instance, managing thermal comfort at home can be carried out with minimal thought) (Giddens, 1984; Ilmonen, 2001). Small daily routines, have also been shown to be decisive for the energy demand of a household, and therefore carbon emissions (Gram-Hanssen, 2008). And routines are not just confined to domestic life, but are also inherent in working practices (e.g. Hitchings, 2010; Pink *et al.*, 2010).

Social psychologists contend that it may be possible to alter old habits and establish new ones by disrupting individuals' unsustainable routines and cueing more environmentally sound responses; 'the critical ingredients for any [behavioural change] interventions include (1) changes in the old performance environment that disrupt existing habits coupled with (2) opportunities or experiences that encourage performance of the desired response' (Verplanken and Wood, 2006:99; Wood and Neal, 2007). Behaviour change campaigns therefore commonly encourage householders to modify their daily regimes to lower their electricity bills. Similarly, a report by the New Economics Foundation (NEF, 2011) suggests that major life events, such as moving house, can act as distinct 'moments of change' and induce changes in environmentally-relevant behaviours.

These messages tend to have an extended rationality and economic basis to action. Indeed, the authors of the 'Moments of Change' report concede that their proposition is based on 'very much a theory-driven hypothesis, arising from conceptual models… rather than from any strong basis in behavioural observation' (NEF, 2011:159). This said, some researchers present a different understanding of socio-technical change based on tapping into and reorganising routinised patterns. Shove (2012) suggests a research avenue of exploring how habits secure the resources of time, space and devotion required to keep them 'alive' in everyday society. Similarly, Shove (2009) and Southerton (2009) suggest approaches to potentially reorder or relocate the temporal rhythms and spatialities constituting everyday life. Whilst routinised actions have been associated with 'ordinary' or 'inconspicuous' patterns of resource consumption (Gronow and Warde, 2001), and it is important to understand these patterns, sustaining low-energy housing requires more than affecting unconscious and mundane modes of behaviour.

2.2.2.3 The socio-technical configuration of low-energy households

The third strand of the contextual approach is concerned with how materials, technologies, and infrastructures, and their organisation, shape everyday behaviour. Whilst the cognitive perspective understands the material world as an external constraint on human behaviour (Hargreaves, 2009), this body of literature focuses on the interplay between 'the technological, the social, the economic, and the political' (Rydin, 2012:25). Researchers in this field argue that we need to consider socio-technical change in systemic terms, moving the argument beyond the attitudes, values and choices of the individual, and the immediate context within which individuals operate. Within this research area, particular attention is given to how human behaviour co-evolves with different technological systems within heterogeneous socio-technical networks (for example see Actor Network Theory (ANT), discussed in Section 2.3.2).

There is a long history of scholarship that explores how large technical systems shape how we live and the governance approaches that determine these arrangements (Bijker *et al.*, 1987; Hughes, 1983; MacKenzie and Wajcman, 1985; Summerton, 1994). Householders are frequently 'locked-in' (Arthur, 1989) to maladaptive practices that become largely unavoidable when homes are directly served by large-scale, centrally managed energy and water supply systems. Chappells and Shove (2004: 142) describe infrastructures such as pipes and powerlines as 'connective tissue' that bind providers and consumers into 'distinctive regimes of resource management' and use. Strengers and Maller (2012: 761) find that 'supply systems characterised by immateriality, perceived and abundance and homogeneity may allow resources to recede into the background of everyday life, shift responsibility and control onto governments and private utilities, and lock-in resource intensive ways of [domestic] life'. Other research in this area contends that appliances are legacies of large-scale systems that deliberately encourage wasteful resource practices, rather than resource conservation (e.g. Soufoulis, 2005).

‘Scripts’ can be designed into devices and household layouts to cue particular responses and to inhibit others (Akrich, 1992; Latour, 1992). Integral to this process of scripting is the concept that human agency can be delegated to what Latour (1992) terms ‘non-human actors’. Scripts are developed by designers and engineers who hold particular moral visions about the contexts within which an artefact is used and its future users, and build these assumptions into hardware/software prescriptions. For example, an electric refrigerator can beep after a period of time to encourage the door to be closed if it has been accidentally left open, thus allowing more efficient operation and keeping the stored food chilled. The user then translates, or decodes the scripts by a process of description. According to Jelsma (2003) in this way technical design and planning can drive behaviour in an intended direction. Crucially however, he also suggests that scripts can be resisted. For instance, the user can decommission the beeper. In fact, ‘even the most prescribed artefacts remain open to resistance’ (Ingram *et al.*, 2007: 9). Jelsma (2006) also suggests that it may be possible to manipulate moral scripts to contain cues that encourage less energy-intensive behaviour. For instance, refrigerators might be redesigned to automatically shut the door if it is left open.

Certainly appliances such as freezers, automated heating systems and washing machines have revolutionised understandings of what it means to maintain household life. These devices also demand extensive and resource-intensive systems of infrastructure. For example, freezers are coupled with energy-intensive global networks of frozen food provisioning (Hand and Shove, 2007), and whilst increasing the convenience of meal times, the frozen food industry is associated with a reduction in cooking skills, decline in family time and a downturn in healthy eating (e.g. Butler, 2013). Both consumers and producers become reliant on and inherently connected to ever resource-intensive infrastructural supply systems. These ‘systems of provision’ (Fine and Leopold, 1993) also create and reinforce particular understandings and needs of contemporary life. Together these structuring contexts can prove hard to alter.

Encouraging less energy-intensive low-energy housing practices, from a socio-technical contextual approach, involves ‘fundamentally changing the socio-technical infrastructures’ supporting the residential sector - a difficult and extremely costly proposition (Hargreaves, 2009: 47). Alternatively, householders need to resist anti-environmental scripts, and codes and standards should be designed to prompt less energy-intensive materials, products and buildings. These challenges require the 'collective [re]negotiation of more sustainable ways of living within particular socio-technical settings' (*ibid.*). Socio-technical contextual approaches to low-energy housing recognises the networked relationships between human and non-human actors/agents and consider how people interact with and mutually construct wider systems of material infrastructure, advancing rational and extended rationality approaches. However from a SPT perspective they have limitations as their emphasis rests on networks of individuals and technical systems as opposed to practices or systems of practice (see Section 2.3.2 for further discussion).

Three contextual perspectives on achieving behavioural change in low-energy households were critiqued in this section – discourses, lifestyles, and technologies. These approaches to understanding the governance of low-energy housing, whilst advancing individualistic techno-rational understandings associated with cognitive approaches, are commonly considered independently. As such they never provide a complete picture of how the varied practices associated with low-energy housing are constituted, undertaken and can change. The following section instead adopts a more holistic, systems based approach for the governance of low-energy housing, which is arguably needed to address the scale of the residential energy challenge.

2.3 Socio-technical systems based approaches to the governance of low-energy housing

This section considers three systems-based approaches to the governance of low-energy housing – Domestication theory, Actor-Network Theory (ANT) and Transitions Theory. For each of these approaches, the focus of investigation is moved away from individual decision-making and the immediate context within which those decisions are made, to consider what people do in terms of socially, politically, economically, and technically mediated, networked environments.

Section 2.3.1 critiques Domestication theory (Silverstone and Hirsch, 1992; Lie and Sørensen, 1996). This concept seeks to understand how newly acquired objects are positioned with respect to existing technologies and practices, and how this (re-)organisation affects the meaning and status of new items, existing objects, and users. Domestication has primarily been applied to the home, but the framework is increasingly being applied beyond the home and incorporates a wider selection of actors and agents. Section 2.3.2 reviews Actor-Network Theory (ANT) (e.g. Latour, 2005). This theory explores how networked associations between humans and 'non-humans' shape everyday reality. The theory particularly focuses on moments of disruption and contestation occurring in these networks, with a view to understanding the potential for socio-technical transformations. Section 2.3.3 critiques Transitions theory (also termed the Multi-Level Perspective (MLP) (Rip and Kemp, 1998; Geels, 2011) as a lens for analysing wide-scale technological and social transformations. The MLP places particular emphasis on how innovations can lead to substantial and irreversible changes in socio-technical systems.

2.3.1 Domesticating low-energy housing technologies

Although the concept of domestication (Silverstone and Hirsch, 1992; Lie and Sørensen, 1996) originated in media studies, it has since been used to analyse processes of technological acceptance, use and rejection (Berker *et al.*, 2006). Commencing with the study of single information and communications technology artefacts (Silverstone *et al.*, 1992), the concept was later extended to include devices extending outside of the home and supported by large infrastructures, such as the mobile phone (Haddon, 2003), the internet (Bakardjieva, 2005) and the car (Sørensen, 2005). Domestication seeks to map processes of integration of technologies in everyday life. The dimensions of domestication - appropriation (acquiring an object), objectification (actively fitting a new object into existing ways of life), incorporation (routinely using the object and starting to learn how to use it in new ways) and conversion (people are capable of inventing new use situations) – trace these developments (Ilmonen, 2004). Whilst designers have preconceived notions of how products will be used (Strengers, 2014), there is scope for consumers to contest technologies, to ascribe unforeseen meanings to them, and use them in unintended ways (Røpke, 2001).

According to the domestication concept, when a household acquires a new object and begins to use it, it is placed within an already meaningful domestic space and amongst existing household routines, both of which might have to be altered for a pattern of use to be established. As noted by Hargreaves *et al.* (2013) in relation to the use of smart energy monitors, whilst at first the object will be recognised as new and different, gradually it becomes 'backgrounded' within normal household practices. Second, the acquired technology interplays with the established social structure of the home, which affects who has access to the artefact and when and how it is used (Røpke, 2001). For example, Gram-Hanssen (2008) examines how some householders adopt specific routines of managing their heating system following negotiation with the household member 'in charge' of operating the thermostat. This assimilation of technologies can sometimes change the power-balance within the home. Third, the technology enters into the external positioning of the household because how technology is used or placed in the home demonstrates the household's priorities, values, status and tastes (Røpke, 2001).

Domestication theory goes beyond technological determinism, cognitive and contextual ways of understanding the appropriation of new technologies and/ or behavioural change. First, domestication highlights the role of users as actively involved in constructing meanings and patterns of use of technology. Second, technologies are understood not simply as purposive tools engaged in consumption, but as objects that have significance in connoting particular meanings and ways of life (Sørensen, 2004). Silverstone *et al.* (1992) conceptualise these contexts of use as 'moral economies'. The household is a moral economy as the productive and consumptive activities of its inhabitants, which are shaped by their histories, perspectives and values, are linked to the public economy. Crucially domestication theory explores a reciprocal process, whereby just as technologies are transformed by existing household moral economies, the moral economies of the household are altered by new technologies, introducing new meanings, practices and identities (Hargreaves, 2012).

Whilst domestication research has taken a multi-sited, multi-actor approach, taking the concept outside of the household domain and away from a focus on single artefacts or individual consumers (Sørensen, 2004), more could be done to explore the wider structural implications of particular technologies. Similarly, although domestication acknowledges that household dynamics are linked to the public economy and have wider implications for socio-technical trends, it fails to convincingly explain broader system based connections and patterns. Domestication also potentially has a normative bias in that it assumes the existing household situation is technologically deficient. For example, Lehtonen (2003) presents the domestication of technologies into everyday routines as a set of trials to be sequentially overcome. The domestication concept also assumes that there is an end-point at which new objects are successfully integrated into everyday (domestic) life, overlooking how the role of materials is continuously renegotiated, with implications for the structuring of systems of social order. Instead, as suggested by Hand and Shove (2007) the adoption and use of technologies should be understood as an ongoing achievement incorporating the active integration of materials, ideologies and skills. This proposal is supported by Reckwitz (2002b), who recommends that the phases of domestication should be considered in terms of how routines are continually established and sustained.

2.3.2 Actor Network Theory

In recent years, an increasing amount of research has thought relationally about socio-technical transformations in response to calls for a greater focus on the politics of socio-technical change (Meadowcroft, 2009) and for less techno-centric and linear approaches (Shove and Walker, 2010; Lawhon and Murphy, 2011). As discussed by Longhurst and Chilvers (2013), concepts developed in response to this challenge encompass different notions including: actor networks (Callon, 1986), hybrid collectives (Latour, 2005), socio-technical ensembles (Bijker, 1995), mangle of practice (Pickering, 1995), agencements (Callon, 2007), assemblages (Deleuze and Guittari, 1986) and action nets (Czarniawaska, 2008). Collectively these conceptualisations are known as 'arrangement' or 'assemblage' theories. Whilst distinct differences distinguish these notions, they all attempt to analyse the complexity of social life (Schatzki, 2002: viii; 2011).

The most notable arrangement theory is Actor Network Theory (ANT) (Latour 1983, 1991, 1992, 1993; Callon 1986; Bijker and Law 1992; Law and Hassard, 1999). Whilst Domestication theory is primarily concerned with the household as a closed system in which new technologies are accepted or rejected, ANT argues that human behaviour co-evolves with different technological systems in heterogeneous socio-technical networks. It therefore has greater potential for understanding systemic transformations of the residential sector and the energy implications of domestic life. ANT seeks to understand how social and material elements – termed actants – interact to generate knowledge of the world, through processes of social construction and material resistance. The theory suggests that the world is assembled through these interactions and networked connections, and that therefore to make sense of socio-technical stability and change these relations need to be understood. ANT is based on three principles: (1) generalised symmetry between social and material actants; (2) radical relationality between elements; and (3) association between these actants as a means to achieve change (Farias, 2009: 3).

First, a central tenet of ANT is the commitment to according equal ontological status to natural and social objects. For ANT there is no difference between the social, the natural, ideas, policies, technologies, or infrastructures; according to the notion of *generalised symmetry*, they are all considered as actants assembled into networks (see Callon, 1986). People form but one element of any assemblage, and as such, the social is 'nothing other than patterned networks of heterogeneous materials' (Law, 1992: 2). 'If human beings form a social network it is not because they interact with other human beings. It is because they interact with human beings *and* endless other materials too' (Law, 1992: 3, emphasis added). For instance, keeping comfortably warm in a conventionally heated home involves engaging with an extensive heterogeneous network that includes; the householder(s) themselves, heated air, layers of clothing; the heating system and radiators, the energy source and energy distribution system, and regulation and technical procedures relating to energy supply systems, heating systems and housing.

Second, *radical relationality* refers to the principle that there is no *a priori* significance or properties attached to a given object, person or idea. Neither actors, technologies, nor procedures possess fixed attributes that allow them to bring power to play in a given situation. This is because 'all points in a network are potentially equal in terms of their determining power' and 'the ability to determine the shape of the interaction and of the network is produced *by the network*, by the interaction of its parts' (Cavanagh, 2007: 34-35, emphasis in original). For example, a cold spell may lower the gas pressure serving the boiler causing the heating system to fail. But similarly, a householder might lower the thermostat and/or choose to turn-on the heating system only at times when they can obtain a cheap tariff.

Third, ANT networks do not simply link up stable constituents but transform the actors, things and procedures held in the network, what ANT refers to as *punctualising*. As such, a whole network 'acts as a single block' (Law, 1992: 5) becoming greater than the sum of its constituent parts; 'it disappears from view as a network and reappears as a unity, as an actor in its own right' where different parts become 'locked-in' to certain roles (Cavanagh, 2007: 34). If actants are de-enrolled from the network and individual components struggle to pursue their individual goals separately, the capabilities of the network collapse; termed *de-punctualisation*. The overarching processes that allow a network to be represented by a single entity - be that an object, an individual, or another network - is called the 'sociology of translation' (Callon, 1986). This concept was developed in Callon's (1986) account of an attempt to preserve a population of scallops. He described how the initiative was only made possible as marine biologists enrolled fishermen, the scallops and their scientific colleagues to the project. However, the network failed when these actors dissented, breaking relations that held the conservation effort together. In this article, Callon introduced terms for the phases of translation; (1) *problematisation*, (2) *obligatory passage point*, (3) *intéressement*, (4) *enrolment*, (5) *mobilisation* and (6) *black-box* (see Figure 2.7).

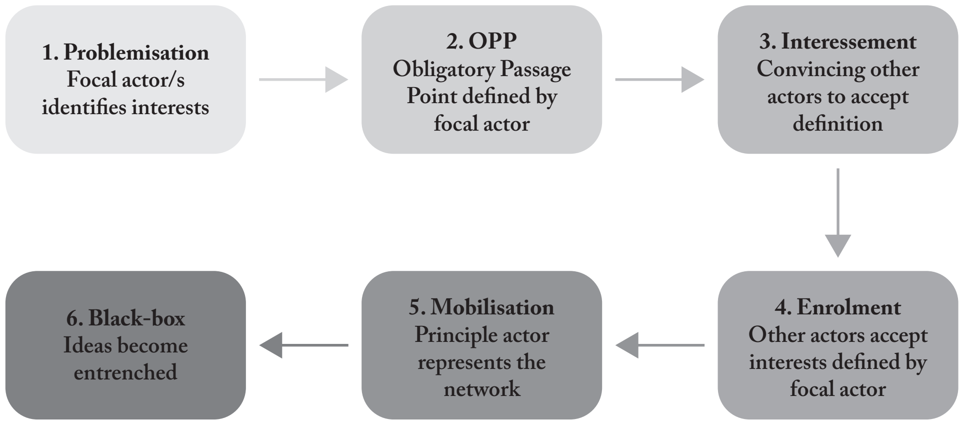


Figure 2.7 – The Phases of Translation

(Source: Adapted from Rodgers *et al.*, 2009)

In ANT, *problematisation* describes the rationale for actors and actants linking in particular networked configurations. In Callon's example, the researchers sought to become indispensable by defining the scallop conservation problem and suggesting that it would only be resolved if an *obligatory passage point*[8] was collectively negotiated, i.e. the researchers' programme of investigation. During *intéressement*, a series of processes strengthen associations between the different entities and support the network's structure. In *enrolment* a set of strategies define and relate the roles allocated to the networked entities. The penultimate stage of translation, *mobilisation*, describes the process of all actors/agents in the network becoming enrolled. Whilst the network can become entrenched and its purpose can become *black boxed* so that it is not questioned, Callon (1986) explained how translation is a process, never a complete accomplishment, and may fail, as occurred in the case of the scallop research project.

[8] Obligatory passage point: In ANT, these are critical network points, which are often designed by the primary actor to ensure that they become functionally indispensable to the network.

Whilst such relational thinking about socio-technical aspects of everyday life has been applied to housing (e.g. Røpke and Christensen, 2012), planning (e.g. Rydin, 2012) and a range of energy issues (e.g. Day and Walker 2013; Buzar, 2007; Harrison and Popke, 2011; Schatzki, 2011; Powells, 2009; Longhurst and Chilvers, 2013), ANT has proven a polarising theory. First, the notion of 'symmetry of agency' is contested. For Actor Network Theorists, human actors are only able to exercise agency through the 'effect[s] of the socio-material networks within which they are entangled' (Longhurst and Chilvers, 2013: 5). Whilst this extends individualistic, purely cognitive understandings, practice theorists argue that whilst 'objects…make a contribution, …the nature of that contribution depends on us' (Schatzki, 2002: 17). Reckwitz holds that,

> 'When artefacts can only be effective within practices insofar as they are 'handled' by human agents and when they are sites of 'materialised understanding', then their status obviously cannot be completely 'equal' with that of human agents and their embodied understanding' (2002b: 214).

SPT, in contrast, pays greater attention to the capacity for people's actions to influence the trajectory of an assemblage, and highlights the value in labelling the different elements of practice, as opposed to treating the components of a network as equivalent.

Second, whilst ANT adopts a more systems based understanding of social life, the theory is vague and contradictory in its account of what initially prompts a network to develop. Questions remain as to what leads a network to be initiated, and whether recruitment of actors and agents to the network describes goal-directed action. ANT proponents rebut this criticism by downplaying the importance of the inception of a network arguing that these moments can not explain how networks are perpetuated and diffuse; 'the initial force of the first in the chain is no more important than that of the second, or the fortieth, or the four hundredth person' (Latour, 1986: 267). Furthermore, it is suggested that far from the everyday being made up of predictable networks, 'inconstancy, multiplicity and indefiniteness' are inherent in real life (Law, 2004: 145; Berker, 2006). Related to this point, ANT can also be criticised for failing to explain why one form of network might be actualised over others, and for not being clear as to how networks are bounded.

Whilst ANT provides useful notions for studying the networked complexity of socio-technical life and how it changes (or remains stable), these limitations require that this research looks outside of this theoretical perspective.

2.3.3 Analysing socio-technical transitions using the Multi-Level Perspective

The third socio-technical systems based approach for examining environmentally sustainable transformations within the housing sector is Transitions Theory or the Multi-Level Perspective (MLP) (Rip and Kemp, 1998; Geels, 2011). This theory is concerned with questions of innovation and socio-technical development. MLP researchers typically pursue these questions, to better understand how transitions in socio-technical systems can be deliberately engineered. The MLP was first developed to historically trace the development of technologies in whole socio-technical systems. For example, transitions from horse-drawn carts to automobiles (Geels, 2005a) and transitions in water supply and personal hygiene (Geels, 2005b).

The starting point for understanding the MLP framework, is to explain the notion of a technological regime, described as:

> '…the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems – all of them embedded in institutions and infrastructures' (Rip and Kemp 1998: 338).

Rip and Kemp go on to position regimes as the meso-level of the MLP framework, explaining how, '[r]egimes are intermediaries [situated] between specific innovations as these are conceived, developed and introduced, and overall socio-technical landscapes.' As such, the MLP comprises three analytical levels: niches (micro-level), regimes (meso-level), and the socio-technical landscape (macro-level). MLP researchers contend that these three levels form a 'multi-layered backdrop of novelty and irreversibility' (*ibid.*)(see Figure 2.8).

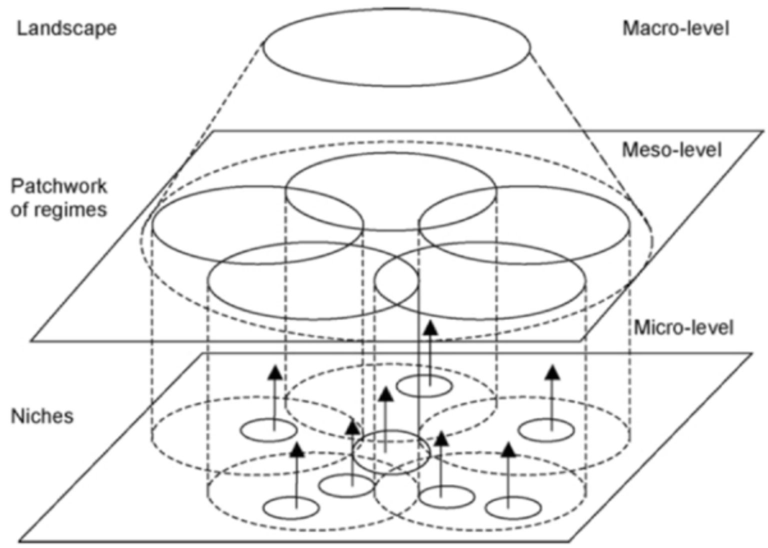


Figure 2.8 – Multi-level framework on socio-technical transitions

(Source: Adapted from Geels, 2002)

Different processes occur at these three levels: '(a) niche innovations build up internal momentum, through learning processes, price/performance improvements and support from powerful groups, (b) changes at the landscape level create pressure on the regime and (c) destabilisation of the regime creates windows of opportunity for niche innovations' Geels and Schot (2007: 400). The MLP suggests that when these processes align, novel approaches (such as low-energy housing construction) breakthrough into mainstream markets, where they compete with the existing regime. If conditions are favourable, a shift in regime occurs, resulting in a transition - a major and irreversible change in the way that particular societal functions (e.g. housing provision) are met (Hargreaves *et al.*, 2013).

The MLP approach to understanding the governance of socio-technical systems has gained some traction in politics and industry as a managerial tool used to encourage more sustainable regimes to take hold (Berkhout, 2002). Transition Management (Kemp and Loorbach, 2006) and Strategic Niche Management processes (Kemp *et al.*, 1998) can attempt to: nurture innovations within 'niche' spaces by providing protection from mainstream markets and pressures; alter exogenous landscape processes (for example, by shifting public attitudes and cultural conventions); and dismantle embedded regimes (for example, by changing existing policy and practice) (Hargreaves *et al.*, 2013; Moore *et al.*, 2014). Amongst other applications, these tools have been applied to understand: the emergence of a passive house network (Mlecnik, 2014); uptake of low-energy housing refurbishment (Killip, 2013); and the potential transformation of the housing construction sector by green niche developments (Berry *et al.*, 2013). Application of the MLP has also received critique. For instance, Shove and Walker (2007) and Scrase and Smith (2009) raise concern over its ability to attend to everyday politics and to direct the trajectory of complex social systems.

The MLP has received considerable theoretical criticism (see responses by Geels, 2011). Originally accused of technological bias and of failing to adequately attend to the role of social actors in transition processes, the concept of technological regime was expanded to 'socio-technical regimes' (Geels, 2004) (see Figure 2.9). Transition theorists have rebutted the criticism that the MLP neglects societal and cultural aspects of change, claiming that the framework is in fact 'shot through with agency, because the trajectories and multi-level alignments are always enacted by social groups' (Geels, 2011: 29). However minimal attention is given to forms of 'social innovation' by the MLP, and actors are defined narrowly as stakeholders of the socio-technical regime under study (Hargreaves *et al.*, 2013). Further, Shove and Walker point out that the MLP has emphasised how innovations are 'shaped by social processes rather than… ways in which technical systems are implicated in defining and reproducing daily life' (2010: 404).

Second, the MLP has been accused of having a bias towards bottom-up socio-technical change, by focusing on how innovations emerge and may/not take-hold in regimes. This emphasis occurs 'at the expense of processes which… operate 'downwards' from general features of the socio-technical landscape' Berkhout *et al.* (2004: 62). In an effort to understand not just innovations and vertical relations between emerging niches and incumbent regimes, but also how the normality of everyday life is maintained, Shove and Walker take this critique further. Instead of linear change, they highlight the 'horizontal circulation of elements' of practice and argue for a 'flatter model characterised by multiple relations… of reproduction [that cut] across different scales' (2010: 474) (see Section 3). Such critiques have resonated with transition theorists who have increasingly deviated from the notion of 'nested hierarchy' and acknowledged that 'levels…refer to different degrees of stability, which is not necessarily hierarchical' (Geels, 2011: 37). Further, some researchers have identified points of intersection between the vertical plane (innovation in regimes) and the horizontal plane (innovation in practices) (e.g. Hargreaves *et al.*, 2013; Jensen, 2014), and suggested that the MLP and SPT could be used to provide complementary perspectives on a research problem.

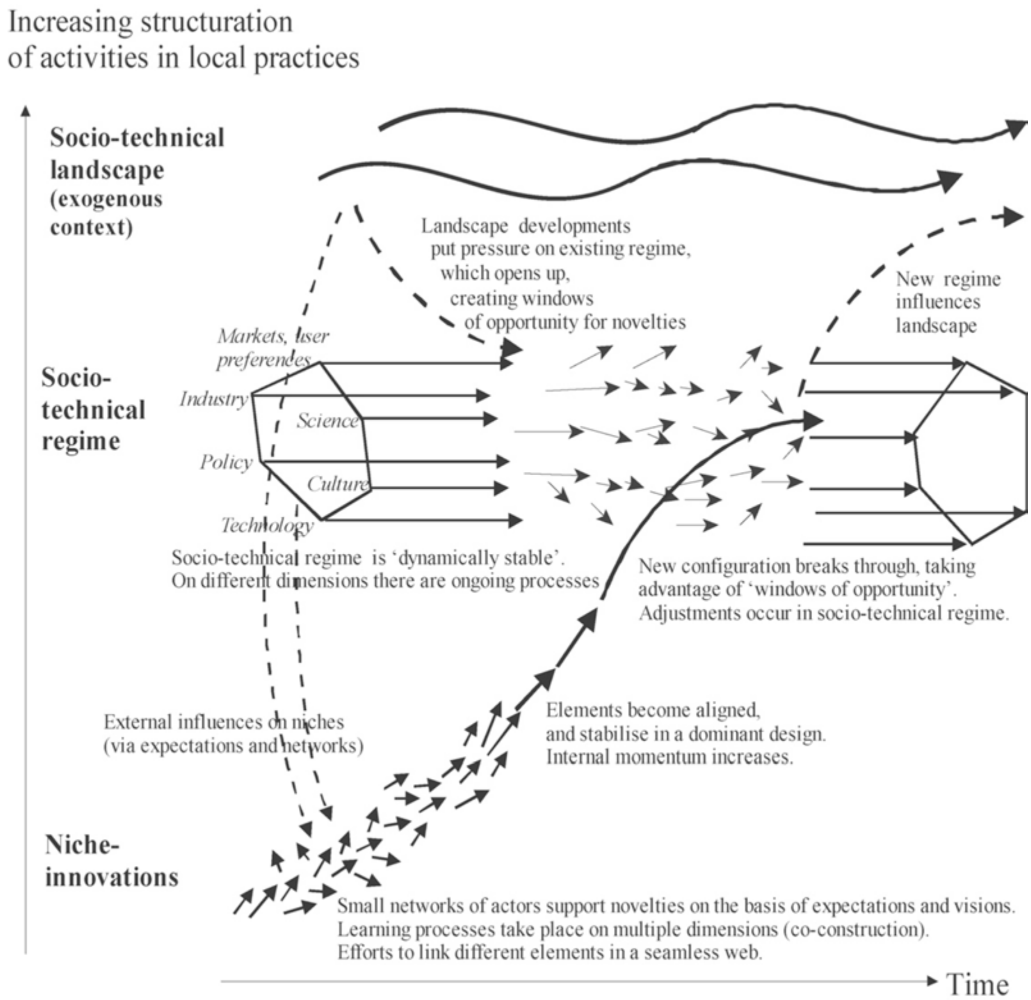


Figure 2.9 – A dynamic multi-level perspective on transitions

(Source: Adapted from Geels, 2004)

Third, the MLP primarily adopts a single system focus, drawing boundaries around socio-technical systems and regimes of particular interest. To use low-energy housing as an example, the MLP and transition management tools have variously been used to explore transitions in: the energy regime (e.g. Verbong and Geels, 2007; Foxon *et al.*, 2010); eco-cities (e.g. Rohracher and Späth, 2014) green building renovation (e.g. Horne and Dalton, 2014; Killip, 2013) and the new-build housing construction regime (e.g. Jensen, 2012). Whilst each of these regimes upholds multiple everyday ways of doing, overlapping relations connecting these different regimes have largely been overlooked by the MLP. Consequently, calls have been made for attention to be given to how variously sustainable practices become embedded in social life, how wider 'systems of systems' hold social-technical structures in place, and whether and how reorganisation of these systems may enable more environmentally sustainable ways of life (Shove, 2003; Watson, 2012).

In terms of providing a framework to study socio-technical change in the housing sector therefore whilst the MLP adopts a systems-based approach to change and contemplates transitions in socio-technical structures, it arguably still retains a technological bias. Whilst it has gained traction in policy circles, this approach would examine the housing sector in isolation from overlapping systems and policies. In addition, MLP theorists have only recently begun to acknowledge 'flatter' less-hierarchical change mechanisms. Given the limitations of this theory, and the two other socio-technical systems based approaches discussed in Section 2.3 (Domestication Theory and Actor Network Theory), there is a need to look beyond these theoretical frameworks in order to understand the governance of low-energy housing.

2.4 Practices in the governance of low-energy housing

The previous sections have compared and contrasted different theoretical approaches for understanding the governance of low-energy housing for environmental sustainability. I have explained how Domestication theory is primarily concerned with the household as a closed system within which new technologies become accepted or rejected. ANT has greater potential for understanding sustainability transformations as it purports that human behaviour co-evolves with different technological systems in heterogeneous socio-technical networks. However, it fails to adequately explain how or why these networks take the form that they do and it gives non-human objects the same ontological status as people. The MLP analyses transitions in socio-technical regimes and systems but traditionally adopts a linear and hierarchical account of innovation and change, which privileges technological solutions. In distinct contrast, SPT is concerned with a different unit of analysis – transformations in *practices* (Shove, 2012b). This is achieved by focusing on the 'doings' of everyday social life, the elements of which are brought together and interact through practices (Giddens, 1984; Schatzki, 1996).

Social Practice Theory (SPT) was first theorised through the work of Giddens (1984; 1991) and Bourdieu (1984; 1990), and has recently been developed by Reckwitz (2000a), Schatzki (1996, 2001, 2002), Warde (2005) and Shove and colleagues (Shove, 2003, Shove and Pantzar 2005; Shove *et al.*, 2012). SPT originally emerged out of the individual agency *versus* structure debate. It offered a 'more balanced approach' to either cognitive approaches which neglect the 'profound influences of…systems of provision shaping and sometimes pre-configuring the choices and behaviours of individual[s]…' or structural approaches which 'deny or at least underrate… the crucial role of human agents in the processes of environmental change' (Spaargaren, 2011: 815).

As opposed to methodologically individualist accounts of the 'consumer', SPT offered 'new insights into how consumption is organised and how it might best be analysed' (Warde, 2005: 132). This is because SPT understands resource consumption, not as a distinct entity itself, but as 'a moment in almost every practice' (*ibid.*: 132). This view stresses how much consumption, rather than being concerned with acquisition of new goods, relates instead to the 'routine, collective and conventional' manner that resource demand is created as part of the everyday doings of life (Gronow and Warde, 2001; Warde 2005: 131).

As Spaargaren (2011: 815) states, '[l]ooking 'beyond the individual' does not, however, imply reverting to the systemic, structuralist perspective which tends to forget agency and subjectivity'. By taking practices as the unit of analysis, both interactions occurring between individuals (who possess particular understandings, knowledge and skills) and social structures (e.g. materials, infrastructures, formal procedures, and informal conventions) can be understood. Crucially then, to make sense of social life and to attempt to bring about socio-technical reorganisation that has fewer energy-intensive effects than existing arrangements, it is not the analysis of attitudes, values and decisions of individuals or examination of the operation of formal and informal institutions or technical infrastructures that is needed. Instead, the analysis of practices and the ways in which they connect and can change their composition, performance and organisation is required.

Since first articulated, SPT has contributed to multiple disciplines including: organisation studies, design, media, health, anthropology, and social policy as well as environment and sustainability research (Halkier *et al.*, 2011). Related to low-energy housing, the SPT framework has been used to research: thermal comfort (e.g. Wilhite *et al.*, 1996; Gram-Hanssen, 2010; Strengers, 2010; Shove, 2012b; Hitchings, 2013; Royston, 2014); use of domestic appliances and services (e.g. Shove, 2003; Hand and Shove, 2007); sustainable product design (e.g. Kuijer, 2014), home improvement and retrofitting (e.g. Hand *et al.*, 2007; Horne *et al.*, 2011; Karvonen, 2013; Bartiaux *et al.*, 2014); and energy demand management (e.g. Hargreaves *et al.*, 2013; Strengers, 2014). The theory has also been applied to research; low and zero carbon construction (e.g. Foulds, 2013); construction-related codes and standards (e.g. Shove and Moezzi, 2002; Chappells and Shove, 2005); technological transfer and change (Shove, 1998); and low-energy housing policy (e.g. Karvonen *et al.*, n.d.; Strengers and Maller, 2011; Shaw and Ozaki, 2013; Gram-Hanssen, 2014).

Here, I critically examine how SPT can help to understand and inform the governance of practices associated with (low-energy) housing and the energy implications of everyday domestic life. I explore contributions made by SPT theorists in terms of: understanding the composition of practices (Section 2.4.1); how practices are created, performed and reproduced through everyday social life (Section 2.4.2); how existing practices evolve and transform, and how interventions in practice can potentially reorganise practices, and the connections between practices, in less energy-intensive directions (Section 2.4.3). On the basis of this review, I identify gaps in SPT (Section 2.4.4) that have relevance for answering my research questions (set out in Section 2.5).

2.4.1 Practice elements and their interconnections

Theories of practice are very heterogeneous (Schatzki *et al.*, 2001) and there is no fully integrated theory of practice (Schatzki, 2001). Despite this, practice theorists agree that to understand social life, how it is maintained and how it can be reconfigured, analysis needs to focus on the composition and performance of socially recognisable practices. Social practices have been variously interpreted (Gram-Hanssen, 2011). Reckwitz defines a practice as:

> '…a routini[s]ed type of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge' (2002a: 249).

Schatzki suggests that a practice is a 'temporally unfolding and spatially dispersed nexus of doings and sayings existing in three forms: 1) shared understandings 2) explicit rules and 3) teleo-affective structures' - the 'ends, projects and tasks' associated with moods and emotions (1996: 80, 89). Shove and Pantzar (2005)'s study on 'innovation in practice' adopted a distilled practice definition. This framework, shown in Figure 2.10, was refined in the book 'The social dynamics of practice' (Shove *et al.*, 2012: 14), and describes practices as constituting three elements;

- '*Materials:* including things, technologies, tangible physical entities, and the stuff of which objects are made;
- *Competences:* which encompass skill[s], know-how and technique; and
- *Meanings:* including symbolic meanings, ideas and aspirations'.

Some warn of falling 'prey to the scientific urge to build simplifying diagrammatic models of social life' (Schatzki, 2002: xii). Aware of this limitation, this thesis adopts Shove and Pantzar's (2005) three elements and links practice framework. It does this in order to understand how practice elements, and practices themselves, connect to one another and how links can be broken, changing their configuration and distribution, with potential environmental implications for socio-technical life.

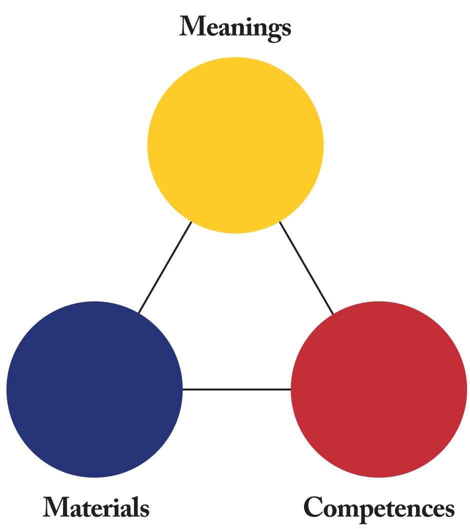


Figure 2.10 – The three elements model of practice

(Source: Adapted from Shove and Pantzar, 2005)

I illustrate the SPT framework (Figure 2.10) by 'zooming in' (Nicolini, 2009) on the composition of low-energy housing construction practices and describing each of the three elements: materials (stuff), competences (skills), and meanings (images). First, clearly materials, technologies and infrastructures are crucial to the composition of low-energy housing practices. Low-energy housing requires; building *materials* (e.g.

bricks, timber, insulating materials, concrete); technologies (e.g. resource efficient heating systems, triple glazed windows, mechanical ventilation equipment, energy monitoring units, solar photovoltaic panels); and connection to centralised energy, water, transport and community infrastructures. Whilst 'things' were largely missing in some early conceptualisations of SPT (e.g. Schatzki, 1996), and indeed Schatzki's later formulations of SPT continue to distinguish between 'bundles of practices' and 'material arrangements', he acknowledges that 'practices are intrinsically connected to and interwoven with objects' (Schatzki, 2002: 106). Reckwitz (2002a) emphasises that 'objects are necessary components of many practices – just as indispensable as bodily and mental activities'.

SPT takes a different position to ANT's principle of generalised symmetry because objects need to have 'materialised understanding' to act as resources within practices. As such, without human activity there can be no practices. At the same time, not only bodies but also artefacts form sites of understanding in practices (Reckwitz, 2002b). Furthermore, undertaking most practices necessarily demands using particular things in certain ways (Reckwitz, 2002a). In this respect, SPT moves beyond culturalist understandings of the material that attempt simply to ascribe meaning to objects (e.g. Reckwitz 2002b). Similarly, the theory develops concepts of appropriation and domestication by studying how 'havings and doings' are embedded in the routines of daily life.

More recently, SPT theorists have adopted a broader understanding of objects, suggesting that they should be thought of 'not as bounded entities, but as sites of flow, mixture and mutation' (Shove *et al.*, 2014: 113; Royston, 2014). This understanding brings into the analytical frame materials such as, flows of warmed air and their generation and management in peoples' homes. Shove *et al.* (2014) suggest that this relational view of the material enables connections to be made between small-scale thermal requirements (e.g. for computer chip design) and very large thermal implications (e.g. energy demand for global climate change). This view provides greater understanding of how objects and people intermingle, how they come to be as they are, and how they might change from resource intensive patterns.

Second, professional low-energy housing construction practitioners need to hone particular *competences*, skills, know-how and techniques. For example, whilst traditional bricklaying requires only the external faces to be flush (for aesthetic purposes), superior air tightness requirements in low-energy housing developments demand flush surfaces both externally and internally (Macrorie *et al.*, 2014a). According to the three elements SPT framework, forms of tacit knowledge, know-how, technique and understanding, described by Giddens (1984) as practical consciousness and by the three elements framework as 'competences' (Shove and Pantzar, 2005), are integral to the doings and sayings of practices. The routinised ways in which 'bodies are moved, objects are handled, subjects are treated, things are described and the world is understood' according to these competences (Reckwitz, 2002a: 250) hold practices in particular forms (or 'variants', Spurling *et al.*, 2013). Just as for other linked practice elements, competences are created, reinforced and transformed through practice performance (i.e. as practices are enacted by human 'carriers' (Reckwitz, 2002a)). Carrying, and performing, a particular practice does not mean though that human actors are passive 'dupes' (Warde, 2005). Instead, through the active and localised performance of practices, individuals can reject particular ways of doing, improvise and creatively reproduce and transform them (Seyfang *et al.*, 2010).

Third, low-energy housing construction practices demand 'buy-in' to symbolic *meanings*, ideas and aspirations, most notably achieving accreditation to particular building energy performance standards, but also broader social discourses, for instance recognition of the need to reduce emissions generated by the residential sector. Mental activities, emotions and motivational knowledge (meanings) form a vital component of practices as well. These aspects of practice represent 'the social and symbolic significance of participation [in a practice] at any one moment' (Shove *et al.*, 2012: 23). Whilst harder to characterise than other elements, in contrast to behaviourist perspectives, SPT theorists agree that attitudes, motivations and values do not 'belong' to individuals, but form necessary components of practices (Reckwitz, 2002a). Described by Reckwitz (2002a: 254) 'wants and emotions thus do not belong to individuals but – in the form of knowledge – to practices'.

The elements of practice combine to inform what *makes sense* for someone to do (Schatzki, 2002). Practices then are defined by interdependent and recursive relations/ linkages/ connections between materials, competences and meanings. Kuijer (2014) elaborates this SPT framework to suggest that the three practice elements are in fact groupings of variously differentiated elements that are interconnected by a multitude of links, where some elements and links are more core to the practice than others. Each time a practice is performed, a combination of materials, competences and meanings are brought together, and it is not possible to undertake a practice unless all requisite elements are available. The ongoing integration of elements is essential to keep a practice 'alive'; 'if specific configurations [of more or less sustainable practices] are to remain effective, connections between defining elements have to be renewed time and again' (Shove *et al.*, 2012: 24).

Developing ideas expressed in Shove and Pantzar (2006) and Pantzar and Shove (2010), it has been suggested that practices have active lifecycles (Figure 2.11). First, elements are gathered together ('proto-practices'), they are then integrated into useful configurations by forming linkages (practices). Elements become detached or are actively removed when links are no longer made ('ex-practices'). They can also endure after having outlived the practice of which they were once a vital part. In this way, practice elements have their own histories and futures, and practices themselves should not be thought of as fixed entities; they are created, persist and disappear as connections between elements are made, sustained or broken.

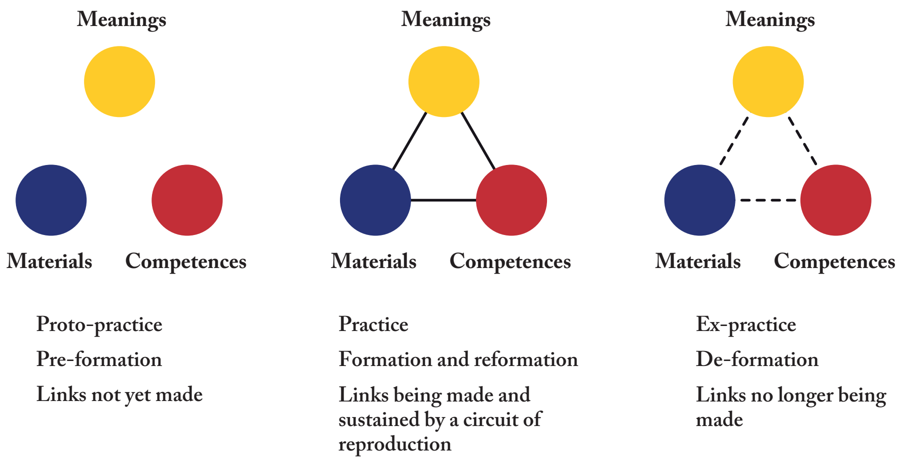


Figure 2.11 – Proto-practices, practices and ex-practices

(Source: Adapted from Pantzar and Shove, 2010)

Links are developed and destroyed, not just within a single practice, but also between multiple practices sharing a similar element (Shove *et al.*, 2012). This can lead to ripple effects across the cultural landscape. For example, altering meanings of the Australian dream of building a detached family house on a quarter-acre block, to satisfaction with home rental or apartment living, would have tremendous sustainability implications. This modesty could potentially lead to people to altering linked practices or to revising practices that share similar meanings (for example driving, which is currently dominated by high performance car ownership with high associated emissions).

Understanding practices, and their elements, as continuously being (re)formulated contrasts distinctly with end-goal linear processes, such as rational behaviour change, technological diffusion, domestication and normalisation. Taking this matrix of more, and less, dynamically changing practices into consideration has profound implications for the governance of socio-technical life, and explains why interventions might not deliver linear or anticipated outcomes. This SPT understanding also suggests that targeting the composition and relational arrangement of elements and practices – how they develop, combine and circulate - may offer an effective means by which to intervene in the current unsustainable practices of the residential sector. It is to these dynamics of practice performance, reproduction and potential transformation that this discussion now turns.

2.4.2 The creation, performance and reproduction of practices

Practices are recognisable to particular societies, whether or not societal members perform the activity themselves or not, or have encountered fellow practitioners. For example, most people can describe building a house, and the elements of which it is composed, even though they may not have physically undertaken this activity. Because practices exist beyond particular individuals, it is possible to identify *practice-as-entities*. These 'spatio-temporal entities' (Schatzki, 1996) also have trajectories. For instance, domestic heat comfort practices in the UK have changed distinctly from the mid 1700s to present day; coal stoves and early hot water radiators (1870s), gave way to portable electric heaters (early 1900s), central heating systems and radiators (1970s), and standardised assumptions that to be comfortably warm requires the home to be heated to 22 degrees Centigrade (Shove and Moezzi, 2002).

Practice-as-performances are the observable doings of particular individuals (e.g. turning up the thermostat, or producing a particular architectural design / formulation of housing policy). Schatzki (2001) refers to this manifestation of practice as the 'activity dimension'; the point when elements become integrated, by people, through particular activities (Kuijer, 2014). These performances are slightly different each time, allowing variety, and potential change in the practice. Moreover, practices (such as achieving heat comfort at home) are done in different ways across the world (e.g. Wilhite *et al.,* 1996), change through time (e.g. Chappells and Shove, 2005), and can involve different elements and configurations in their performance (e.g. snuggling under a duvet in bed, putting on additional layers of clothing, or waiting for the programmed central heating to start up).

The practice-as-entity and practice-as-performance are inherently associated; indeed they constitute each other. Practice entities are dependent on repeated performances to be sustained and remain 'alive'. At the same time, practice entities order performance. They therefore have a degree of momentum, which largely ensures the continuity of performances over space and time. They also 'contain the seeds of constant change' (Warde, 2005: 140). Spurling *et al.* (2013: 8) and Spurling and McMeekin (2014) argue that practice as performance (i.e. 'behaviour') is therefore 'just the tip of the iceberg', and instead sustainability policy should concentrate on better understanding the practice-as-entity, (i.e. 'the social, cultural and technical underpinning of behaviour'). Whilst more sustainable practices may be honed through repetition of less resource-intensive performances, I agree that understanding how practices-as-entities come to be made manifest within the fabric of society, offers greater opportunity for achieving wider-spread, and potentially longer-lasting, transformations towards sustainability.

Pantzar and Shove (2010: 450) and Shove *et al.* (2012) develop the notion of three '*circuits of reproduction*' to explain how particular practices come into being, are maintained and become stabilised. First, for practices to endure, their circulating elements need to be linked together and consistently integrated. This connection can become mutually reinforcing; for instance, heating thermostats (materials) have become closely associated with expectations of the flexible delivery of thermal comfort according to the needs of the household (meanings), and (skills) of programming the thermostat to synchronise with household movements throughout the week.

The second circuit of reproduction concerns links and ties between whole practices as they relate to, and associate with, one another (Pantzar and Shove, 2010: 450). Schatzki (1996: 98) distinguishes between *dispersed* practices – single actions common across many domains of everyday life (e.g. designing, explaining, following rules, measuring) and more complex *integrative* practices (e.g. policy-making, house-building, maintaining heat comfort at home). Similarly, Shove *et al.* (2012: 17) distinguish between *bundles* of practices that form 'loose-knit patterns based on co-location and co-existence', and *complexes* of practices that represent 'stickier and more integrated arrangements including co-dependent forms of sequence and synchronisation'. Whereas practices remain distinct in bundles (e.g. thermal comfort can associate with particular lighting and music practices), complexes are so tightly connected that constituent practices become 'black-boxed', forming a new entity (e.g. housing construction is dependent financial, planning, design, materials procurement, surveying, training and health and safety practices).

The third circuit of reproduction relates to temporal dynamics and path dependence - how previous and coexisting configurations of practice act to limit/enhance and shape how other practices evolve. Pred (1981) discusses current 'dominant projects' – complexes of practice that orient the ways in which people spend their time and the priorities around which their lives are organised. Whilst Schatzki (2010) highlights how, the organising, ordering and scheduling of practice entities, coupled with the location of their performance, generates distinct social infrastructures of when, where and how things are done - 'timespaces'. Unless we are able to multi-task, performing a particular practice (e.g. office-work between 9am-5pm) can limit engagement in other practices (e.g. childcare at home) and structure performance of associated practices (e.g. commuting to and from work). Past performances too have relevance for shaping current practices because they have obdurate qualities (Hommels, 2005; Spurling and Blue, 2014). For instance, many houses were built decades ago according to different construction priorities, standards and ideas of 'normal life', which are now irrelevant (e.g. each room having a hearth for a coal fire, when the chimneys have been capped and central heating has been installed).

Pantzar and Shove (2010) suggest that these three circuits of reproduction work together to simultaneously limit, or facilitate, the reproduction of elements, integrate with other practices, or transform particular practices. It is then through these intersecting circuits that practices-as-entities develop and are maintained, but arguably also how practices are transformed and change. This presents a radically different understanding of socio-technical change to existing policy documents and the technical, behavioural and contextual theories on which they are based.

Seeking to understand how individuals are influenced by 'social norms' or 'context' presents a view of change based on influencing external driving factors and the removal of barriers. This 'language of driving factors [associated with behavioural approaches fails to capture] the extent to which forms of practical knowledge, meaning and competence are themselves forged and reproduced through the process of doing' (Shove *et al.*, 2012: 144). Furthermore, SPT supports an emergent and process-based understanding of change, based on the unit of analysis (i.e. practice) 'undergo[ing] metamorphosis over time and chang[ing its] meaning' (Geels and Schot, 2010: 79). This contrasts with cause-and-effect explanations for why the socio-technical world is as it is and how it changes, which insufficiently attempt to explain any deviations to predictions using theories of variance. The ways in which practices are created, performed and reproduced, the range of practice performances that can occur, and the ways in which practices can link together, provides great scope for analysing social life and for encouraging more environmentally sustainable approaches.

It is to this challenge of transforming practices, as well as their elements, bundles, complexes and relations, in more environmentally sustainable directions, that this discussion now turns.

2.4.3 Transformations and interventions in systems of practice

As practice complexes are carried out, interdependencies between connected practices are developed and reinforced. As these interdependencies become broader reaching and more embedded in time and space, they condition reproduction of the practice(s) that they make-up. As well as retaining recruited individuals, they encourage more practitioners to take part in the given practice (i.e. recruit more carriers) (Watson, 2012). In this way particular practice complexes, with varying environmental implications, can become dominant. For example, installation of air conditioning units in new-build properties in Australia has risen from 10 to 67 percent over the past 40 years, recruiting a large proportion of the population to residential air-cooling practices, and enabling associated 'chilled' domestic activities, whilst also contributing to peak energy demand challenges (Strengers, 2010). Healy (2008) describes how this trend is leading to the 'homogenisation' of people and built environments (i.e. standardising energy-intensive cooled environments for work, shopping and driving practices with significant energy demand and supply implications).

For practice theorists, to attempt to promote less resource-intensive ways of life means understanding and reconfiguring the practices of which society is made. Building on work by Shove *et al.* (2012), Spurling *et al.* (2013) and Spurling and McMeekin (2014) set out three novel problem framings for attempting to modify the composition of, performance of, and connections between, practices. They suggest that these problem framings provide three potential intervention routes for the reconfiguration of practice arrangements, through which socio-technical change can be attempted.

First, *re-crafting practices* seeks to reduce the resource-intensity of existing practices by altering the elements (i.e. materials, competences and/or meanings) of which the target practice constituted (see Figure 2.12). On first appearances, this framing is not dissimilar to many current sustainability policies, particularly as it does not seek to challenge conventions around resource demand (Spurling and McMeekin, 2014). It bears similar resemblance to; public information campaigns, professional training schemes, and technical initiatives which each focus on altering specific practice elements (albeit in accordance with a different theoretical lens). However re-crafting practices suggests a 'more systematic approach' (Spurling *et al.*, 2013: 22) than adopted by current policy initiatives, (e.g. deliberately identifying and removing particular unsustainable elements, to enable the enactment of less resource-intensive practices).

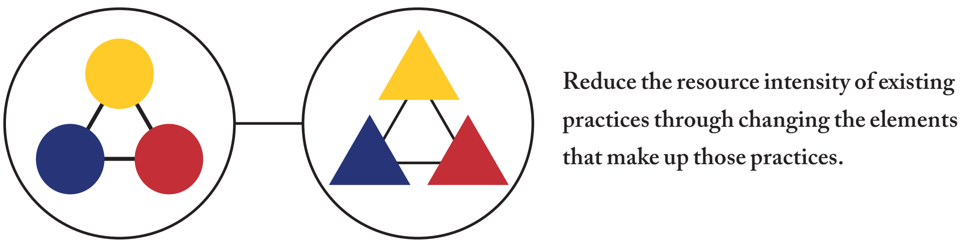
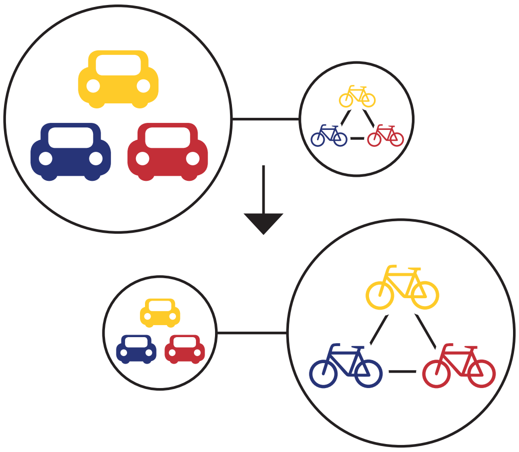


Figure 2.12 – Re-crafting practices

(Source: Adapted from Spurling *et al.*, 2013)

Second, *substituting practices* involves replacing practice entities that are environmentally unsustainable with more sustainable alternatives (Spurling *et al.*, 2013) (see Figure 2.13). In this framing, the demand for current levels of the practice is taken to be 'non-negotiable' (Shove and Chappells, 2001); rather the focus is on how this demand can be met. Communities might be designed to encourage defection from unsustainable practices and recruitment to more sustainable alternatives. For example, when considering mobility practices, a shift from driving to cycling might be encouraged by providing bicycle racks at a new housing development as opposed to car parking spaces. Similarly, more sustainable versions of existing practices might be encouraged, for example, considering laundry practices - homes can be designed to have in-built air-drying amenities rather than tumble-drying facilities.



Replace less sustainable practices with more sustainable alternatives.

Figure 2.13 – Substituting practices

(Source: Adapted from Spurling *et al.*, 2013)

Whilst most SPT research has focused on isolated practice elements, or individual practices, to address environmentally unsustainable practice complexes and bundles, and reconfigure the organisation of contemporary socio-technical life, it is vital to understand the relations that hold different practices together. As such, the third mode of intervention addresses relations between practices, or the way that practices 'interlock' (see Figure 2.14). Spurling *et al.* (2013) suggest that these complex interactions can be altered, by intervening in the sequencing and/or synchronisation of practices. In this problem framing, demand for the practice itself is 'viewed as malleable, contingent and emergent' (Spurling and McMeekin, 2014: 92). Attention shifts to how interventions can affect the wider 'system of practice' that generates the demand (Shove and Walker 2007, 2010; Pantzar and Shove, 2010; Shove *et al.*, 2012; Watson, 2012; Spurling *et al.*, 2013; Macrorie *et al.*, 2014a&b (see Appendices O&P); Spurling and McMeekin, 2014). For example, this might involve attempts to reduce evening energy demand peaks by encouraging flexible working hours. Spurling *et al.* (2013) draw on the example of the CSH describing how the Code enables housing developers to 'earn' one point by providing home offices for residents.

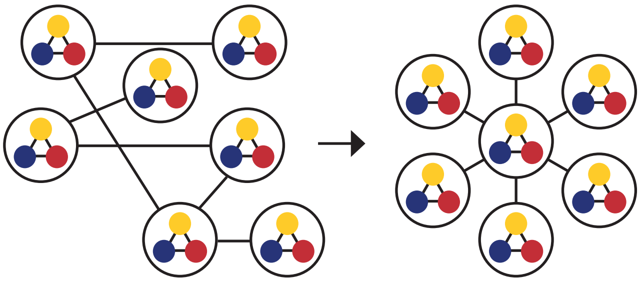


Figure 2.14 – Changing how practices interlock

(Source: Adapted from Spurling *et al.*, 2013)

Acknowledging that specific practices are connected into more extensive 'systems of practice' leads to the crucial understanding that 'any intervention in any single practice – whether intentional or not – will have ripple effects throughout the whole system of practices of which it is a part' (Macrorie *et al.*, 2014a: 98). As Watson observes:

> 'Processes of change, whether to the elements of a practice or to the patterns of recruitment and defection of practitioners to it, are rarely endogenous to the practice concerned. Rather they arise because of the shifting relative location of a practice within broader *systems of practice*' (2012: 491) (emphasis in original).

I define a system of practice as a relatively stable configuration of linked practices and relations that together sustain a particular socio-technical mode of doing (for instance, a particular way of designing, building and living in homes). A system of practice can vary in size and complexity from a modest complex or bundle of practices, to an intricate, multi-dimensional configuration of practices. This builds on previous conceptualisations of inter-related practices, for instance Pred's (1981) concept of practices contributing to dominant projects (see Figure 2.15). This concept is described by Shove as providing a way to get close to how practices are organised in relation to each other:

> "In everyday life, projects, which take many forms, are significant devices deployed in bounding and in making sense of the temporal flow, and in orchestrating and interweaving complexes of practices" (2007: 144).

Modifying a practice invariably affects linked practices and the configuration of a practice system. In the previous example, developing flexible working practices from a home office would have the knock-on-effect of enabling the performance of activities normally prevented during conventional office-opening hours. This might allow avoidance of traffic congestion or facilitate use of appliances powered by domestic solar panels during daylight hours.

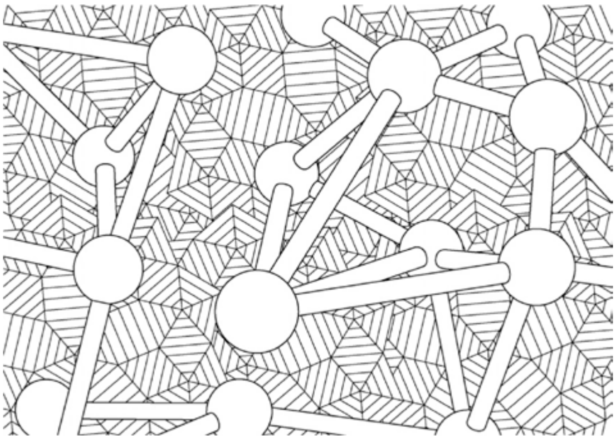


Figure 2.15 – Practices contributing to projects

(Source: Røpke and Christensen, 2012: 351)

Recognising the importance of systems of practice is vital for understanding how practices evolve and how they might be reconfigured in less energy-intensive directions. As well as bringing into view many more practices than would be by focusing on a 'target' practice alone, this understanding also introduces a wider range of potential points for, and agents of, intervention (Macrorie *et al.*, 2014a). In relation to low-energy housing, a systems of practice perspective reveals the shortcomings of research and policy initiatives that focus solely on the technical and energy performance of houses themselves and that only examine the daily practices performed by householders within them. Rather it adopts the understanding that homes form one potential intervention site among many, and that householders are merely one set of carriers among many others in systems of practice (*ibid.*). Taking into account the complexity of this systems based organisation has distinct implications for research and governance approaches, which are acknowledged in Section 3.4 and are examined in detail in Chapters 6 and 7.

Connections between practices within a system are not fixed rather they can be understood as 'webs of co-dependence that are not evenly arranged (but include knots, nodes, relays etc.) continually rewoven as practices are reproduced' (Shove *et al.*, 2012:

94). For example, where home cooking, and repairing and mending were once tightly joined to the practice of household management, they are today clearly separated. In attempting to conceptualise these dynamics, Shove *et al.* (2012), in similarity to the MLP, invoke ecological metaphors of collaboration and competition between more or less dominant practices. They also draw on ideas of patterns of practice 'emergence', 'colonisation', and 'hybridisation', suggesting that:

> '… there is no break in the stream of daily life: no moment when social arrangements start over afresh. Each 'new' combination of elements and practices is in some sense an emergent outcome of those that went before' (Shove *et al.*, 2012: 125).

These dynamics and patterns can, dependent on particular forms of hybridisation and reconfiguration, influence the emergence of 'dominant projects' (Pred, 1981) and structure the course that other practices take. Whilst the 'chains of interdependence' (Shove *et al.*, 2012: 88) that link practices can result in complex hierarchies, practice change within and across systems of practice does not need to follow a linear and pre-determined course. Objecting to the MLP notion of three tiered niches, regimes and landscapes (critiqued by Shove and Walker, 2007 amongst others), Schatzki describes how, to understand socio-technical change, SPT researchers need to understand systems of practice as:

> 'a plenum of practice-arrangement bundles and constellations [which] is always on the move in myriad usually – but not always – small ways, [and] whose path and issuance are not predetermined' (2011: 22).

This flatter ontology has profound implications for the governance of socio-technical transformations as it means that change can arise from anywhere within the practice system (see Chapters 6 and 7).

This section has presented a novel interpretation of socio-technical organisation and transformative change as understood through systems of practice. This research approach seeks to understand and potentially influence: how practices recruit and lose practitioners; how practices bundle with one another; and the dynamics and feedback processes that operate within and between practice systems. I have contrasted this approach with other systems based, but hierarchical and technically oriented, understandings of socio-technical change (such as the MLP). Finally, I have begun to explore the governance approach advocated by a systems of practice perspective, which as opposed to targeting isolated practices, would identify a range of intervention points that could add momentum to positive feedback processes and would affect practices right across the socio-technical system (Watson, 2012). In so doing, I have identified a conceptual framework that has, as yet underexplored, merit for understanding and reconfiguring the existing environmentally unsustainable housing system of practice.

2.4.4 Gaps in practice

A systems of practice perspective advances SPT understandings by providing a dynamic and relational account of how practices are organised. This conceptualisation explains how through practice performance, dynamics and feedback, both within and across systems of practice, socio-technical life is reproduced and also has potential to change. This section highlights how this concept can be advanced, by identifying three pertinent research gaps.

First, the recently proposed notion of 'systems of practice' (Shove and Walker, 2007, 2010; Pantzar and Shove, 2010; Shove *et al.*, 2012; Watson, 2012; Spurling *et al.*, 2013; Spurling and McMeekin, 2014; Macrorie *et al.*, 2014a&b) has not yet been fully conceptualised, and nor has it been empirically tested. Locating elements and practices as part of a system is 'not… simply to place them together in a rag-bag' (Watson, 2012: 492). However, for the concept to be useful, it is necessary to understand how practices and their assemblages inter-relate in structured and systemic ways, leading to the emergence of dominant processes and modes of doing. As yet, ways to bound systems of practice, to negotiate their complexity and to prioritise particular practices and/or relations for examination, have not been fully described. Only in very recent years have practice theorists considered the different types of practice relations that might exist and their effects. Shove *et al.* (2012) acknowledge that practice relations can adopt different forms – collaborative, competitive, weak or strong. Whilst, Schatzki (2011: 10) identifies five types of association that link practices and 'arrangements' (previously described); causality, prefiguration, constitution, intentionality and intelligibility. In addition, the concept has yet to be empirically applied or tested in a in-depth ethnographic study (Schatki, 2011). As such, 'theories of practice have [an under-explored] potential to illuminate processes across… systemic scales…' (Watson, 2012: 491).

Second as Watson notes, '[p]ractices recruit carriers in board rooms, the physical spaces of futures trading and government offices as much as they do on streets and in homes' (2012: 496). To date however, there has been a prevalent SPT focus on the doings and sayings of everyday, and a particularly preoccupation with how households perform resource-consuming practices. At the same time, despite the growing interest in how to intervene in practices, the practices of policy makers and initiative organisers – potentially capable of intervening at the level of practice-as-entities – have received scant attention. In this thesis, I seek to address this gap by examining how networked practices relating to low-energy housing (directly and indirectly), are performed at multiple sites and scales, by a broad range of actors and agents.

Third, whilst the concept of systems of practice does 'not rule out the possibility of thoughtful, practice-oriented policy intervention' (Shove *et al.*, 2012: 163), and indeed I suggest that systems of practice can provide hugely useful perspectives, tools and processes for policy interventions, it remains at the periphery of accepted modes of political decision-making (Spurling *et al.*, 2013). In part this is because the concept has not been fully operationalised. It is also because a systems of practice based approach challenges dominant political regimes and power structures, and threatens ingrained socio-technical systems (Shove, 2010). Further conceptual, empirical, and applied application of systems of practice is therefore required. SPT theorists also have a responsibility to disseminate the findings of their research further afield than academic audiences.

2.5 Research questions

This chapter has described how contrasting theoretical perspectives are associated with different understandings of low-energy housing governance. These approaches each concentrate on distinctive objects of governance, and advocate alternative ways of gaining evidence, intervention tools and processes and assessment approaches. Technological understandings of the governance of low-energy housing prioritise the uptake of 'techno-fixes' in order to address the low-energy housing challenge. Behavioural approaches concentrate on understanding and influencing individuals' attitudes, values and choices and (potentially) seek to alter the context in which these decisions are made. Socio-technical perspectives adopt a systems-based understanding of change, encourage greater consideration to be given to connections between the social and the technical, and seek to understand the continuous remaking of connections within the socio-material world.

Building on this review, in line with the SPT perspective, this thesis understands the governance of low-energy housing as occurring through the social organisation and performance of interrelated practices. I seek to develop a systems based understanding of practices as applied to low-energy housing in a particular context.

As outlined in the introduction, the over-arching research question for this thesis is:

How can social practice theory inform the governance of low-energy housing?

In addition, the following three sub-questions have emerged from this review, and underpin the rest of this thesis.

1. **How can the Code for Sustainable Homes (CSH) be conceptualised as an intervention in practice?**

Most existing literature fails to recognise the social significance of codified technical standards (such as CSH), and contends that by providing information and incentives to individuals and/or overcoming contextual barriers to implementation, optimum building performance will be achieved. These conventional approaches have been widely criticised for giving precedence to 'technological fixes' (e.g. Reid and Houston, 2013; Foulds, 2013), focusing too much on individuals and their beliefs and values (Guy & Shove, 2000; Shove, 2010), and/or failing to integrate different forms of context identified (e.g. discourses, technologies, lifestyles etc.) (Hargreaves, 2009). At the same time, much existing literature tends to adopt a linear understanding of the implementation of regulation and standards, whereby it is assumed that through meeting all necessary criteria, a desired outcome will be achieved.

This thesis will apply SPT to understand the process and effects of implementation of the CSH standard. Instead of analysing the Code's outcomes in terms of technical performance, or appraising individuals' values and attitudes in isolation, analysis is directed to the organisation, performance, and extent of transformation in practices related to low-energy housing. The intention is that this approach will provide a sophisticated and holistic understanding of the everyday doings associated with low-energy housing, and their social, cultural, technical and institutional mediation.

2. **What effects does CSH have as an intervention in practice?**

'At first sight, the development of more and better [building energy performance] standards is an unquestionably 'good thing'' (Shove and Moezzi, 2002:1). The CSH, as a techno-rationally informed building standard, was intended to drive-up the energy credentials of new-build housing and reduce carbon emissions from the residential sector, by encouraging the adoption and use of sustainable construction techniques and materials. The building energy performance outcome of these technical innovations forms the focus of many low-energy housing initiative appraisal, and accreditation processes. This provides a distinctly narrow view of sustainability transformations in housing.

Where aspects of social life are considered in conventional building performance research, people and their actions tend to be problematised, and technology transfer is understood as an attempt to overcome non-technical barriers that are seen as inhibitory to realising proven technical potential (Shove, 1998). In attending to interrelations between the social and technical world, exploring how housing construction processes, domestic routines and building standards are socially, as well as technically, constructed, Science and Technology Studies (STS) extend this technical perspective. As discussed however, these perspectives are also limited in their conceptualisations of stability and change in the everyday doings of individual actors, and the socio-technical world of which they are part.

SPT contends that interactions between individuals (who possess knowledge, skills, values etc.) and structures (such as technology, infrastructure and institutions) are crucial to understanding processes of low-energy housing governance. These interactions produce socially recognisable practices, which shape individuals and social structures, and should form the main unit of social analysis. To date however, much practice-based research has prioritised the domestic environment and experiences of householders, as opposed to making connections with the everyday governing practices of policy-makers and initiative managers. SPT has also predominantly considered practices that have stabilised, as opposed to explicitly exploring novelty in practice. This thesis will use a SPT framework to analyse the effects of the CSH standard as an intervention in professional and householder practices. As such it will extend the traditional focus SPT focus on domestic routines, will analyse practices undertaken by different types of practitioner, and will explore the extent to which, and how, if at all, these practitioners' practices change.

3. **What is the potential for applying 'systems of practice' to the governance of low-energy housing?**

This chapter has revealed how much early SPT work focused on analysing the composition and evolution of specific, individual practices. Recent research has responded to the critique that SPT has merit only for micro-scale analyses of the 'everyday' (e.g. Geels, 2010) by pointing out that individual practices are '…always and inseparably bound up in wider systems of practice that extend across space and time' (Macrorie *et al.*, 2014a: 97). Whilst this approach has, to date, had little attention from policy-makers, understanding practices as spatially and temporally dispersed systems of practice, holds tremendous potential for delivering change towards sustainability in the residential sector (and potentially further afield).

This systems based way of understanding organisation and change patterns within the socio-technical world, presents a distinctly different perspective to other more linear and hierarchical theoretical concepts (such as techno-rational perspectives or the MLP). As such, recognising the importance of systems of practice provides an important first step in understanding how practices are organised, relate, evolve and might be transformed to be more environmentally and/or socially sustainable. However, conceptual work completed on systems of practices remains underdeveloped, and further empirical work is required to understand its application and use. One area where application of the concept has distinct potential is the residential sector, and the challenge of directing housing practices in less energy-intensive directions.

In attempting to apply more of a systems based understanding of SPT, attention must first be directed to the methodological implications of such an approach. This challenge is addressed in Chapter 3.

Chapter 3. Researching low-energy housing-related practices

This chapter explains the particular research approach required to answer the questions posed in this thesis. It outlines in detail how the methods used for data collection and analysis enabled my research objectives to be met (outlined in Chapter 1). I justify how the selected methods are commensurate with my 'ways of knowing' (Schwartz-Shea and Yanow, 2012), and highlight how alternative investigative and analytical techniques would not have been suitable for this research.

Research methods do not act as simple conduits to an external and objective reality, but different logics of inquiry and research techniques themselves play an important role in what it is possible to know and how the world can be interpreted. In this chapter, I argue that interpretive research needs to ensure a design process that reflects and 'make[s] space for its iterative, recursive and adaptive character' (Schwartz-Shea and Yanow, 2012: 55). The importance of attending to my own positionality throughout the research design, data collection and analysis stages of the project is highlighted.

The chapter begins by outlining the methodological reasoning behind selection of an interpretive research approach (Section 3.1). It then details my case study method and reasons for selecting the case of the Code for Sustainable Homes (CSH) as an example building sustainability performance standard. Section 3.2 describes how an exemplar site intended for the implementation of CSH to the highest sustainability rating was selected (i.e. CSH level six, carbon neutral). It also explains how access to the development, and knowledge of the practices of its multiple stakeholders (including residents), was acquired. I describe how whilst I initially understood the development as a one-off demonstration project, my understanding of the case-study type altered (Flyvbjerg, 2006) as I grew more familiar with 'systems of practice' thinking (Shove and Walker, 2007, 2010; Pantzar and Shove, 2010; Shove *et al.*, 2012; Watson, 2012; Spurling *et al.*, 2013; Macrorie *et al.*, 2014a&b (see Appendices O&P); Spurling and McMeekin, 2014). The decision to 'zoom in' (Nicolini, 2009) on the performance and changing composition of heat comfort practices at a domestic level is explained.

Section 3.3 explains considerations associated with data collection in the field, describes how the mass of data that interpretive research design generates were analysed, and explains the decisions made in relation to writing-up the empirical material. In formulating and conducting this research, the prospect of developing an explicitly relational system of practice oriented approach to understanding contemporary housing challenges presented an exciting opportunity. The research design approach developed in this chapter is intended to extend current SPT theoretical and methodological approaches. It also holds valuable merit for policy and practice, the implications of which are discussed in Chapter 7.

3.1 Starting out: Developing ways of knowing and framing research questions

Before designing a research project, both a topic of research and a research question are required. Whilst sometimes used interchangeably, the two are not the same:

> 'Articulating that research question itself can reveal the approach or logic of inquiry it contains and rests on; and that logic of inquiry – that way of knowing – itself presupposes the answer to the question: Where does this research question come from?' (Shwartz-Shea and Yanow, 2012: 24).

Before setting out the research approach for this thesis therefore, it is necessary to understand how I arrived at my research topic and questions. As such, rather than commencing this chapter with a philosophical discussion of ontological and epistemological antecedents, I describe how I arrived at my research questions and use these accounts to explain my methodological approach. Reflecting on what shaped this investigation, it is important to acknowledge the role of three different ways of knowing: i) prior knowledge, ii) theory and the literature review, and iii) abduction (each are addressed in turn below).

My previous research experiences played a vital role in shaping how I approached, designed and conducted my doctoral project. As a Research Associate at the University of Bradford, I compared and contrasted implementation of three consecutive water and energy resource efficiency retrofit initiatives in the water-stressed UK designated growth town of Ashford (Kent) (Sharp *et al.*, in press). This project aimed to understand how the design and implementation of new low-energy housing developments, particularly how householders were framed, led to - or failed to result in - water demand and emission reductions. It also investigated the extent of institutional learning that occurred between initiatives, and the implications of these understandings for future governance. I came to this doctoral research therefore understanding the rationale for urgently reducing residential carbon emissions. Acknowledging the carbon implications of existing homes, I was interested in the energy implications associated with new-build homes and their future legacy, and was attracted by the opportunity to conduct novel environmental social science research into one of the first UK carbon-neutral housing developments.

With an *a posteriori* awareness of the implications of different governance approaches for the successful implementation of retrofit initiatives, I sought to further explore this concept in the new-build housing sector. I had however developed growing frustration at the seeming institutional blind faith in technological measures to deliver energy and carbon reductions, and had first-hand experience of the deficiencies of individualistic approaches in delivering long-term behavioural change. As such, rather than conduct a building energy performance appraisal of the carbon-neutral homes, I wanted to understand how people fitted into the UK Government's proposed eco-town concept, CSH standard, and zero carbon homes target (described in Chapter 1). In addition, rather than investigate individual, household and community decision-making around energy and carbon (as proposed in the initial research proposal[1]), I wanted to adopt a more sociologically-informed understanding of change, and to explore the governance implications of such an approach.

With this initial framing of my research, I undertook a literature review to critically appraise the low-energy housing and associated household behavioural change *corpus* of knowledge and to help situate my topic of inquiry (see Chapter 2). Faced with an extensive body of literature replete with many theoretical and methodological approaches and multiple possible avenues of exploration, this was a somewhat daunting task, which revealed the limitations of dominant technical, behavioural and socio-technical approaches. Importantly, the literature review process also led me to explore recent sociological conceptualisations of resource consumption as an artefact of (most) social practices. Whilst highlighting the potential applicability of Social Practice Theory

[1] Energising communities: exploring the dynamics of engagement, learning and behaviour change in EcoTowns – Case for support prepared by Dr. Jason Chilvers, Jane Powell and Irene Lorenzoni (2011). This proposal was not funded by the Economic and Social Research Council (ESRC), but led to the subsequent funding of this PhD in the School of Environmental Sciences - UEA.

(SPT) to my research, reviewing this body of knowledge revealed several theoretical and applied gaps, which I believe my research will help to tackle (see Section 2.4.4).

In line with the original PhD proposal, I had initially planned to contrast the governance approach employed at a selected CSH level six housing development (Trinity Close, Rackheath, Norfolk – see Section 3.2.1) with an existing residential community that had reduced its carbon footprint by means of a 'bottom-up' governance approach[2]. To start, interested in how the build specification of the Trinity Close social housing properties, coupled with the institutional advice provided to tenants, affected energy-related domestic practices, in March 2012, I conducted eleven[3] loosely structured pilot interviews[4] with new residents in their CSH level six homes. During these hour-long discussions and recorded audio-tours of the homes, I asked interviewees to compare the material set-up and their domestic practices at their previous dwellings to those performed at their new properties. I explored householders' experiences of the induction and organisation of the initiative, and I appraised tenants' understandings, abilities and involvement with the installed energy-efficient materials, renewable technologies and monitoring equipment.

These pilot interviews underscored how residential resource consumption and the governance of new-build housing can be best understood, and potentially intervened in, by analysing mundane everyday practices. From these pilot interviews, three additional outcomes were crucially significant for the subsequent development of my methodology. First, given the amount of interesting practice insights generated by the pilot discussions and the novelty of twelve CSH level six housing developments, I discounted comparative research in favour of an in-depth study of a low-energy new-build housing development. Second, I became interested in the ways that practices are collectively performed through interactions between individual practitioners – 'communities of practice' (Lave and Wenger 1991; Wenger, 1998). Acknowledged as a potential SPT development (Røpke, 2009), I believed that extending SPT in this way, would help to understand how low-energy practice performances were refined

[2] In December 2009, Reepham – a market town in Norfolk - was awarded Low Carbon Communities Challenge (LCCC) funding by the Department of Energy and Climate Change (DECC) to reduce its carbon emissions by 127 tonnes per year. The project used a community fund to deliver a range of projects that targeted: energy-efficient renovation, renewables, transport, behaviour change and food initiatives (http://www.reephamchallenge.org/).
[3] One Trinity Close household (of twelve) was not available for interview.
[4] Social housing tenants moved into Trinity Close (Rackheath, Norwich) in late September/October 2011. As such the pilot interviews were conducted approximately six months after tenant handover.

as tenants collectively negotiated their new material environments, and as housing practitioners jointly mastered a codified low-energy approach to house-building. Third, I realised that I could not focus on householders' practices in isolation, but had to examine the relations and dynamics established between professional housing-related practices, householders' domestic practices, and low-energy homes themselves.

I therefore proposed an in-depth study to investigate how the technical specification and organisation of CSH level six housing and the composition and performance of domestic energy-related practices, shaped one another. I was particularly interested in how the 'would-be governors' (Macrorie *et al.*, 2014a) responsible for developing the CSH building standard and implementing it locally, made and reproduced the systems and arrangements that reinforced, and potentially transformed, everyday domestic energy practices. Ambitiously, noting the importance of interaction and collective doing in transferring modified practices, I also aimed to investigate the roles that communities of practice (both domestic and professional) played in configuring the relations and dynamics of domestic energy-related practices.

To do this, I proposed a combination of quantitative and qualitative methods. These included: a systematic documentary analysis reviewing the initiative organisers' objectives and approach; analysis of electricity consumption monitoring data for the twelve households at a circuit and key appliance level (collected by pre-installed monitoring equipment); a series of household semi-structured interviews (Valentine, 1997) (including SPT interpretation of analysed domestic energy performance results) (e.g. Foulds *et al.,* 2013). I also proposed to conduct: audio tours (Pink, 2007; 2009); participant observation (Cook, 1997); and household 'experiments in practice' (Kuijer and de Jong, 2011; Scott *et al.,* 2012; Kuijer, 2014) that would appraise the malleability of heating and cooling comfort domestic practices. I aimed for this combination of techniques to provide a rich appraisal of whether, and how, sustainability criteria enshrined in housing performance standards could reduce residential domestic energy consumption and carbon emissions in situated contexts.

My upgrade workshop[5], however, prompted me to both scale-back and hone my research ambitions and proposed methodological approach. Following this discussion, I realised that whilst it would be possible to conduct an SPT analysis of quantitative data

[5] Attended by: Drs. Irene Lorenzoni, Jane Powell, Tom Hargreaves, Chris Foulds, Jennifer Monahan, Charlie Wilson, and Richard Hauxwell-Baldwin - 6th December 2012, UEA School of Environmental Sciences.

(e.g. Browne *et al.,* 2014), to be commensurate with my selected theoretical approach, I should identify and measure the energy implications of specific household practices and how they change, or remain stable. Given the labour intensity of this assessment, the planned quantitative assessment of these data by an environmental consultancy, and as it turned out, the lack of timely availability of monitoring data, I decided to support my qualitative research with a secondary data review (Llobera, 1999: 74) of domestic energy performance results from the selected housing development.

Second, I chose to adopt a broader understanding of governance than simply appraising how the CSH standard was implemented at one housing development site. This was necessary given that the assumptions and actions of initiative organisers are one of many things that shape domestic energy-related practices. Organisers' intentions can go awry, and professional practitioners are themselves governed by their practices (Macrorie *et al.,* 2014a). SPT has tended to place investigative focus on 'users and consumers and their ordinary doings' (Watson, 2012: 496). By analysing the 'doings' and 'sayings' (Schatzki, 1996) of the range of professional housing practitioners involved with the exemplar development, as opposed to simply accepting official institutional rhetoric, I could establish connections between the many sites at which housing-related bundles and complexes of practices were undertaken. As suggested in the upgrade meeting "what happens in Whitehall, matters for what you do in your living room" (Hargreaves, T., personal communication, 6th December 2012). Taking SPT beyond a preoccupation with the isolated practices of householders in this way, I decided that I could examine how different housing practices relate and with what effects.

Given the research implications of this relational line of inquiry, and to streamline my research design, I also decided to abandon the communities of practice question, and to focus on one domestic energy-related practice (heat comfort practices – i.e. how people maintain sufficient thermal warmth at home). Finally, as opposed to undertaking an explicit experiment in domestic practice, it became clear that any involvement, whether in a professional or domestic capacity, that my research subjects had with the CSH standard, low-energy housing, and constituent materials and technologies, would form a possible intervention in practice. Similarly, in accordance with a reflexive stance on my own positionality (see Section 3.1.1), I realised that with every empirical observation made, conversation held and investigative action undertaken, I too would be potentially intervening in practice. These considerations led me to tailor my research scope, objectives and proposed methodology (see Section 3.1.2).

Whereas positivist research design requires the researcher to hold fast to the initial research question and design, the preceding paragraphs have explored how the research approach for this thesis was formed through an iterative process drawing on my prior knowledge, a review of pertinent literature, and processes of 'abductive reasoning' as I stumbled across new insights in the field, as I became more familiar with the literature, and in my upgrade meeting. Schwartz Shea and Yanow explain how in abductive reasoning:

> '…the researcher's thinking is led, or, more actively, directed in an inferential process, from… surprise toward its possible explanation(s). The researcher [grapples with] the process of sense-making: of coming up with an interpretation that makes sense of the surprise, the tension, the anomaly' (2012: 28).

They go on to explain how unlike inductive (and deductive) reasoning, abductive reasoning's point of departure is the puzzle or surprise and subsequent sense-making process, as opposed to inducing general principles or propositions from specific events. Additionally, rather than following a step-wise, linear logic, abduction follows a 'circular-spiral pattern', in which the researcher 'tacks continually, constantly, back and forth in an iterative-recursive fashion between what is puzzling and possible explanations for it…' (Schwartz Shea and Yanow, 2012: 27, 28). This exciting process enabled me to continuously respond to, and subtly adjust my thinking and approach, as new insights came to light throughout the research investigation.

3.1.1 Constructing low-energy housing practices

> 'For research to be persuasive, the choices of method need to be consistent, [and fit] logically with the methodology – the presumptions about the 'reality status' (ontology) of what is being studied and its 'know-ability' (epistemology)' (Schwartz-Shea and Yanow, 2012: 19).

In seeking to understand the composition, relations and dynamics of practices related to the housing system of practice, and performed in a particular contextual setting, I situate my work in the interpretive tradition of social scientific inquiry (Rabinow and Sullivan, 1987; Schwandt, 1994; Schwartz Shea and Yanow, 2012). This approach to making sense of the social world focuses on the subjective meanings that actors construct and attach to certain situations in their everyday interactions (Goffman, 1959; Geertz, 1973). Interpretive researchers attempt to understand phenomena by accessing and reconstructing these meanings, and in this way, 'what we [as researchers] call our data are really our own constructions of other people's constructions of what they and their compatriots are up to' (Geertz, 1973: 9). Participants are constituted not as objects but as subjects – knowledgeable, agentive actors, whose behaviour is not determined solely by structures and power external to themselves. The subjectivity of the researcher too is emphasised by the interpretive approach as the their knowledge of reality is also situated, contingent and partially complete. In contrast to the assumptions of positivist science therefore, for interpretive research, there is no objective reality that can be discovered and replicated in subsequent investigations (Walsham, 1993).

An interpretive approach, in emphasising the contingency of knowledge claims, resonates with social constructivism (Berger and Luckman, 1967). For social constructivists, research efforts are concerned with reconstructing multiple realities as opposed to searching for one *objective* reality (Denzin, 2010). To analyse particular contexts therefore, constructivism urges the researcher to deconstruct the layers of social structure, and interpret cultural texts and artefacts, codings and symbols. In this research, I have sought to understand how individual practitioners construct ideas about low-energy housing and how these ideas are incorporated into daily practice.

Adopting a social constructivist ontology has two key implications. First, this position demands that I am reflexive about my own positionality as a researcher who 'can never assume a value-neutral stance, and is always implicated in the phenomena being studied' (Orlikowski and Baroudi, 1991). Throughout my research, both the project and my positionality was multiple and changing. As explained by Crang:

> '…our projects are often unstable entities which are not only presented, but actually exist, in multiple versions given to funders, colleagues, friends, family, peers and (different) respondents, none of which need be necessarily the 'true one'. Moreover, researchers… may refashion themselves not only between locations, but over time, and [in how] they are constituted' (2003: 497).

As opposed to there being a single researcher with an unchanging and knowable identity, social constructivism acknowledges that research accounts are formed 'within a fragmented space of fragile and fluid networks of connections and gaps' (Pratt, 2004: 179). As such, at all stages of the research process I tried to be continuously aware of my tacit knowledge and assumptions, and my reactions to participants' interpretations. For example, I became aware that for different research participants, I played different roles – whether perceived as: an auditor; technical specialist; trusted confidant; an adviser; a social researcher; a mediator; or an informant. This required me to negotiate individuals' different expectations without compromising the objectives and ethics of the research investigation. I attempted to maintain this reflexive stance without becoming overtly self-reflexive and denying reality beyond my perspectives (as cautioned by Wolcott, 1999).

Second, if knowledge can only ever be partial, social constructivist research raises the question of exactly whose knowledge is incorporated into practice (Hargreaves, 2009; Walker *et al.,* 2011). As Bent Flyvbjerg explains in his book Rationality and Power:

> 'Power determines what counts as knowledge, what kind of interpretation attains authority as the dominant interpretation. Power procures the knowledge which supports its purposes, while it ignores or suppresses that knowledge which does not serve it. Moreover, the *relations* between knowledge and power are decisive if one seeks to understand the kinds of processes affecting the dynamics of politics, administration and planning' (Flyvbjerg, 1998: 226, emphasis in original).

Power relations are therefore inherent to this research process. Whether reviewing academic literature, analysing documentary evidence, undertaking interviews, or observing participants and their interactions with the material world, I paid attention to whose perspectives were being propagated and reinforced, and to whose ideas and practices were being marginalised (see Chapters 4, 5 and 6). The research participants to some degree had a stronghold over me in terms of empirical data provided, meetings that were arranged or cancelled, and the extent to which they opened-up about their experiences. At the same time, I held power over my research participants in causing them to reflect on, and provide a particular interpretation of, their actions and words. Indeed, whether through engaging with the research process, or by considering its outcomes, this investigation had power to affect how the participants, and myself as researcher, conducted our everyday lives (Briggs, 2003).

Acknowledging that these philosophical issues underpin how I have constructed and conducted this research, the next section discusses the implications for researching the housing system of practice, their relations and dynamics, within a particular context.

3.1.2 Studying low-energy housing practices

To understand how research participants perform practices, I employed an interpretive qualitative approach that demands that research is conducted *in situ* and attempts to 'make sense of, or interpret, phenomena in terms of the meanings people bring to them' (Denzin and Lincoln, 2005: 3). This methodological approach is different from traditional quantitative research methods used in the disciplines of engineering and building science, which continue to dominate household energy studies but fail to provide the 'finely grained and detailed information' necessary to thoroughly examine socio-cultural influences on residential energy consumption (Wilk and Wilhite, 1986: 8; Crosbie, 2006). Interpretive qualitative research also retains methodological difference to social science approaches that enact positivist philosophical modes of scientific knowing, as prevalent in much psychology and economics (e.g. the possibility of objective knowledge, generalising universal laws).

This research therefore adopts an ethnographic approach (Hammersley and Atkinson, 1995). Ethnographies enable researchers to grasp the meaning of social action from the perspectives and everyday experiences of the actors who live them out (Cook and Crang 1995; Dainty, 2008). When coupled with theories of practice, they arguably provide a more theoretically sophisticated way of understanding work on housing and construction than research from the positivist tradition (Pink *et al.,* 2010). Ethnographic approaches enable depth and validity to be achieved at the expense of breadth and generalisability, as might be gained from large-scale social surveys and statistical analysis or technical models. However, whilst they produce only partial and positional accounts, the richness of data that ethnographies generate proves immensely valuable (Reissman, 2008).

However, my goal is not only to learn about how a codified approach to building environmentally sustainable housing affects energy-related practices at a particular site, but also to produce explanations that resonate with a broader social or cultural group (Mason, 1996). In this respect, the social constructivist version of practice theory carries two analytical affordances. First, it enables researchers to move beyond analysing individual consumer choices and instead analyse how ways of performing housing practices are 'entangled in webs of social reproductions and changes' (Halkier and Jensen, 2011: 106). Second, residential energy consumption can be understood as 'continuous dynamics and relational accomplishments [that occur] in [the] intersectings of multiple practices in everyday life, as opposed to analysing consumption as fixed types and over-estimat[ing] the stability of such categories' (*ibid.*: 107). This research attempts to take into account 'sets of [dynamically] interlocking practices that may achieve scales of sustainability transition not afforded by existing problem framings' (Spurling *et al.,* 2013: 51). The methodological implications of this epistemology for data-production are discussed in Section 3.3.

This research therefore needed to move beyond a reliance on qualitative small-scale studies that focus on the 'lifecycles' of specific practices, to explore interactions between multiple practices (Pullinger *et al.,* 2013: 8-9). Macrorie *et al.,* (2014b) discuss five methodological approaches for doing just that, when studying systems of practice. They suggest that systems of practice can be understood by analysing: i) practice bundles/complexes and their interconnections; ii) the changing dynamics of practice, iii) variety in practice composition and performance, iv) geographically dispersed practices, and/or v) detecting large-scale socio-technical trends. This investigation directly employs three of these methodological approaches in seeking to understand the relations and dynamics of a housing practice system in a particular context.

First, the research explored practice *bundles/complexes and their interconnections* by focusing on 'a particular locus of practice intersection' (Macrorie *et al.,* 2014b: 17) – various housing-related practices, carried by different types of actor, which came together through their performance at a carbon-neutral housing exemplar site. Relations within the studied housing practice system were analysed by tracing the performance of a particular target practice – domestic heat comfort practices – which acted as an 'entry-point to explore [practice] connections' (*ibid.*:17) (Section 3.2.3). Second, the research investigated variety in the *composition and performance* of codified housing practices at a particular site. Third, the research studied how heat comfort practices and associated domestic practices, professional housing design and construction practices, and housing policy-making practices, *changed* over the course of eighteen months, and sought to expand out the analytic focus from a single isolated practice, to take account of the dynamics and relations occurring within a housing system of practice.

Before introducing the chosen case study and sample site, it is necessary to explicate the methodological approach demanded by a social constructivist practice theory. Such an approach understands consumption as an artefact of practice performance, as opposed to the result of individual mental motives and choices, or structures of cultural 'scripts' (Warde, 2005: 137). For this reason, gathering an in-depth understanding of practices, and not conducting quantitative assessment of technical functioning or consumed units of energy, is crucial. This research seeks to understand how everyday practices associated with a particular housing system of practice are comprised, performed, experienced, and interpreted – in other words it aims to 'follow the practice' and the connections that they form. In so doing, I draw on previous research that seeks to 'follow a thing' between multiple sites in order its networked connections (e.g. Cook, 2004; Cook and Harrison, 2007). This approach also has resonance with a concept from Actor Network Theory (ANT) that advocates 'follow[ing] the actors themselves' to learn about them and about the networks within which they operate (e.g. Latour, 2005).

This research therefore distinctly contrasts with behavioural research that 'theoretically and methodologically privileges individual choices, and… under-estimate[es] the importance of the social organisation of consumption' (Halkier and Jensen, 2011: 117; Shove, 2010). It also differs to research that assumes that consumption is dependent on cultural structures (such as lifestyle research based on work by Bourdieu, 1984). Understanding practices as the fundamental unit of all social life (Schatzki, 1996) the performance of which generates social categories and dynamics (Halkier and Jensen, 2011) neither is it sufficient to use reductive abstract, laboratory-based or modelled scenarios and extrapolate their results to the 'real world'. Furthermore, to learn about systems of practice, their dynamics and their implications for interventions for sustainability, certain kinds of data and styles of enquiry are required (Shove *et al.,* 2012; Macrorie *et al.,* 2014b). Using a multi-site, multi-actor, and multi-method research approach provides a clear way for SPT researchers to map and analyse complex systems of practice (see Table 3.1).

No.	Methods used to meet the research objectives (Listed in Section 1.3)
1	Field notes
2	Documentary review
3	Secondary data review of quantitative building electricity performance monitoring results
4	Trinity Close Steering Group meetings attendance
5	Professional practitioner semi-structured interviews
6	Participant observation – household & professional practitioners
7	Household pilot & repeat interviews semi-structured interviews
8	Household audio tours
9	Household heat comfort research diaries & follow-up discussion
10	Discursive game on energy-related domestic practices
11	Household living room temperature monitoring & household interpretation of recorded data log

Table 3.1 – Meeting the research objectives using a mixed-methods approach

3.2 Presenting the case study, sample site and target practices

This research forms one of the first in-depth, multi-method (primarily qualitative research) investigations of low-energy housing. Whilst some research has been conducted on the energy-performance of low-energy house-builds post handover, it has primarily taken a technical and quantitative approach (e.g Monahan and Powell, 2011). Where 'social factors' and 'residents' behaviour' have been taken into consideration, researchers have investigated consumer responses to economic cues and information (e.g. Carroll *et al.*, 2014) and contextual factors that support or hinder carbon reduction innovations (e.g. Cole *et al.*, 2008; Reeves, 2011). Alternatively, research has sought to understand people's attitudes, values and choices using interviews & surveys, with a view to manipulating peoples' decisions and bring about domestic energy savings (e.g. Cotton *et al.*, 2015).

Where researchers have sought to shift focus from the individual consumer towards the collective, and from the spectacular towards more mundane aspects of everyday consumption, researchers such as Gram-Hanssen (2010; 2011) and Hitchings (2013) have studied the energy implications of changing household heat comfort practices. Some SPT researchers have placed attention solely on housing-industry and policy stakeholders (e.g. Karvonen *et al.*, n.d.; Osmani and O'Reilly, 2009; Faulconbridge, 2012). Other practice theorists have taken into consideration both professional and household practitioners when examining the energy implications of low-energy housing (e.g. Foulds, 2013; Ozaki and Shaw, 2013). Whilst these studies have helped to contextualise the design, construction and lived-in energy implications of new-build housing, they have failed to adequately examine the implications of connections and dynamics existing between different actors' practices, as well as the elements constituting those practices. Furthermore, very few SPT researchers have studied the CSH standard as a particular case of low-energy housing design, construction and occupation (*cf.* Karvonen *et al.*, n.d.; Osmani and O'Reilly, 2009; Ozaki and Shaw, 2013). This relative lack of relevant preceding research highlighted the need for my study to be exploratory and as a result I elected to use a case study approach and to conduct an in-depth study of a single housing development site.

The case study involves 'an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence' (Yin, 1981; 1993). That the research is focused on a particular phenomenon in context is important. Indeed in some circumstances the term 'site' might be preferable because 'it reminds us that a 'case' always occurs in a specified social and physical setting: we cannot study individual cases devoid of their context in a way that a quantitative researcher often does' (Miles and Huberman, 1994: 27). In 'focusing on [the seeming] minutiae' of everyday life (Flyvbjerg, 2006: 238), and closely examining unfamiliar phenomena and processes (Hartley, 1994) and how they change through time, in-depth case study research reveals particular cases as 'many-sided, complex and sometimes conflicting…' (Flyvbjerg, 2006: 238). Finally, in being open to 'use of multiple methods of evidence or data collection', (Robson, 2002: 179) this approach enables the links, relations, and dynamics occurring between different practices, to be studied. Such an approach was therefore appropriate for the kind of study that I wished to produce.

Despite the merits of the case study, and whilst commended as a preliminary investigative strategy, this data collection approach is regularly criticised for: lacking generalisability, not being statistically representative, being subjectively biased in tending towards verification rather than falsification of hypotheses, and for being unable to develop general propositions and theories on the basis of specific cases. Flyvbjerg's insightful article 'Five Misunderstandings About Case-Study Research' commences by highlighting his frustrations with these claims:

> '"You cannot generalise from a single case" some would say "and social science is about generalising". Others would argue that the case study may be well suited for pilot studies but not for fully-fledged research schemes. Others again would comment that the case study is subjective, giving too much scope for the researcher's own interpretations. Thus, the validity of case studies would be wanting, they argued"' (2006: 219).

He goes on however to refute these misunderstandings and contend that the 'force of example' (*ibid.*:228) has been generally underestimated in all research. I agree that where the objective is to really understand the 'why' and 'how' of a given problem, it is often more important to gain rich information and clarify the deeper causes and mechanisms, as opposed to describe the symptoms of a problem and how frequently they occur. As such, case study research is dependent on the strategic selection of cases, chosen for their relevance to the research objectives.

Initially, I sought to identify an 'extreme', or one-off, case of doing housing differently (*ibid.*:230), where housing-related practices were constituted and performed in line with a low-energy codified standard. As I began to collate my findings, think about housing-related practices as connected within a system, and situate my argument within the academic *corpus* of knowledge, I realised however that my selected case study of the CSH could be considered a 'paradigmatic case' (*ibid.*:232). In undertaking one of the first in-depth, multi-method investigations of a housing development accredited to CSH level six, and in being one of the first SPT researchers to empirically study systems of practice, findings from this case study investigation (see Chapter 7), can help progress systems of practice research, as well as inform housing practice and policy. As such, I believe that my selected case can act as a prototype. Whilst not claiming that the implementation of other building performance standards will proceed in the same way, this case will provide a useful reference point for other systems of practice and housing research.

3.2.1 Standardising low-energy housing: The case of the Code for Sustainable Homes

First proposed by the Labour Government in 2004 (ODPM, 2004), the Code for Sustainable Homes (CSH or the Code), formed part of UK policy response to meet the UK zero carbon standard (see Chapter 1) and came into effect in 2006 (DCLG, 2006). It was intended to provide 'a single national standard to guide industry in the design and construction of sustainable homes [and to] driv[e] continuous improvement, greater innovation and exemplary achievement in sustainable home building' (*ibid.*:4). As well as being intended to bring about a step-change in sustainable home building practice, the CSH was seen as a tool that would enable developers to differentiate themselves in a competitive market, and a way to assist home-buyers in their choice of home (*ibid.*). To this end, the Code was intended to complement the system of Energy Performance Certificates (EPCs) subsequently introduced in 2007 under the European Union's Energy Performance of Buildings Directive (EPBD) (Gibbs and O'Neill, 2015).

According to the CSH, progressive improvements in the sustainability performance of new-build housing developments would be demanded by interim step changes, in order to enable the zero carbon housing 2016 target to be met. Initially introduced as a voluntary framework, in 2010 level three (a 25% energy performance improvement relative to 2005 Building Regulations) was made mandatory for all new build homes (Planning Portal, 2010), and it was originally planned that in 2013 level four would be made mandatory for all new housing (DCLG, 2007b). Some commentators suggested that the UK house building industry would be completely unprepared for the challenges posed by this introduction of increasingly stringent sustainability standards, and were concerned that the sector did not have the technology, knowledge or institutional structures required to deliver this transformation in practice (Lowe and Oreszczyn, 2008). To overcome these perceived 'barriers' to change, the Government also developed an institutional framework to support changing practice by forming the 'Zero Carbon Hub' (ZCH) - a public-private partnership to guide the zero carbon programme - and the Technology Strategy Board's (TSB) Low Impact Buildings Innovation Platform (Gibbs and O'Neill, 2015).

The CSH was to differ to Part L of the Building Regulations, in that it would address wide-ranging aspects of sustainability performance as opposed to concentrating on the conservation of fuel and power alone. The Code would use a rating system to assess nine 'code design' categories – energy/carbon emissions, pollution, water, health and well-being, materials, management, surface water run-off, ecology and waste. A system from one to six stars based on performance against these design categories would communicate the overall sustainability performance of a new-build house - where one would be the lowest (or 'entry level') and six the highest standard, reflecting exemplary development. According to the original definition of this standard, a level six home would be deemed a zero carbon home, defined as having 'zero net emissions of carbon dioxide from all energy use in the home including heating, lighting, hot water and all other energy use' (Panagiotidou and Fuller, 2013: 197). In an attempt to encourage innovation and cost-effectiveness, while based on performance, the Code was not prescriptive in how these levels should be attained (Gibbs and O'Neill, 2015).

'At first sight, the development of more and better energy-efficiency standards [to improve housing construction and building energy performance] is an unquestionably 'good thing" (Shove and Moezzi, 2002: 265) and it would seem sensible to argue for their widest possible adoption. Shove and Moezzi point out, however, that the uptake of standards involves a 'diffusion of the cultural and historically specific assumptions and conventions in them' and warn that they can 'inadvertently legitimis[e] unsustainable habits, practices and conventions' (*ibid.*: 276,7). The CSH, whilst seeking to modify certain areas of daily life, carries and reproduces many assumptions about normal everyday life, and fails to question the extent to which these assumptions perpetuate established ways of doing (Spurling *et al.,* 2013). For example, when considering house size, the Code makes special provision for calculating energy loss in bungalows – indicating that this potentially less thermally-efficient type of house building should be accommodated. Should then building energy performance and sustainability be viewed as a 'single state of affairs' (as with universal standards) or as 'a matter of degree, and of contest and negotiation' (*ibid.*: 46)?

It was intended that the Government's approved methodology for assessing the energy rating of dwellings, the Standard Assessment Procedure (BRE, 2009; 2012), would underpin the CSH accreditation process. This calculative method would appraise the typical annual energy costs and carbon emissions per house for heating, hot water, ventilation and internal lighting, including provision for energy savings from micro-energy generation (McManus *et al.,* 2010). This assessment procedure, which also underpins the Building Regulations, is measured on a scale from 1 to 100+, where 100 means that the house is zero carbon and dwellings that have a SAP greater than 100 are net exporters of energy. The calculation, takes into account a range of technical factors that contribute to energy-efficiency, for instance, thermal insulation of the building fabric, efficiency of the heating system(s) and solar gains (BRE, 2009; 2012). This quantitative SAP methodology has distinct limitations however, as it does not take into account: household size and composition, ownership and efficiency of particular domestic electrical appliances, or heating patterns and temperatures. Furthermore, this methodology overlooks how the everyday lives of household residents determine how a house is lived-in, and influence a home's overall energy balance.

From the outset, a particular area of contention with the CSH standard was the precise definition of zero carbon. Whilst the original definition stated that 'net carbon dioxide emissions from *all* energy used in the dwelling are zero or better' over the course of a year (DCLG, 2006; 2007a), the practical implementation of CSH level six was far from clear and led to contestation by builders, architects and policy organisations alike (McLeod *et al.,* 2012). According to some definitions, zero carbon could be met by including on-site micro-generation of electricity at the level of a development rather than an individual dwelling. In addition, offsetting - compensating for emissions from a dwelling by low carbon power generation off-site - was left to be decided at a later date (Gibbs and O'Neill, 2015). Furthermore, although discussed during the consultation process for the new regulatory framework, embodied carbon[6] was excluded from the first definition (DCLG, 2007a; McManus *et al.,* 2010; Monahan, 2013).

Given the conservative nature of the housing industry, it was perhaps unsurprising that there were immediate objections to the ambitious scope of the carbon zero housing target. A UK Green Building Council (UKGBC) Task Group report warned that '…anywhere from 10% to 80% of new homes may not be able to meet the current definition of zero carbon' through on-site measures alone (UKGBC, 2008: 5), and the majority of large housing developers expressed concerns regarding the 'cost of building to this definition… and its impracticality on many sites' (ZCH, 2013: 4). In response, the Government launched a consultation on the workability of the zero carbon

[6] Embodied carbon: Carbon dioxide emitted during the manufacture, transport and construction of building materials, together with end of life emissions.

definition (ZCH, 2009). The definition of zero carbon housing was revised in the 2011 Budget, in line with the SAP, to exclude operational emissions attributed to 'plug-in' appliances, such as televisions and computers, and to only target energy use from heating, hot water, fixed lighting and building services (ZCH, 2011).

This revision effectively led to CSH level six standardising carbon zero *houses* rather than *homes* as the definition no longer considered the operational energy and carbon consequences of lived-in properties. It also transferred the task of providing clean energy for new homes from the house-builder to the wider power sector.
The new definition was particularly problematic, as energy-dependent appliances are expected to increasingly constitute a greater proportion of domestic energy consumption, as heat loss standards improve and electrical 'gadget' ownership continues to rise and devices demand higher energy inputs (EST, 2012; DCLG, 2007a). For some, this revision therefore represented a serious dilution of the zero carbon standard. For example, it led to the World Wildlife Fund's resignation from the zero carbon task-force (WWF, 2011).

The DCLG consultation also set out a tiered approach to delivery of Zero Carbon homes. This proposal shifted the zero carbon standard from the individual house to the housing development and allowed for carbon emissions abatement off-site.
The proposed hierarchical approach to defining zero carbon homes (Figure 3.1) was founded on high minimum standards of fabric energy-efficiency and the use of efficient heating, cooling, ventilation and lighting systems DCLG (2008a; ZCH, 2012).

Renewable technologies and directly connected district heating solutions situated on the site of the building itself formed the second tier and also had a minimum carbon compliance standard. Beyond this, emission reductions could be achieved through a range of cost capped off-site Allowable Solutions. Examples of such measures would include use of, or investment in; large-scale renewable energy technologies, district heating projects, low carbon street lighting, or contributions to the Green Deal (DECC, 2015d). 'By paying into an Allowable Solutions fund (to pump-prime carbon-savings projects elsewhere), a lower on-site emissions target could be set for house-builders while preserving the zero carbon policy goal' (ZCH, 2013: 4). This provided developers with an economic way of compensating for hard to achieve on-site carbon emission reductions, but crucially also 'effectively introduced a buyout clause' for the housing industry, and avoided 'the source of the problem' (McLeod *et al.,* 2012: 27, 29).

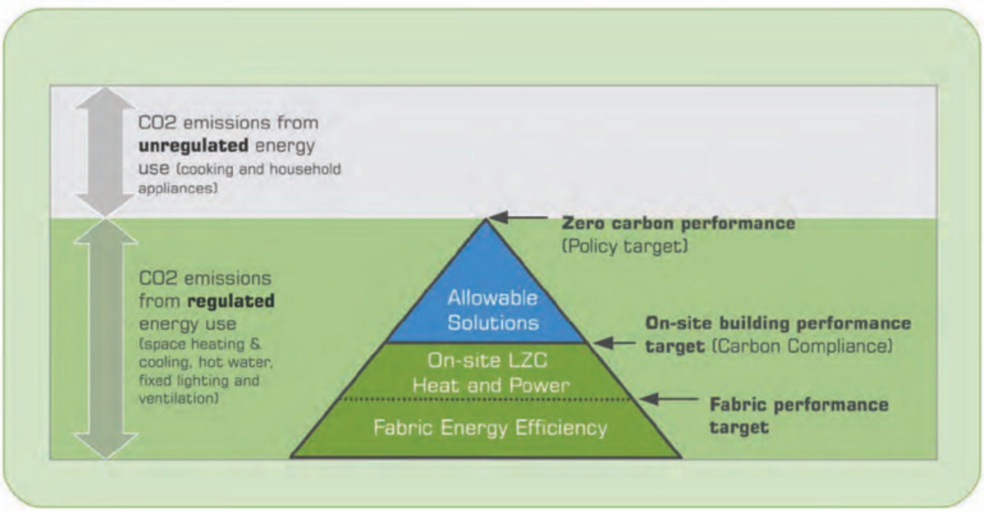


Figure 3.1 – Hierarchical approach to defining zero carbon homes

(Source: ZCH, 2012: 6)

Reducing residential energy demand and carbon emissions from new housing has long been defined as a technological problem. In seeking to phase-in higher standards of low-energy housing design and construction the CSH building performance standard set ambitious transformative goals for the residential sector. Its ambitious targets and broad understanding of sustainability make the CSH an interesting case of housing performance enhancement. However, this section has shown that the standard was underpinned by a quantitative calculative assessment that failed to consider the house as a lived-in home, and the ambitions of CSH were diluted following housing industry lobbying. It has also raised concerns regarding the role of building performance standards in the housing industry, which whilst seeking to transform industry practice, can also unwittingly lock-in an accepted reliance on energy-related services, and increase the overall energy balance of the residential sector.

3.2.2 The Trinity Close low-energy housing site

Having opted to study the Code for Sustainable Homes (CSH) as an example sustainable building performance standard, and to undertake an in-depth mixed methods study, I first needed to identify and gain access to a suitable research site. I was fortunate that my Research Group at the University of East Anglia had previously developed good working relations with both the local district council (Broadland District Council – BDC) and its environmental consultancy (Low Carbon Innovation Centre (LCIC), now Adapt Commercial Limited (Adapt)), and through these contacts, I became aware of the construction of an exemplar sustainable housing development.

Trinity Close, Rackheath is an affordable housing scheme of twelve properties, located five miles north-east of Norwich, Norfolk, built to achieve CSH level six (i.e. carbon-neutrality). This site featured in the original comparative research proposal (discussed in Section 3.1) as it originally formed the pilot project for an anticipated Department for Communities and Local Government (DCLG) funded eco-town development[7]. As explained in Chapter 6, development of this large-scale initiative ultimately did not come to fruition. Nevertheless, in seeking to attain CSH level six, Trinity Close represented a unique opportunity to research the bundle of housing practices associated with low-energy housing. Between April 2007 (when the Code became operational) and end September 2011 (when construction was completed), only thirty-nine properties in the U.K. had received a post-construction stage Code level six rating (DCLG, 2011)[8].

The Trinity Close build was completed in September 2011, which tied in well with timings for my research design and data collection. As such, after introductory meetings with the two respective gatekeepers, and in exchange for providing BDC with a stakeholder report on my initial findings (Macrorie, n.d., see Appendix A) and sharing articles from my final thesis, I was granted access to the new social housing residents and permitted to contact the professional stakeholders. Given the scarcity of CSH level six developments in my locality (and the U.K) and the pre-established research links with the commissioning local authority, arguably, the process of sample site selection 'happened to me' (Flyvbjerg, 2006: 231), as much as I selected it.

Funded by DCLG, Trinity Close, Rackheath was developed by the housing construction company Dove Jeffery Homes (DJH) for Wherry Housing Association (WHA) and their local authority partner BDC. The mixed affordable housing development (see Table 3.2) was designed to achieve a high level of thermal performance and was originally planned to be zero carbon emissions in line with CSH standard's original level six requirements. The low-energy housing development was also 'designed for sensitive integration into the local community through traditional aesthetics' (DJH, 2012). As such, the twelve pilot properties formed a sustainable housing demonstration site, from which findings could be made, and that could potentially be delivered en-masse by the housing industry, both in Broadland district (as part of the Rackheath eco-town) and further afield.

[7] The Rackheath (Norwich) eco-community (P36 – Appendix K)

[8] Between April 2007 and March 2012, 142 dwellings received a Code level six rating at the post-construction stage (DCLG, 2012).

Number of properties	Type	Bedrooms	Floor area (m^2)	Occupants	Solar (kWp)
2	Bungalow	2	67	2	4.9
4	Semi-detached	3	88	4	5.0
1	Semi-detached	2	76	2	5.5
1	Semi-detached	4	108	6	6.5
2	Ground floor flat	2	65	2	4.6
2	First floor flat	2	65	1	4.6

Table 3.2 – Description of the different house types built at Trinity Close, Rackheath

(Source: Monahan, 2014)

The development incorporated renewable and low-carbon technologies to achieve the high levels of energy-efficiency demanded by CSH level six (see Table 3.3 and Figures 3.2 and 3.3a&b). In addition to the installation of these energy-efficient materials and renewable technologies, BDC's contracted Green Energy Options (GEO) to supply electricity monitoring equipment intended for technological performance assessment and to establish post-occupancy energy-efficiency (see Chapters 4 and 5). Monitoring was planned to continue for five years. In addition, BDC's environmental consultant, Adapt, was commissioned to produce a whole life cycle carbon costing, from commencement of the development through to the eventual demolition of Trinity Close (Adapt Low Carbon Group, 2012).

Householders took-up residency at the properties in late September 2011, their homes having been allocated on a needs basis through the local housing register (as opposed to the new residents having espoused particular green credentials). This was significant for my research as far from having developed pro-environmental practices, the residents can be considered 'passive adopters' of their low-energy homes (Monahan and Powell, 2011: 297). As described, a condition of tenancy was that electricity monitoring occurred and residents were also required to consent to being part of regular consultation and feedback to explore their post-occupancy experiences. This provided an exclusive opportunity to obtain detailed accounts of domestic life as encountered in new-build low-energy homes.

Figure 3.2 – Photographs of Trinity Close, Rackheath

(Source: Dove Jeffery Homes, 2012)

Renewable and low-carbon technology	Intended function
'Schüco' photovoltaic monocrystalline and polycrystalline solar photo-voltaic (PV) panels mounted on roof areas.	Decentralised electricity generation at individual house level - total optimum capacity 61,460Watt peak.
'De-longhi' air-source heat pump, with a back-up electric immersion heater, under-floor heat distribution, and thermostatic controls in each room.	Provision of space heating and hot water.
'Titon' mechanical heat recovery ventilation (MVHR) system.	Distribution of warmed air to provide a comfortable internal living environment.
Green Energy Options (GEO) Trio electricity monitoring unit, in home display (IHD) device, and five plug-bugs.	Circuit level electricity consumption monitoring, household provided feedback on electricity consumption/cost/carbon emissions, electricity monitoring of household selected plug-in appliances.
'Kingspan' super-insulation (180mm thick).	Excellent thermal performance and air-tightness.
Triple glazing & passive solar design	To maximise solar heat capture and retention.
Properties served by mains electricity.	Mains gas not available.
*'Ecoplay' grey water recycling system	Recycles bath and shower waste for toilet flushing.

*Trinity Close was required to meet CSH level six for water-efficiency. This assessment focuses on energy – demand side household electricity efficiency specifically.

Table 3.3 – Renewable and low-carbon technologies installed at Trinity Close

(Source: DJH, 2012)

Figure 3.3a – Cross-section showing low-energy materials and renewable technologies installed at Trinity Close, Rackheath

(Source: Adapted from Dove Jeffery Homes, 2011)

Figure 3.3b – Cross-section showing low-energy materials and renewable technologies installed at Trinity Close, Rackheath

(Source: Adapted from Dove Jeffery Homes, 2011)

As described in Chapter 2, the low-energy housing literature has a preoccupation with technological performance assessment, and frequently fails to acknowledge how residents will interact with and use their new properties. In line with this stance, the CSH standard accreditation process is completed prior to tenant handover. Where occupants are considered, appraisals tend to focus on the extent to which installed technologies are correctly utilised, or analyse whether residents make informed choices to change from wasteful energy-related routines. Whilst most post-occupancy building research focuses on tenants' actions and experiences, this research looks beyond users' practices to understand how different practices connect together to form a low-energy housing system. As such, this research is uniquely positioned. To begin analysing how the 'mass of happenings – doings, sayings and other events – … add up to [the] mix of change, stability, fluidity and continuity' (Schatzki, 2011: 5) occurring at Trinity Close however, I needed first to identify target practices on which to focus.

3.2.3 Defining boundaries for the Trinity Close low-energy housing system of practice

Having selected a sustainable building standard as a case study and a sample housing development site for investigation, I needed to establish which housing practices I would explicitly 'follow' and analyse, whilst acknowledging that everyday doings were entangled within a mesh of practices that comprised the low-energy housing system at Trinity Close. I decided to purposely follow particular practices and relations within the bundle of practices related to the Trinity Close low-energy housing practice system. These linked practices were identified on the basis of their potential to reconfigure the system of practice in less energy-intensive directions. They were also identified on the basis of whether they were dominant (energy-related) housing practices conducted by the key stakeholders involved in the development. Table 3.4 outlines the particular housing-related practices and connections investigated in this research.

Examined Practices	Related Practices (not examined)
Initiative management	Financial practices
CSH standard implementation	Land acquisition
Local authority planning	Environmental policy making
Affordable housing development	Housing policy making
Housing construction	Legal and advisory practices
Architectural practices	Media promotion
Tenant engagement	Low-carbon technologies manufacturing
Monitoring and measurement	Energy-efficient materials manufacturing
Housing maintenance and repair	Utilities distribution and supply
Environmental consultancy	CSH standard accreditation
PhD research	Community consultation
	Local Parish representation
	Activism/protest
	Housing industry association practices
	Everyday working/shopping/education/travel/etc.
	Regulatory practices

Table 3.4 – Defining boundaries for the Trinity Close low-energy housing system of practice

The analytical focus shown in Table 3.4, which was broader than a conventional single target practice, presented several methodological issues. First - issues of practice definition, bounding and recognition. Initially my interest lay with understanding how the tenants would live in their low-carbon properties, the ways in which, if at all, their domestic practices would change in their low-energy homes, and the implications this would have for energy and carbon emissions. Realising that I needed to understand the composition, performance and relations of domestic practices, I decided to concentrate on thermal comfort practices. However, my pilot householder interviews (see Section 3.3.2) produced a tremendous amount of data, and as such, I realised that I needed to further narrow down the practice of interest. When considering domestic practices therefore, I focus on 'residential heat comfort practices' (Gram-Hanssen, 2010: 175) and their relations with associated energy-related domestic practice bundles and complexes.

Whilst research and policy efforts to reducing domestic energy demand have focused on energy-efficient buildings and technologies, over the past fifty years there has been an acknowledgement that the energy consumption for space heating is determined not only by the efficiency of the equipment but also by inhabitants' use (Gram-Hanssen, 2010). As such, greater attention has been given to understanding and modelling how householders experience thermal sensation, and how they regulate their indoor climate (e.g. Huang *et al.*, 2014; Soebart and Bennetts, 2014). Studies have also sought to understand how residents can be 'educated' to use heating/cooling equipment optimally (e.g. Day and Gunderston, 2015). Socio-technical academics have moved away from these techno-rational assumptions to explore how contemporary expectations of indoor thermal climate are historically and socially specific, and thus have potential to change (e.g. Shove *et al.*, 2008). They have also investigated: how thermal comfort standards shape the built environment and lifestyles (Healy, 2008); the malleability of social conventions around thermal comfort (Parkhurst and Parnaby, 2008); and how everyday routines are implicated in constructing a need for (heating or) cooling (Brown and Walker, 2008).

Some SPT researchers have studied heat comfort as a practice, focusing on specific elements (e.g. competences (Royston, 2014) or materials (Hitchings and Lee, 2008)). Others have focused on how elements are gathered together in practice performance, with implications for residential energy-demand and product design (e.g. Gram-Hanssen, 2010; Kuijer and de Jong, 2012). More recent research has considered thermal comfort practices in terms of: whether they can adapt dependent on location and infrastructure provision (Maller and Strengers, 2011; Fuller and Bulkeley, 2013), in relation to a range of overlapping policies (Strengers and Maller, 2011), and in terms of their contributions to cultural conventions (Hitchings, 2013). Studies have also conceptualised thermal comfort practices as the more fluid management of thermal flows within the home (Royston, 2014; Shove *et al.*, 2014). This research will build on these broader SPT-based understandings, to investigate heat comfort practices as part of system of low-energy housing practices enacted at Trinity Close.

Second, the initial household interviews, and my review of existing SPT literature (e.g. Watson, 2012), confirmed that to understand the intersections, relations, and entanglements occurring between practices, I needed to widen-out investigation from a focus on occupant practices. I therefore aimed to understand how the Trinity Close properties were constructed and supported by the codified building performance frameworks produced by housing policy-makers, and how the practices of the actors and institutions involved in the Trinity Close build were shaped by requirements of the standard. I decided to analyse these institutionalised housing practices by undertaking a series of professional interviews (see Section 3.3.2) and conducting a documentary review (see Section 3.3.5). I aimed to take account of both organisational rhetoric and the range of perceptions and approaches tacitly adopted by individual professional practitioners in the field.

More than focusing on the low-energy housing practices of these three groups of actors – housing policy-makers, housing design and construction professionals, and housing residents – I was presented with the challenge of understanding how these practices, and their associated complexes and bundles, were associated or interrelated (if at all), and with what consequence. Whilst Shove *et al.* (2012) have helpfully devised initial concepts to capture features and processes at work within the practice 'plenum' (Schatzki, 2011), namely: the circulation of elements; recruitment to and defection from practices; circuits of reproduction; diffusion of practices; and types of connections between practices, research on the relational nature of practices remains largely conceptual. I therefore took my lead from Schatzki, who suggests that,

> 'There is no easy template for studying… socio-technical change. Studying it requires examining actual cases through investigations of the interrelated bundles and constellations involved that are informed, not by theories or models, but by concepts and typologies with which aspects of this mass can be analysed' (*ibid.*: 25).

Whilst not initially informed by relational systems of practice thinking, the pilot householder interviews led to later data collection being undertaken with these concepts broadly in mind. I paid attention to how low-energy housing practices were 'carried' (Reckwitz, 2002a) by different actors at Trinity Close, and noted how practices were linked, intersected and overlapped and the extent to which this produced, modified, and sustained the distinct configuration of practices performed at the exemplar housing development. For example, as opposed to focusing on how householders interacted with the installed heating technologies, and the control they had over managing their heat comfort, I was interested in how heat comfort management was constituted through the combination of a number of related practices. These included: heating technology usage, but also related to seemingly unconnected practices within the home (e.g. cooking, clothing, exercising, child-care), and outside of the home (e.g. travelling in temperature controlled cars and shopping in air-conditioned precincts).

Finally, given that the 'plenum' of practices is 'always on the move', in 'changing mixes of continuity and of quicker and slower, larger and smaller developments' (Schatzki, 2011: 22), I needed to examine the dynamic nature of (low-energy) housing practices as they arrived, were reproduced, were potentially reinforced, and/or as they left Trinity Close. Undertaking an in-depth, multi-method investigation provided a way to analyse this change, as I was able to track and trace how certain practices evolved. Conducting repeat householder interviews (see Section 3.3.2) gave me insight into the incremental, and more radical shifts, occurring in domestic practices, and their bundles and complexes, at Trinity Close. Where repeat discussions and long-term observations were not possible, for example for professional practices, I traced how policy arguments developed, encouraged interviewees to reflect on how their work activities had changed over time, and prompted discussion on the perceived success of the housing development.

3.3 Collecting and making sense of empirical data

Having discussed the underpinning ontology of this research – 'what [I] believe constitutes social reality' and epistemology – 'the possible ways of gaining knowledge of social reality, whatever it is understood to be' – this section is concerned with the ways in which empirical data collection and analysis were undertaken in order to answer my research questions (set out in Chapters 1 and 2) (Blaikie, 2000: 8). As such, the rest of this chapter turns away from the large philosophical issues informing this research, to address the practicalities of conducting the research reported in this thesis. I first contemplate how my world-view dictates a reflexive approach to data collection and discuss the implications of this position (Section 3.3.1).

Next I discuss the different types of empirical data collection methods used in this research. Understanding how (low-energy) housing-related practices are formed, performed, inter-connect, and are potentially reinforced or transformed, requires use of methods commensurate with a social constructivist SPT theoretical approach. In addition, as my interest shifted towards understanding Trinity Close as a particular configuration of housing-related practices, a distinctive methodological approach was needed. To take full account of practice relations within a system, data gathering and interpretation processes had to be: multi-site (i.e. government offices/stakeholder offices/Trinity Close development site/residents' homes), incorporate multiple sets of actors (i.e. policy-makers/local authority/housing design and construction professionals/environmental consultants/residents etc.), and had to involve multiple qualitative methods. The multiple sources of evidence used (see Sections 3.3.2 – 3.3.5) provided different, and potentially conflicting, social constructs for examination, and helped to establish a nuanced understanding of the Trinity Close site.

Finally, Section 3.3.6 outlines the ethical considerations applicable to this research, and Section 3.3.7 explains how I analysed and wrote-up the emergent investigative findings.

3.3.1 Reflecting on my research position & interpretations in the field

As a social constructivist practice theorist, it is impossible to agree with the positivist notion that a researcher can be objective throughout the research process and remain independent of the reality being studied. Instead, as I went into the field, I took some notion of, and continually related my interpretations to, the concepts and ideas that I had critiqued as part of the academic literature review process. Rather than deliberately looking out for these ideas and the data collection process being confirmatory in nature however, I remained open to new observations and thoughts that came to light through conversations, processes, and events that I experienced (see Section 3.3.3).

In accordance with my world-view, all humans are 'observers, participants, and agents who actively generate and transform the patterns through which they construct the realities that fit them' (Reich, 2009: 40). As the researcher, these interpretive and transformative processes also applied to me, because how I designed, undertook and analysed the research invariably shaped how reality was constructed at Trinity Close. Given this, it was essential that I was reflexive about how my own position affected the construction and representation of everyday life. England describes reflexivity as: '… self-critical sympathetic introspection and the self-conscious analytical scrutiny of the self as researcher' (1994: 244). She argues that being reflexive can lead to new insights and hypotheses about the research questions, and allows the researcher to remain open to any challenges that their theoretical stance almost inevitably raises.

Throughout the fieldwork period I found myself constantly negotiating my role at the Trinity Close site, whether interviewing household or professional practitioners, or attending stakeholder meetings. Indeed, my positionality was multiple and flexible - I was understood differently by different actors, and it changed over time (Horwood and Moon, 2003). When I first approached the residents of Trinity Close, many of the householders understood participation in the interview process as an obligation that they had to fulfil as a requirement of their tenancy. As such, several interviewees were initially reluctant to share information about their experiences of everyday life at Trinity Close, and the challenges that they encountered, for fear of their accounts jeopardising their tenancy agreement. At first, several householders gave glowing reports of the events following handover, which later in the interview process proved to be doctored accounts providing me with information that the householders thought I wanted to hear, and that portrayed them positively (i.e. self-reporting action bias) (Foddy, 1993). As such, I worked hard to stress the impartiality of my research.

Some householders viewed me as an energy or technical consultant and asked my advice as to how to optimise their energy-efficiency and operate the installed technologies. For example, several households requested my advice as to how to operate their heating system. In these situations, I made suggestions where possible and advised householders to contact WHA for more detailed information. A third concern was that in some situations, where householders were challenged, I felt conflicted, as I wanted to help solve arising issues. These instances included: where households were suffering from thermal discomfort; were anxious due to energy bills that were higher than anticipated and that they were struggling to pay; and where I identified technical problems, particularly the failure of energy monitors to remain online. As opposed to reporting back my observations regarding individual households to WHA or BDC, so as not to breach confidentiality, I decided to broadly highlight to Adapt (the environmental consultancy) that it would be worth getting in contact with the Trinity Close residents to check on their progress.

A final concern was participants' desire to discuss efficiency and the operation of particular installed technologies, as opposed to describing their actual practices. This demonstrated how the institutional rhetoric of energy-efficiency and technological optimism had, to some degree, become entrenched within, and begun to structure, the discourses and doings of the residents' everyday lives. To get past this tendency, it was necessary for me to phrase interview questions in ways that would interrogate householders' energy-related practices, and to sometimes provide examples by sharing details of my own practices.

When observing and conversing with the professional practitioners at Trinity Close, I also adopted different positions, which evolved throughout my involvement. When first gaining access to Trinity Close, I spoke with representatives from BDC and their environmental consultancy (Adapt). In this exchange, I was aware that Adapt had been commissioned to provide a technical appraisal of the initiative, was responsible for the 'behaviour change' element of the initiative[9], and would be keen to form an affiliation to benefit from the results of my planned qualitative research. Both BDC and Adapt held particular ideas that my research would help validate the technical housing initiative. However I was conscious of retaining my independence as a researcher, not operating as a consultant, and not over-promising that I would share my research thoughts and findings with Adapt or BDC until they were formulated, particularly as I was interested in both organisations as Trinity Close stakeholders themselves. In my field notes I wrote,

> *"The Trinity Close Steering Group see me as an informant, but I need to be clear that this is independent and impartial research and I don't want to negatively influence that process. What I can promise is to accurately take an account of the processes occurring on site according to my understandings and experiences".*

Initially Adapt insisted that they arranged all pilot tenant interviews. I was concerned that this initial contact would lead the householders to think I had been commissioned by the Trinity Close Steering Group (TCSG), and would hamper my research. Fortunately, when Adapt struggled to contact the householders, the consultancy permitted me direct access to the residents. As my data collection process developed, and I grew familiar with happenings on the ground at Trinity Close, my researcher role evolved. Schwartz-Shea and Yanow (2012: 65) describe how a researcher's role can vary from one where they participate as researcher alone, to adopting the 'dual role of situational participant and researcher'. In between these two poles lies a repertoire of role combinations.

I experienced, and had to carefully negotiate, this range of roles as I developed ideas about the workings of Trinity Close. For example, in producing a report for BDC on my initial findings from the pilot household interviews (Macrorie, *n.d.,* see Appendix A), during attended stakeholder meetings (see Table 3.8), and sometimes during

[9] Subsequently the electricity performance monitoring appraisal was undertaken by an independent environmental researcher (Dr. Jennifer Monahan), and not Adapt Commercial.

professional practitioner interviews, I was seen as an expert on low-energy (particularly domestic) housing practices. For example, during the interview with a senior planner at BDC, I was asked for my opinion on the merits of pursuing the CSH standard,

> *"I'd be interested in your thoughts, to take [a housing development] from Code four to Code six, do you get your value for money? Is that a good use of public money at this time?"* (PP8, BDC).

I was also seen as a potential means to enhance communication channels with the residents (PP6, BDC), and my research was positioned by the TCSG as potentially informative to the future design decision-making processes in Broadland (PP9, DJH). Whilst my position at the research site was never entirely stable or clear, in writing-up field notes, transcribing, and analysing my data away from Trinity Close, I was able to retain some critical distance (see Section 3.3.7).

3.3.2 Household and professional practitioner interviews

Given this research is informed by a social constructivist perspective which holds that we live in a world of potentially multiple inter-subjective social realities, interviews were used to understand how the different Trinity Close stakeholders experienced particular events and interpreted their practices. Whilst revealing of action, using participant observation alone (see Section 3.3.3) would have overlooked peoples' understandings of their 'doings' and 'sayings'. Using semi-structured interviews provided a chance for 'interviewees to construct their own accounts of their experiences by describing and explaining their lives in their own words' (Valentine, 1997: 111).

Atkinson and Coffey (2003) suggest that interaction and communication that occur during interviewing are expressions of action or 'enactments'. Halkier (2010) suggests that these enactments are revealed through interviews - as well as by other types of qualitative data (e.g. focus groups, research diaries etc.) – and can be used to describe and reflect on the 'doings' and 'sayings' of social life. Furthermore,

> '[i]f different interview participants provide different versions of the event or practice, that is normal and to be expected. Indeed, it is precisely those differences that are of analytic interest to the researcher, as they suggest… what

> is *meaning-ful* about the event [or practice] to each person speaking' (Schwartz-Shea and Yanow, 2012: 41, emphasis in original).

As such, by accumulating and analysing different interviewee accounts, I was able to explore where differences in respondents' experiences and interpretations lay, and their significance for the composition, performance and relations of practices at Trinity Close.

Some researchers question the appropriateness of interviews for researching everyday life arguing that they fail to access 'unspeakable' aspects of social practices and are potentially inaccurate as peoples' accounts change over time (e.g. Bissell, 2010; Macpherson, 2010; Spinney, 2009: 829). However, I agree with Hitchings (2012: 61) who argues against those who claim that interviews, 'can only ever provide an unsatisfactorily washed out account of what previously took place' (*c.f.* Thrift and Dewsbury, 2000). Hitchings contends that participants are 'entirely able to talk about relatively mundane actions, such as continuing to sit in [a thermally regulated] office or putting blankets over knees at home [to stay warm], that may, in some part, usually be performed unthinkingly' (Hitchings, 2012: 65). In the same way, whilst at first I found it awkward to ask about the very mundane aspects of peoples' lives, as my interviewees realised the intention of the interview was precisely that, they opened up, and seemingly enjoyed taking me through their domestic routines and/or professional experiences. To optimise the interview process, I sought to: be clear about the purpose of the research project; present alternatives as prompts if responses were not forthcoming; use a serial interview approach and attend to respondents' reactions, tailoring my questions appropriately (*ibid.*: 66).

The first steps in the interview process were to define my sampling approach and to recruit interviewees. I wanted to hold repeat conversations with the tenants of all twelve Trinity Close properties to understand how, if at all, their existing housing practices interacted with the low-energy housing initiative – i.e. purposive sampling (Bernard, 2002). As previously discussed, when I undertook pilot interviews between 1st March – 27th April 2012, Adapt initially acted as the gatekeeper for establishing contact with the Trinity Close tenants. It was subsequently agreed that I could approach any remaining households by door knocking. I followed up these interviews approximately one year later, in April 2013, to understand how, if at all, residents' heat comfort practices, and their relations with other domestic practices, had changed (see Table 3.5).

		Household reference* (including one mutual exchange)											
Interview	Date	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
Pilot interview & home audio-tour (A)	01/03/12 – 27/04/12	■	■	■	■	■	■		■	■	■	■	■
Heat comfort practices research diary & follow-up discussion (B)	11/03/13 – 12/04/13		■	■	■		■		■	■			
Repeat interview & home audio-tour (C)	11/03/13 – 23/03/13	■	■	■	■		■	■	■	■		■	
Discursive game on energy & domestic practices (D)	11/03/13 – 23/03/13	■	■	■	■			■	■	■			
Temperature monitoring & interpretation of recorded data log (E)	11/03/13 – 15/04/13	■	■	■	■		■	■	■	■		■	

Shaded cells = household participated in data collection process.
* Trinity Close household reference anonymised (i.e. different to property number).

Table 3.5 – Qualitative data collection undertaken at Trinity Close properties

When enlisting professional practitioner interviewees, I used a combination of purposive (Bernard, 2002), snowball (Seale and Filmer, 1999) and theoretical sampling (Glaser and Strauss, 1967). In other words, as well as targeting stakeholders that met particular requirements (purposive sampling) (for example, representatives from institutions directly involved with implementing the Trinity Close initiative), I asked my interviews whether they could recommend others that I should talk to (snowball sampling). To some degree I also selected what data to collect on the basis of codes and findings emerging from the ongoing data analysis process (theoretical sampling) (see Section 3.3.7). This data collection approach helped me to develop a 'systems of practice' conceptualisation for studying low-energy housing.

Table 3.6 lists the interviewed Trinity Close stakeholders and their formal role(s) in the housing initiative. In total thirteen interviews were conducted with professional practitioners (including one exchange completed using emailed questions and responses) between the dates 10th December 2012 and 19th June 2013. Whilst I did not interview a representative from the Department for Communities and Local Government (DCLG), I received a delayed response from Rt. Hon. Don Foster M.P.

on 3rd October 2013 (see Appendix B). Analysing my interview data between visits to the field (see Section 3.3.7), I stopped conducting interviews when my theoretical categories started to reappear and were producing diminishing returns, i.e. when I had reached 'theoretical saturation' (Strauss, 1987).

No.	Role(s)	Description of role(s)	Organisation	Role(s) in Trinity Close initiative	Professional practitioner ref. (PP-)
1	Politicians	Specific roles in Government related to low-energy housing, and/or energy demand, or on relevant committees.	Department for Communities and Local Government (DCLG)	Defined CSH; project funders; specified requirement for building performance monitoring.	Minister for Housing and Local Government
2	Local authorities & regulators	Development and implementation of housing policy at a district & local level.	Broadland District Council employees and councillors (BDC)	Led the Trinity Close housing initiative. Instigated proposal for Rackheath eco-community (see Chapter 6).	PP1, PP4, PP5, PP6, PP8 (Roger), PP13
3	Developers	Providers of (private and) social housing.	Wherry Housing Association (WHA)	Registered social landlord; led delivery of Trinity Close scheme; tenant handover & management; building repair & maintenance.	PP7 (Dave), PP12
4	Architects and housing contractors	(Design and) construction of housing developments.	Dove Jeffery Homes (DJH)	Researched CSH approved energy-efficient building materials & renewable technologies; designed and built 12 housing units.	PP9 (Tom), PP10
5	Consultants	Provide expert advice to assist with the build process, & post-occupancy appraisal.	Adapt Low Carbon Group (Adapt)	Responsible for tenant behavioural change; building electricity performance monitoring & appraisal; undertook embodied carbon study.	PP2 (Brian), PP3
6	Low-carbon technology manufacturers	Design & manufacture of energy-efficient building materials & renewable technologies	Green Energy Options (GEO)	Manufactured & installed electricity performance monitoring system.	PP11
7	Social housing tenants	Rent property from registered providers of social housing.	Trinity Close residents	Rent property from WHA. Received energy-saving advice as part of the initiative. Trialled low-carbon technologies in CSH level six properties.	H1 to H12

Table 3.6 – Interviewed Trinity Close stakeholders

Second, I developed, and continually refined, interview topic guides (Seale, 1999: 206) for the household and professional interviews (see Appendices C and D). Topics listed in these guides emerged from my field notes and were shaped by ideas and concepts gathered during the literature review (see Table 3.7). In line with my social constructivist stance, rather than developing a prescriptive survey or protocol, the topic guide acted as a loose checklist, to which I could refer, that would encourage each interviewee to talk about particular themes. To ensure informal discussions, I posed open questions (Seale and Filmer, 1999:130) and my line of inquiry followed experiences and interpretations raised by the participant. Sometimes however, I dispensed with my interview protocol guide, and followed off-topic themes, as suggested by the interviewees, that seemed pressing and relevant to my research. As such, my role was explicitly 'non-directive' (Seale, 1999: 207).

Household pilot	Household repeat	Professional practitioner
• Details of previous property & comparison with TC • First impressions of TC • Induction process • Interactions with low-energy technologies as part of everyday life • Social interactions with respect to managing domestic practices	• Experiences of life at TC • Management of heat comfort practices & related practices • Noticeable changes in domestic practices (particularly heat comfort) • Impressions of governance of TC • Opinion on Phase Two TC	• Professional background • CSH and best practice in building low-energy homes • Organisational involvement & objectives for TC • Designing & implementing TC • Monitoring & appraising TC • Behavioural change • Resident heat comfort management • Organisational relations during TC • Initiative outcomes & findings • Phase Two TC

Table 3.7 – Themes of Trinity Close interview topic guides

Whilst professional practitioner interviews were undertaken at the interviewees' place of work, or at the University of East Anglia, both relatively neutral spaces, the household practitioner interviews were held at WHA tenants' homes – where 'most of what matters to people is happening' (Miller, 2001:1). Conducting ethnographic research in people's homes is far from easy and, whilst practice researchers have spent up to 24 hours observing people at home (Higginson *et al.,* 2013), this, to me, involved an unacceptable intrusion into householders' private lives and intimate spaces. Indeed, at times, my questions, particularly regarding heat comfort management, were necessarily personal, and I had to work with participants to overcome any social awkwardness. Rather than undertake a traditional immersive ethnography therefore, I sought to gain insight into the residents' (low-energy) housing practices using a serial and mixed methods data collection approach. I also focused on the practice of (managing) heat comfort, and sought to understand how this activity related to, and influenced, other domestic practices.

Prior to conducting each of the interviews I explained the broad purpose of my research and provided the interviewees with an information sheet summarising my research goals (see Appendices E and F). I recorded each interview with an MP3 player, apart from one in which my recording device would not work. I gave each participant the option not to be recorded, also asking them to sign a consent and release form (see Section 3.3.6 and Appendix G). After each interview, I wrote up brief notes on the conversation, the setting, interviewees' responses and body language, and any analytical or theoretical thoughts arising. I then transcribed the interviews *verabatim* (see Appendices H & I for an extract from a household and professional practitioner interview transcript).

3.3.3 Sharing in practice: Participant observation and household audio tours

Interviews are certainly not the only means to access and study practices, and arguably to understand practices, discussions need to be located within ongoing and situated action (Evans, 2011). A wide variety of methodological approaches can be used to 'get at' social practices, and researchers are increasingly using a wide array of tools to bring practices, their performances, and relations into focus. To reveal the intricacies of (low-energy) housing practices, their bundles and complexes, in ways that retrospective discussion sometimes cannot (Hitchings, 2012), I combined semi-structured interviews with Trinity Close stakeholders with participant observation (Cook, 1997). This combined ethnographic approach enabled me to watch how practices were conducted, listen to what was said, and ask questions to probe into peoples' experiences and interpretations of their doings and sayings (Hammersley and Atkinson, 1995). I also analysed how professional practitioners conducted their everyday practices, and how they changed over time, in a range of Trinity Close stakeholder meetings (see Table 3.8).

TCSG meeting	Attendees (researcher +)	Date
Introductory meeting	Adapt (PP2), Dr. Jane Powell	21/10/2011
Trinity Close access meeting	Adapt rep., Dr. Jane Powell	14/12/2011
Introductory meeting	Adapt rep., BDC (PP6),	16/02/2012
Trinity Close update meeting	Adapt rep., Dr. Jane Powell	05/07/2012
Trinity Close update meeting	Adapt rep, Adapt (PP3)	15/10/2012
Trinity Close Phase Two planning application committee meeting	BDC planning application committee, DJH (PP9)	11/06/2013
Trinity Close update meeting	BDC (PP6), WHA (PP7)	22/04/2014
BDC Environmental Excellence Board	BDC (PP6)(PP8), WHA (PP7), BDC Environmental Excellence board, Dr. Jennifer Monahan	21/01/2015

Adapt rep: Adapt environmental consultant unable for interview

Table 3.8 – Trinity Close meetings attended by researcher

Conversations were held in the offices of the professionals' organisations, on a housing development site, as well as in WHA tenants' homes. At each of these sites, I recorded ethnographic observational data by making field notes, which ideally comprised, 'fairly concrete descriptions of social processes [and practices] and their contexts and which set out to capture their various properties and features' (Walsh, 1999: 228). In reality, my note taking was more of a stream of consciousness (Cook 1997). Before narrowing down the target domestic practice, I recorded information about broad ranging, and sometimes incongruous, household practices that included: hair dye applied during showering later reappearing in the toilet basin due to the grey-water recycling system; the desire for cosy lighting; electronic appliance selection; and the ways in which food was prepared at home. Once I had decided to focus on heat comfort practices, my observations became more focused. To ensure that nothing was forgotten, I tried to write down my field notes as soon as possible after the events observed.

Early on in the research process, this meticulous note taking became overwhelming. 'As social scenes are inexhaustible, some selection ha[d] to be made' (Walsh, 1999: 228). As the investigation progressed, I streamlined this process. I found that by holding a broad 'generative question' (Strauss, 1987: 17) in my head, I was able to observe practices making-up the housing system of practice at Trinity Close, whilst omitting almost nothing. My question was:

How does the CSH standard interact with daily practice at Trinity Close?

At the same time, I navigated my way through data collection using a set of sensitising concepts (Charmaz, 2006: 16) arising from the SPT three elements framework (Pantzar, and Shove, 2010) and more recent conceptualisations of the relations and dynamics that are inherent to systems of practice (e.g. Shove *et al.,* 2012) (see Chapter 2). These concepts were particularly crucial, given the range of theoretical ideas that I had been exposed to during the preceding months spent reviewing literature. Whilst a positivist perspective might see this as leading to observational bias, deliberately not being prescriptive or deductive about data collection enabled new ideas, typologies and concepts about the nature and relations of practices at Trinity Close, to come to the fore. Furthermore, to avoid being led by existing theories, I wrote up analytic memos in my field diary at the end of each data collection period, attending to how my observations led to theoretical ideas and related to larger concepts, as well as how they developed and changed (Walsh, 1999: 229). This allowed me to treat these sensitivities as 'hypotheses to be tested, disproven, and refined, rather than paths to be followed blindly' (Hargreaves, 2009: 85).

Where possible, I undertook home audio-tours using an MP3 player as part of the pilot and repeat household practitioner interviews (see Table 3.5). During these tours, I asked participants to 'talk and walk me through their routine activities' (Pink and Leder Mackley, 2013: 684) of managing their heat comfort in each room. This method revealed flows of shared practice performance within the home (Watson, 2012). I followed the paths that my participants took and their practical undertakings as they moved through their homes describing ways in which they stayed warm. Household participants also demonstrated how they undertook this practice by interacting with thermostatic controls and materials (e.g. blinds, draught excluders and blankets), and altering connected practices (e.g. cooking, entertaining and bathing). As well as providing routes to 'get at' the embodied and shared knowledge of 'doing' heat comfort (Pink *et al.,* 2010), the home audio tour in being more 'touchy, feely, look-see' than other qualitative methods (Crang, 2003: 494), also provided a means to compare householders' actual practice doings to their verbal accounts and 'canonical' practice (Brown and Duguid, 1991). 'Following the practice' and understanding its relations and intersections in this way, contrasts to other techno-rational approaches that foreground the optimal use of technologies for thermal comfort management and energy-efficiency (see Chapter 2).

I found the audio-tours to be a productive means to explore householders' practices for three reasons. First, the act of walking me around their home shifted the balance of power between interviewer and interviewee – a relationship that is traditionally seen as dominated by the academic, who examines the lives of research subjects to obtain information. The interviewees became more comfortable and tended to talk openly as new sightings in their home acted as cultural probes (Gaver *et al.,* 1999), triggering associated thoughts and memories. Second, by engaging with particular devices and objects, including walking into new spaces, the householders were actively performing and demonstrating what it was to manage their heat comfort. Third, walking with the householders, allowed me to 'produce empathetic and sensory embodied (emplaced) understandings of another's experience…' (Pink, 2007: 250). For instance, I too could feel the changing room temperatures, touch the dials and controls used to manage the heating system, and smell where damp had accumulated in the home. These 're-enactments' (Pink and Leder Mackley, 2013: 68) or 'go-alongs' (Kusenbach, 2003) provided a route to understanding how heat comfort and energy use was indirectly part of tenants' everyday lives at Trinity Close. They also allowed me to understand how, and why, residents' heat comfort practices and associated bundles and complexes, changed over time.

3.3.4 Reflecting on practices: Research diaries, discursive games, and interpreting temperature data logs

A heat comfort practice diary was developed and completed by six participating Trinity Close households (see Table 3.5 and Appendix J). This method was inspired by a diary approach used in two related projects on household bathing practices (Scott *et al.,* 2012; Kuijer and de Jong, 2011; Kuijer, 2014). Whilst the diary was informed by social practice theory, it was designed to be accessible and was intended to be an activity in which the entire household could take part – as such, I provided examples and invited contributions in the form of words, pictures and photographs. The diary was also designed to be personal and portable, so that it could be carried between rooms. The diaries were introduced to whole household (where possible) and (whilst initially designed for a week long period) were completed over a three-week period (see Table 3.5). Whilst I was concerned that I had missed the heating season, at the time that the diaries were completed (March 2013), the variable spring weather conditions coincided with a cold snap that brought snow.

Figure 3.4 and Table 3.9 outline the variety of ways in which the research diary attempted to explore the composition, performance, dynamics and relations of heat comfort household practices undertaken at Trinity Close. Figure 3.4 shows how, throughout the three weeks, residents were encouraged to observe and define moments when they noticed that their heat comfort had changed, and the ways in which they adjusted to these changes. In this way, the diary sought to build reflexive awareness of heat comfort practices (Reid *et al.,* 2011). However, participants found it difficult to step outside of their routines and reflect on how they embodied this practice, itself an interesting finding. For instance, one householder described how; *"you don't often think about your temperature, your body temperature, or even just your room heat. You don't really notices or think about things like that"* (H9B). Table 3.9 lists activities devised to access the different elements and traits of heat comfort practices. The final activity encouraged participants to suggest ways in which they might be prepared to modify their heat comfort practices in order to save energy, based on the idea of 'experiments in practice' (Scott *et al.,* 2012: 6).

Appendix J provides an excerpt from a completed research diary. Whilst this method proved useful to some degree, only half of the Trinity Close residents were prepared to complete a research diary. Furthermore, most diary exercises were partially completed, or involved 'copy-cat' responses (Strengers, 2009: 76), where participants based their entries on the provided examples. As such, direct material from these diaries is used sparingly throughout this thesis to complement other data. Despite this, I found that using the diary as prompt in follow-up recorded interpretive discussions - when I asked the participants to talk me through their entries - proved a useful way to obtain tenants' reflections on managing their heat comfort, how, if at all, this practice changed at Trinity Close, and what effects this had on other domestic activities.

KEEPING YOUR DIARY

Notes space is available at the back for more of your ideas!

Use this diary to note down times during the week when you become aware that how warm or cool you feel has changed.

You might have changed your temperature and comfort on purpose or you might have reacted to a change in your surroundings. Aim to complete at least 2 entries per day (more would be even better!) to describe the different types of changes that you make to your comfort and why you make them. Try to provide as detailed entries as possible. As an example have a look at the illustration below.

TIME	ROOM	WHAT WERE YOU DOING?	HOW DID YOU FEEL WHEN YOUR TEMPERATURE CHANGED?	HOW DID YOU WANT TO FEEL?	WHAT DID YOU DO TO 'FIX' YOUR COMFORT?
9am	Bathroom	Showering - came out of the hot shower	Felt cold as bathroom was cool in comparison to shower	Warmer	Dried off quickly and got into snuggly dressing gown
3pm	Kitchen	Friends arrived unexpectedly	Kitchen was already cool as heating was not on. Felt embarrassed and wanted to be a good host.	I wanted others to feel comfortable	Put heating on and had hot drinks
WHAT MIGHT TODAY'S ENTRIES MEAN FOR HOW WE CAN USE LESS ENERGY TO KEEP AT A COMFORTABLE TEMPERATURE?					
I noticed the temperature difference between the hot shower & cold bathroom. Maybe I would have less hot showers if the bathroom walls were insulated? ~ When guests came I was embarrassed that my house was cold. There is an expectation that houses must be warm.					

Each day there's an activity to think about how we might use less energy to keep at a comfortable temperature in our homes. Be creative & have fun! Photographs or drawings of your ideas would be great! Please either print photos out or email the digital file to r.macrorie@uea.ac.uk

Figure 3.4 – Excerpt from heat comfort diary instructions

No.	Activity
1	Think about the ways in which you kept warm and cool in your **previous home** compared to your new home. What sorts of things are the same? How are things done differently? What difference do these changes make?
2	Make notes on, draw or take photos of the **technologies and equipment** in your house that affect how warm and cool you are. Think about their design and your experiences of using them.
3	Make notes on, draw or take photos of how different types of **clothing**, their **fabrics** and the way in which they are worn affects how warm and cool we are. You might also want to think about how **eating & drinking** can affect how warm and cool we are at home.
4	How do different types of **activities** that we do at home affect how warm and cool we are? Why might particular activities need to be done at a certain temperature? Make notes on, draw or take photos of your ideas.
5	Make notes on, draw or take photos to explore how **room layout and furnishings** can affect how warm and cool we are at home. Consider the living room in particular.
6	Make notes on, draw or take photos to explore how **different members of the family** might prefer different temperatures & how compromises are made about temperature. You might also want to talk to someone of an **older generation**, or give your own opinions, about how the ways in which we keep warm and cool have changed in recent years.
7	Based on the last week, make notes, draw or take pictures to **identify any ways in which you could make energy savings in the ways you manage how warm and cool you are at home**. Identify any help you might need to make these changes.

Table 3.9 – Heat comfort diary activities

As part of the repeat interviews I devised and played a discursive game on energy-related household practices with eleven of the households (see Table 3.5). I did this partly as a means to inject some fun and humour into the data collection process (Delph-Janiurek, 2001), but also as a means to understand how householders understood domestic practices (particularly heat comfort) and their associated energy consumption. Using UK Energy Sector Indicator data from DECC (2012), I developed five cards representing the practices of lighting, cooking, heating, bathing and cleaning (using hot water), and entertainment/computing (using electrical appliances) (see Figure 3.5 – although the 'answers' were not depicted on the game cards). For each practice, I asked the household to place a number of counters (out of a provided one hundred counters) onto each card to represent the percentage energy used in an average UK home (gas, oil and electricity consumption). As the game proceeded, I asked participants to talk me through their rationale, asking them the probe questions (Seale and Filmer, 1999: 130) such as 'why did you place the counters on the cards in that way?'

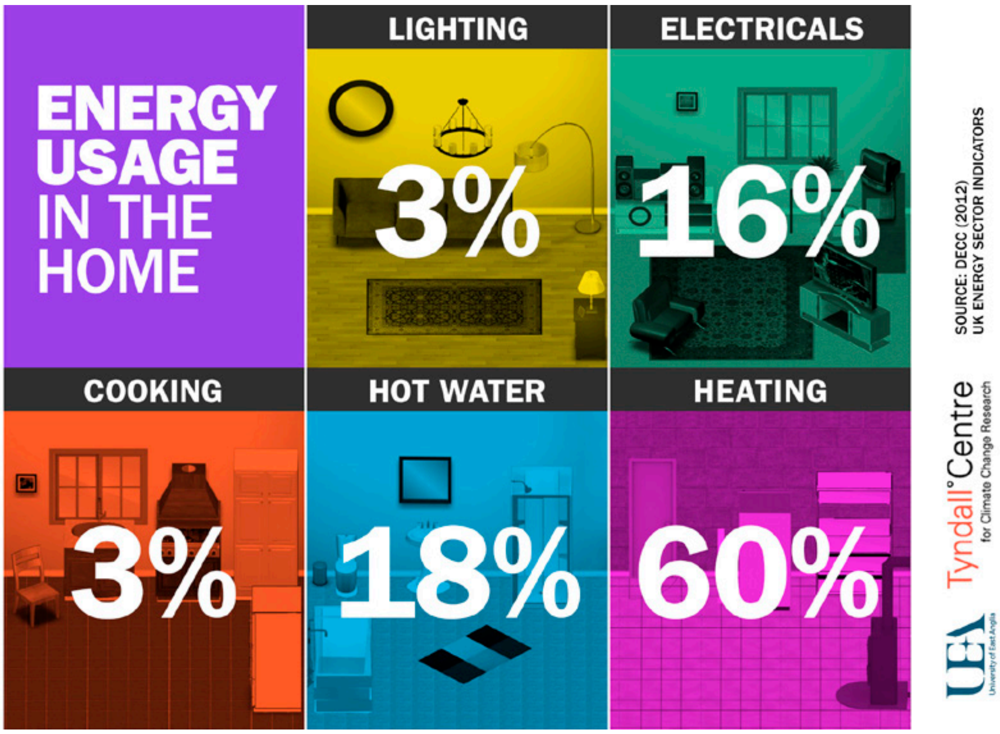


Figure 3.5 – Discursive game on energy-related domestic practices

Most of the participants appeared to enjoy participating in this game, suggesting that it provided respite from the interview process and was informative. Whilst I recorded the outcome of the game (see Table 3.10), it proved most useful for setting the participants at ease and empowering them through their active involvement. It was noticeable that whilst most residents considered that heating was an energy-intensive domestic practice, none of the participants appreciated that in 2012 heating accounted for as much as 60% of energy used in the average UK home (DECC, 2012). This emphasises Burgess and Nye's (2008) suggestion that energy is 'doubly invisible' to householders – both in respect to being a concealed force delivered through hidden wires, and in forming part of inconspicuous routines (Shove, 2003). It also underscores the importance of talking to participants in terms of their domestic practices, as opposed to their consumption of units of energy/carbon emissions. At the end of the game, as a thank-you for their participation and a reminder that could encourage reflection on the performance of their domestic practices (and implications for energy demand), I left each household a postcard (see Figure 3.5).

Household ref.	Heating	Washing/ cleaning	Lighting	Cooking	Entertainment/ computing
H1	30	10	20	10	30
H2	40	10	5	10	35
H3	25	20	10	20	25
H4	30	30	7.5	20	12.5
H5	*	*	*	*	*
H6	15	19	10	15	41
H7	20	20	20	20	20
H8	30	10	10	20	30
H9	20	20	20	15	25
H10	*	*	*	*	*
H11	High	-	-	-	High
H12	*	*	*	*	*

Shaded cells = Practice considered by participants to be the most energy intensive within an average UK home.
* = Household did not participate.

Table 3.10 – Outcomes of energy-related domestic practices game

In addition to collecting data on householders' experiences of their heat comfort practices using research diaries and the discursive game, I asked householders to collate and analyse temperature data in a central room of their home. To access heat comfort practices in this way, I installed a LASCAR EL-USB-2 data logger (a relatively unobtrusive pen-stick, approximately 10cm long) in participating households' living rooms (away from direct heat or cold sources). This device recorded the temperature at five-minute intervals. Nine Trinity Close households participated (see Table 3.5), and for these properties I set up the data logger to collect readings over a two-week period, coinciding with completion of the research diary (between 11th March and 15th April 2013). It is interesting to note here that, it was necessary for me to install the data logger, as the monitoring and measurement of temperature (or relative humidity) – potential indicators of residents' comfort levels - was not prioritised by the TCSG. Figure 3.6 depicts the collated temperature data for the nine participating households during this period.

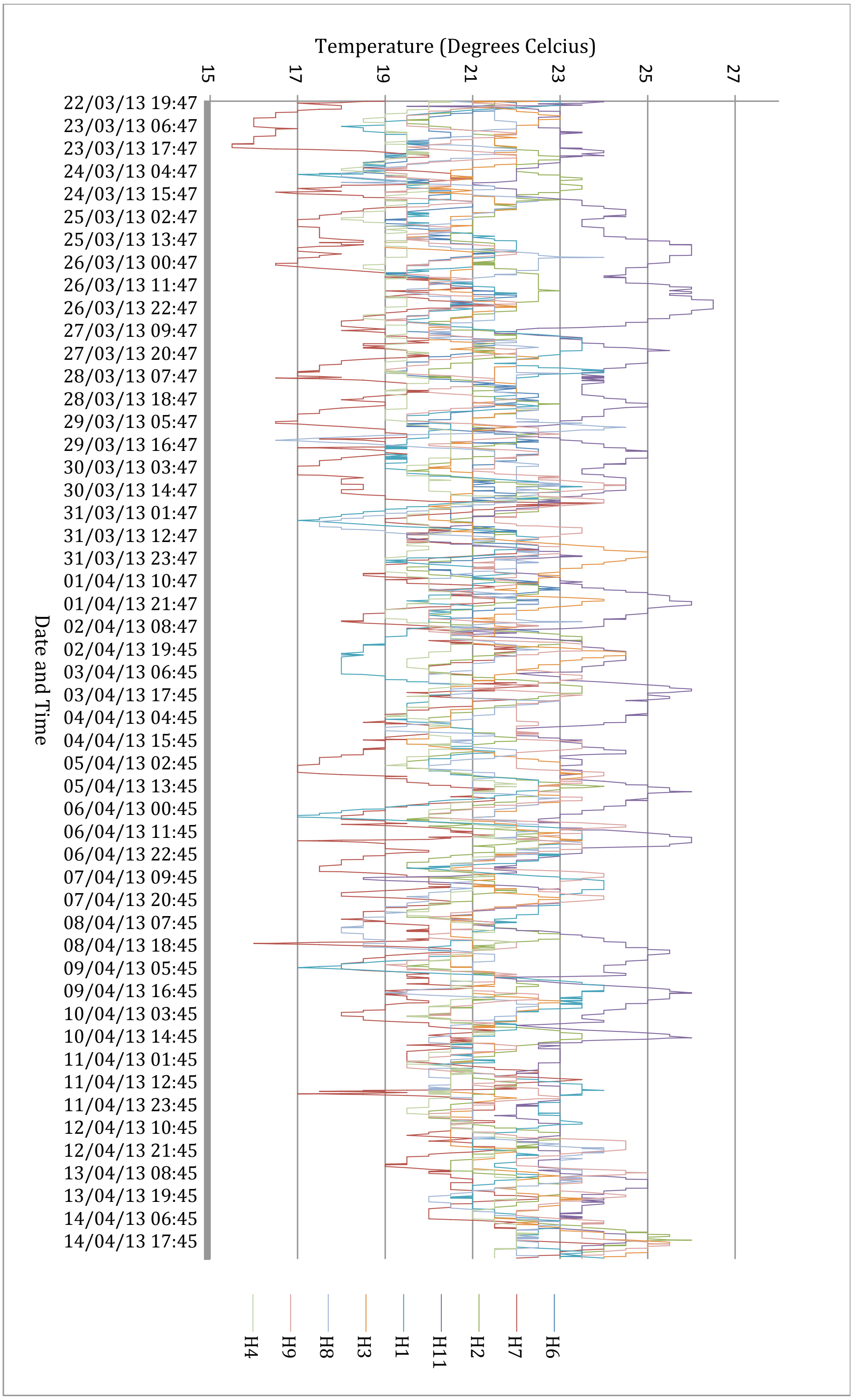


Figure 3.6 – Living room temperature in nine Trinity Close properties (recorded between 11th March and 15th April 2013)

Figure 3.6 demonstrates variability in recorded living room temperature - with an average mean temperature of 21.17°C, maximum temperature of 26.5°C, minimum temperature of 15.5°C and overall standard deviation of 1.15. Given that building materials and insulation levels were constant between Trinity Close properties, the living room temperature was a product of: operation of the heating system; relative humidity; room orientation and solar energy received; and furnishings (amongst other factors). However, these temperature plots and figures alone, tell nothing of how residents uniquely experienced and maintained their heat comfort during this period. Therefore, I used these plots as cultural probes (Gaver *et al.,* 1999) to initiate discussion about actions taken by residents to maintain their heat comfort, and about how other routines and activities, overlapped and intersected with this practice. Householders were particularly interested in examining the temperature 'data spikes' produced. Explanations for these peaks and troughs enabled the 'careers' (Pantzar and Shove, 2010) and dynamics of individual householder heat comfort practices, to be 'traced' throughout the monitored period (e.g. Browne *et al.,* 2012). More helpfully, using the data log as a prompt, these discussions, which were recorded by MP3 and later transcribed, often led to broader conversations around domestic practices, their relations and dynamics.

There is no 'notification system' for practices (Nash, 2000). As such, the question is raised as to how embodied, shared and dynamic three-dimensional practices can be recorded and analysed. The home audio tour, research diary, discursive games, and interpretations of temperature data logs provided insight into heat comfort practices, and their associated relations and dynamics. However ultimately I was best able to get closer to these practices by following-up on new insights generated by these prompts through discussions with the household residents.

3.3.5 Documentary review

Positivist researchers approach data generation with the expectation that evidence produced by the research process will be turned into quantitative indicators constituting a 'data-set'. In contrast, in interpretive research quantitative forms of data are not privileged over other data forms (Schwartz-Shea and Yanow, 2012: 83). Staying open to different types of evidence has considerable importance for interpretive research, and I therefore thought in depth about how I could collect different forms of evidence, using different methods, to meet my objectives (see Table 3.1). As well as seeking out original (or primary data) about housing-related practices at Trinity Close by interviewing a range of stakeholders, observing their practice performances, and understanding their interpretations of these performances, data were also collected through the analysis of documents.

Throughout the research project, I reviewed 55 and online material relevant to the CSH standard and Trinity Close housing development (see Appendix K). These documents are referred to using the prefix 'P' and respective number (e.g. P12). I selected these documents according to three concepts – 'mapping, exposure and intertextuality' (*ibid.*: 87). First, I mapped what kinds and sources of documentation would be available to review, using a starting point of collecting policy documents related to the CSH, publications related to the Trinity Close housing development, and websites of each of the TCSG partners. Using the principle of exposure, I ensured that the documents collected enabled me to take into account different, perhaps contentious, views in relation to CSH, sustainable housing and the Trinity Close initiative. Intertextuality relates to the way in which I also identified documents by following citations from document to document in a 'hermeneutic spiral fashion' (*ibid.*: 87).

Whilst many of these documents were publicly accessible, some were provided through email exchanges with the TCSG. Indeed, following initial meetings with BDC and Adapt (see Table 3.8), I developed lists of documents brought to light through our discussions that I intended to review. Unfortunately, provision of these documents was often delayed and several of these documents were not provided, even after repeated requests. At times, this restricted my understanding, with potential knock-on effects for data collection. For instance, it wasn't until after having conducted the pilot householder interviews that I learnt the technical specification of the Trinity Close properties.

Reviewing policy documents, websites, protocols and formal guidance (Section 3.3.5), I obtained descriptions of institutionally espoused practice ('canonical practice' - Brown and Duguid, 1991: 41) and idealised descriptions of finished tasks (*opus operatum* - Bourdieu, 1990) which provided insight into what housing practices at Trinity Close were planned to be like. Comparing these descriptions to the realised ‘non-canonical practice’ (Brown and Duguid, 1991: 43) and actual ‘*modus operandi*’ of everyday doings (Bourdieu, 1990), demonstrated how processes of doing housing practices are structured by the constantly changing conditions of work and the world. As a result, planned and realised housing practices, and their associated bundles and complexes, frequently adopted different configurations.

3.3.6 Ethical considerations

All research involving people poses distinct ethical problems (Robson, 2002). Whilst in ethnographic qualitative research, ‘…we may not be able to, or wish to, control the situation, … there is almost always the intention or possibility of change associated with the study. This forces the researcher, wittingly or not, into value judgements and moral dilemmas’ (*ibid:* 66). Kimmel (1998: 69) outlines ten questionable practices in social research, including: involving people without their knowledge or consent; coercing people to participate; invading privacy; and not treating participants fairly, or with consideration or respect. Seeking to avoid such research hazards, I discuss ethical issues relating to participant observation and semi-structured interviewing and explain how I defused these concerns. Research ethics measures implemented were approved by the University of East Anglia (UEA) General Research Ethics Committee.

I was overt about the nature of my research from the beginning, with both the TCSG and householders at Trinity Close, introducing myself as a PhD researcher investigating ‘energy use, carbon reduction and ‘behavioural change’ in low-energy housing’ in accordance with the original research proposal. I still however needed to ensure that I gained full and informed consent for continued participation from each research participant. As such, prior to each professional or household practitioner interview, I provided an information sheet which explained the rationale and approach of my research (see Appendices E and F), and I asked each participant to sign a consent and release form (see Appendix G). This form confirmed that the participant understood the purposes of the research, provided agreement that their participation was voluntary, and stated that it was possible to withdraw from the process at any time.

A second important ethical issue relating to participant observation, document review and interviews is anonymity. Whilst I could have concealed the name of the housing development project itself, I gained written approval from the TCSG enabling identification of Trinity Close, Rackheath. In any case, it would be easy to identify the site given its unique carbon-neutral features and location. At the level of the individual household and professional participants, it was however important to maintain anonymity. The consent form allowed participants to object to their interviews and discussions being recorded and to notes being made, although all participants permitted these data recording methods. In addition all collected data was stored and treated confidentially. Whilst some individuals will be able to recognise themselves, I used pseudonyms and reference codes when citing conversations or describing individuals' practices. I also offered to provide a summary of each conversation to each participant to verify that I had represented our dialogue accurately.

The semi-structured interviews raised ethical issues relating to power relations between the researcher and researched. I attempted to equalise these potentially uneven relations by: introducing myself and being open about the research; using an informal/conversational style; allowing participants to select their interview location or undertaking the discussion in the participants' homes; and reminding participants that they could opt out of the interview at any time without repercussions. No interviewees terminated their interview early or refused to answer my questions, and most appeared to relish the opportunity to talk about their experiences. Whilst some, particularly the professional practitioners confident in leading discussions, sought to pursue their own agenda, I was always careful to bring the conversations back to relevant issues, if I felt that we were going off-topic.

In my initial research plan I intended to provide all participants with a newsletter summarising my findings in an accessible way. Whilst I shared my thesis and papers produced from my doctorate with interested parties, due to timings it was not possible to develop the newsletter. All tenants were however provided with a report summarising their energy performance for the first year of tenancy at Trinity Close produced by Dr. Jennifer Monahan on behalf of BDC and WHA (see Appendix L). In addition, many participants told me that the data collection process had provided a means to reflect on their assumptions, the implications of their everyday practices and their aspirations in terms of environmental sustainability.

In addition, it was important to maintain high standards of integrity, honesty and professionalism throughout my research. The more I got to know participants, and their practices, the more vulnerable I became to 'internal politics' (Foulds, 2013: 83). In such situations, I tried not to get involved or to pass judgment. Rather, I hope that this thesis, and the publications arising from it, will help to appraise the Trinity Close initiative and will contribute to shaping housing policy, and other relevant policies, in Broadland District and further afield. I aim for this research to provide research and applied insights on the relations and dynamics operating in a novel low-energy housing system of practice.

3.3.7 Data analysis & writing-up findings

Analysis of documents, field notes and transcribed interviews started in earnest once the majority of data had been collected (i.e. June 2013). However, even when collecting data, writing up my thoughts and transcribing conversations, I was processing the data, albeit not explicitly. When reviewing the data, in line with a SPT approach, I attempted to identify patterns borne out in enacted social processes and practice relations (Halkier and Jensen, 2011). In addition, practices at the Trinity Close site were continuously dynamic, intersected with many others, and my data analysis needed to take this potential instability into account.

Data analysis was partly informed by the techniques of grounded theory generation (Charmaz 2006; Bryant and Charmaz, 2007) whereby instead of starting with predetermined categories and concepts, they were allowed to emerge from the data. According to this approach, textual data was coded word-by-word or line-by-line, in a process known as open coding (Strauss and Corbin, 1998; Corbin and Strauss 2008). Using digital highlighting, the addition of comments, and the qualitative data analysis software NVivo9, codes were then grouped into themes, categories and sub-categories, to produce 'concepts that seem to fit the data' (Strauss, 1987: 28). The first round of coding generated 130 codes grouped under fifteen categories, each referring to a distinct concept that spanned across the data. Examples of these categories included – relations between TCSG and residents, householder interactions with technologies, practising low-energy house-building techniques, and the role of building standards.

Richards (2005: 86) explains how coding occurs throughout a research project, is concerned with data retention rather than reduction, is flexible, and has the goal of learning from the data. However, after the first round of coding, I felt that I had produced so many categories at largely a topic level that the results became almost meaningless, and I could not easily discern any patterns. To combat this, I undertook a second round of analysis for which I made sure that I interrogated the data by keeping my thinking 'up' at an analytical level (*ibid.*).

Rather than closely analysing the data and seeking out each individual topic or idea, I read whole interview transcripts, documents and field diary entries and analysed them more freely, attempting to make sense of each case and connect it with other parts of the data. I then wrote each of these codes onto an individual post-it note and grouped them into categories, using an approach, which by generating larger meta-categories, can be termed 'semiotic clustering' (Crang, 2001: 226). By using post-it notes I could rearrange the different codes until I was satisfied that my analysis had achieved 'theoretical adequacy' (Cook and Crang, 1995). Knowledge claims made in this research therefore emerged from identification of patterns of categories and dynamics found within the data, which were retained due to their theoretical relevance (Blaikie, 1993: 176-81; Kvale, 1996: 223-34).

In the latter stages of my analysis, I revisited the data with the aim of identifying connections between different practices operating in the Trinity Close housing system of practice. Initially I attempted to map each practice relation and dynamic (see Figures 3.7a&b). However, faced with growing levels of complexity, I streamlined the analytical process to identify routes capable of explaining how practice interactions generated different practice configurations at Trinity Close (see Chapter 6). Data analysis therefore followed an inductive approach in identifying themes, but used theories and concepts – systems of practice (e.g. Watson, 2012) and problematisations (Callon, 1986) (see Chapter 6) - to guide the articulation of meaningful themes and findings.

The constructivist position adopted in this research highlights the impossibility, and desirability, of suspending one's own theoretical dispositions, frames of reference and epistemological commitments (Mahony, 2013b: 99). This is a position embraced by grounded theorists (e.g. Strauss; 1978,1987) and contrasting with that advocated by Glaser (1978) – who claimed that inductive analysis can offer a neutral and transparent understanding of social reality. As discussed in Section 3.1.1, it was important to be reflexive about my role, prior knowledge and assumptions throughout the research. Arguably this was most important during data analysis.

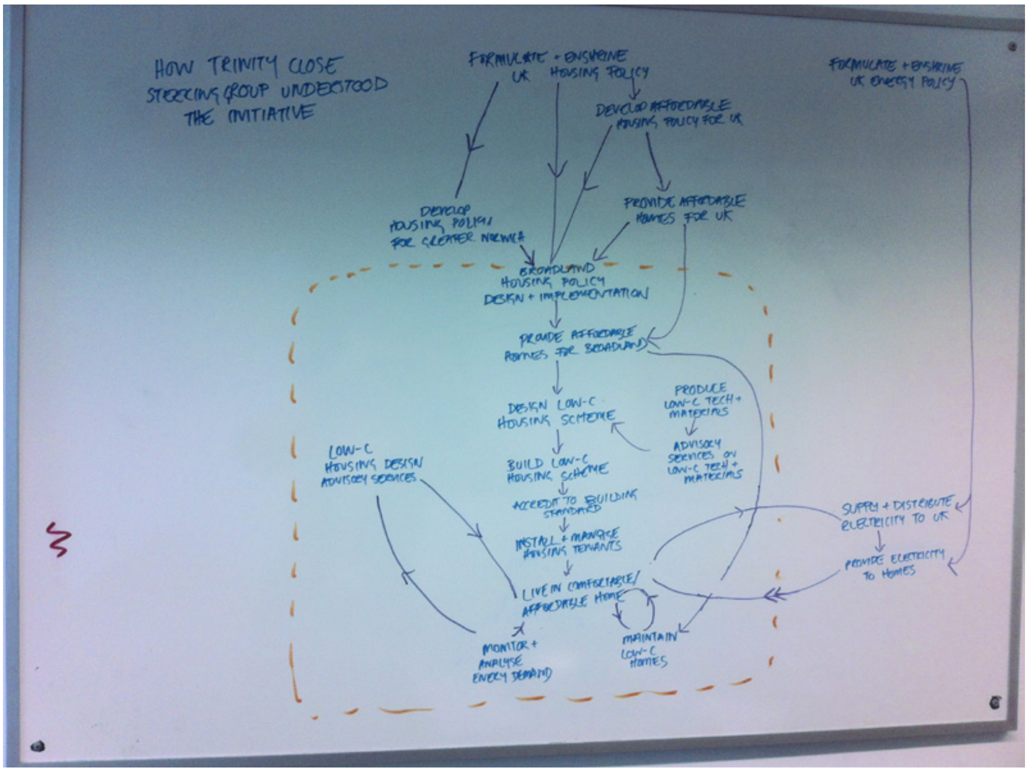


Figure 3.7a – Mapping relations configuring the Trinity Close system of housing practice

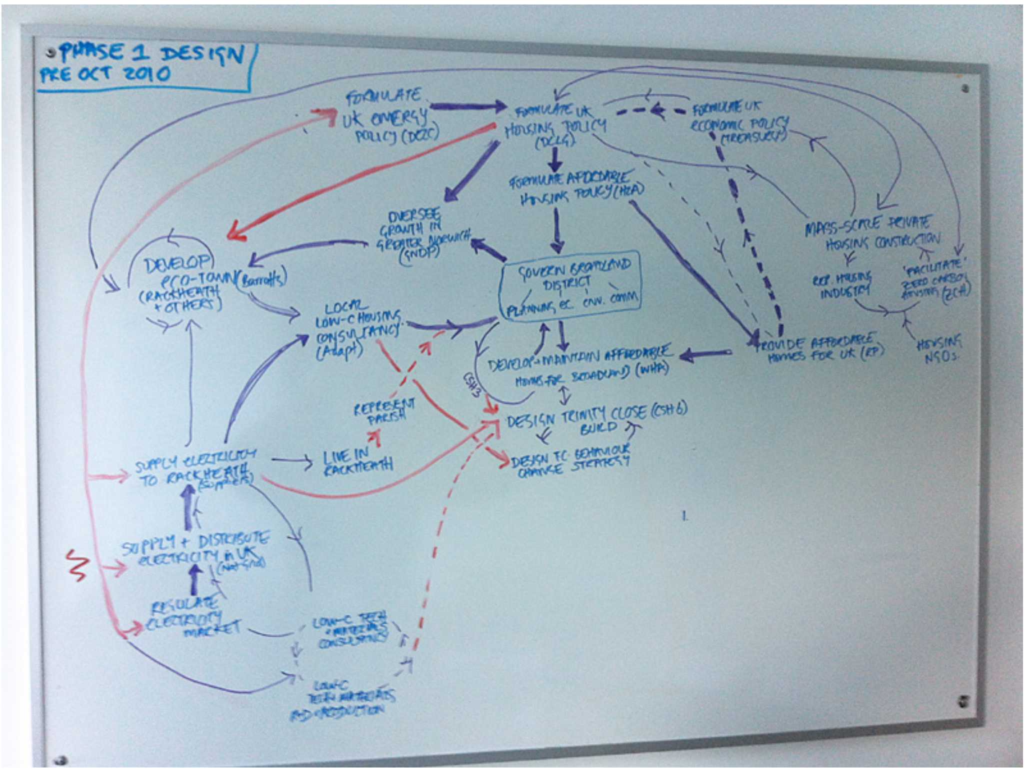


Figure 3.7b – Mapping relations configuring the Trinity Close system of housing practice

In line with Richards (2005: 183), and acknowledging that there can never be one single, right way to write up qualitative research (Becker, 1986), I found that by analysing my data and continually writing throughout the research project, eventually my account 'crystallised'. As Richards states;

> 'Theories are not right or wrong. They do a better or worse job of accounting for the situation, or answering the questions, and of fitting the data. Explanations are more or less adequate. You want your theories to be useful and your explanations adequate. So establishing the grounds for your claims requires adequately knowing, exploring, searching and making sense of your data' (2005: 144).

I have not attempted to use my mixed methods approach to triangulate data and attempt to produce a single truth of the Trinity Close initiative. Instead, each methodological approach has been treated as generating 'equal but different kinds of data that [have] provided different perspectives on, or performances of, the reality of my research problem' (Hargreaves, 2009: 105). In doing this, I have negotiated competing and contested accounts to produce what I hope is a rich, worthwhile and poly-vocal version of events. Similarly, rejecting positivist assumptions about the stability of the social world and how researchers can know it, I do not seek to produce replicability in this case study research. Rather, as Schwartz-Shea and Yanow (2012: 94,95) suggest, interpretive research pursues understandings of meaning-making *in context*, based on the assumption that all social phenomena are dynamic and fluid as well as historically constituted.

Ultimately, as I hope that this section has shown, whilst I attempted to be systematic and rigorous throughout the data analysis process, I also made space for creativity. I believe that my adopted approach is not only commensurate with my ontology and epistemology, but has hopefully produced knowledge claims that are novel, useful, and that are supported by accurate and comprehensive explanations. Although conforming to academic requirements, this thesis has been written with an audience of researchers and applied practitioners from the dominant technical and behavioural change disciplines in mind. It is my intent that these findings will generate interest at an applied and policy level. However, recognising that authors such as Carol Weiss (1986) and Elizabeth Shove (2010) provide sombre warnings as to the difficultly that marginal research can have in gaining leverage (particularly in policy circles), I retain a degree of humility about how these outcomes will be received and taken-up.

Chapter 4. Governing housing practices: Planning the Trinity Close initiative

Chapter 2 suggested that social practice theory (SPT) provides a more nuanced lens for understanding developments in the low-energy housing agenda than technical, behavioural or other socio-technical perspectives. Building on this insight, this chapter introduces the principal stakeholders involved in the selected case study and examines their housing-related practices. Analysing data from the documentary review, professional practitioner interviews and household interviews, here I provide a descriptive account of the contextual beginnings of the Trinity Close initiative. Building on this introduction, Chapters 5 and 6 appraise the aforementioned assertion, and seek to understand how and in what ways these practices and their configuration evolve. This empirical analysis applies and extends the SPT framework to examine empirical data collected from the exemplar Code for Sustainable Homes (CSH) level six Trinity Close housing development (Rackheath, Norfolk).

Throughout these empirical chapters I seek to understand technologies and behaviours as intertwined and embedded in interconnected social practices, which when performed, frequently result in the consumption of energy. This adopted approach contrasts distinctly with dominant disciplines researching low-energy housing (as critiqued in Chapter 2) which interrogate the selection, dissemination and performance of carbon-neutral building materials, examine the design decisions lying behind the selection of particular renewable technologies, and/ or analyse the values and choices underpinning individuals' energy-saving behaviours. Instead of adopting such linear and reductive approaches, by employing a SPT framework I seek to account for the complexity of social-material relationships and multiplicity of change dynamics involved in the pursuit of low-energy housing transformations.

Additionally, when discussing the potential for less energy-intensive housing practices, context, is commonly considered in terms of barriers to social change (see Chapter 2). In contrast, instead of seeking to remove external factors perceived to be impeding individuals' daily actions, SPT suggests that meanings and understandings, social relations, institutional rules, and infrastructures are fundamental to, and constitutive of, social practices (Reckwitz, 2002a; Shove and Pantzar, 2005). At the core of this adopted framing of social life lies the need to understand how the daily 'doings and sayings' of individuals' practices are constituted, faithfully reproduced and change (Schatzki, 1996: 89). To understand the potential for, and processes of, change in practices therefore requires 'close and detailed observation of the *doing* of practice in context' (Hargreaves, 2009: 107).

Given this approach, this 'scene-setting' empirical chapter introduces six emblematic actors pivotal to the CSH exemplar at Trinity Close, and describes their everyday activities or practices, and aspirations for and expectations of the proposed low-carbon housing intervention. The institutional framework informing the Trinity Close exemplar is typical of the UK housing sector as from the outset of the initiative, it formed a site at which many types of actors and diverse sets of practices came together. However, I acknowledge that the organisational make-up of Trinity Close was more complicated than allowed for here, and that it would be possible to provide any number of accounts.

Four organisations making up the Trinity Close Steering Group (henceforward, TCSG) were pivotal to determining the governance of the first development phase of the Trinity Close initiative (i.e. twelve houses built and accredited to CSH level six as part of Phase One Trinity Close). These include; the local authority - Broadland District Council (BDC), registered social housing provider - Wherry Housing Association (WHA), housing contractor - Dove Jeffery Homes (DJH), and an energy consultancy acting on behalf of BDC - Adapt Commercial Limited (Adapt), The Department for Communities and Local Government (DCLG), in developing the CSH standard and funding the housing exemplar, formed the fifth principal stakeholder. The sixth stakeholder comprised the social housing tenants themselves. Having identified the main stakeholders of the Trinity Close initiative, this Chapter examines how these actors' practices contributed to specific conceptualisations and manifestations of low-energy housing and tenant engagement in Rackheath.

Prior to embarking on the Trinity Close initiative, few of the housing development's stakeholders had been exposed to carbon-neutral housing and their everyday routines and practices remained largely ingrained by dominant techno-rational assumptions (Guy and Shove, 2000). For example, DCLG's priorities rested on evidence-based policy-making enlisting models and randomised control trials to predict and assess effective housing policy outcomes. Such methods 'pay no attention to the historically and cultural specific mechanisms within which policy takes effect, and as such can mistakenly assume that an intervention will work (or fail) everywhere because it works (or fails) somewhere' (Spurling, 2014: 51). BDC's housing policy sought to promote energy-efficiency, by changing individual behaviours through provision of information and incentives. These approaches have been widely criticised both on epistemic grounds and for their failure to consider the social, cultural and institutional contexts in which attitudes and behaviours are formed (Owens and Driffill, 2008). The housing contractor, DJH, had previously only built to CSH levels three and four and had prioritised technical efficiency over challenging the practices of subsequent householders. However, as Chapter 2 demonstrated, it is impossible to consider technologies without understanding how people interact with and use them as part of their everyday lives. Furthermore energy-related decisions had not been a feature of everyday domesticity for the majority of WHA tenants in their former homes.

This chapter proceeds as follows; having identified the main stakeholders of the Trinity Close initiative, Sections 4.1 through 4.6 present detailed profiles of six emblematic actors at Trinity Close, providing a more detailed reading of their daily practices and analysing their intended intervention approaches. The extent to which house-building and household 'practice-as-entities' (Shove and Pantzar, 2005) are to be intervened in - and to which new low-energy practice variants are to be established - is debated. Section 4.7 concludes this chapter by appraising how useful and realistic the objectives of the TCSG were for delivering low-energy housing in Rackheath and potentially further afield. Throughout discussion of these stakeholder profiles, analysed policy documents (listed in Appendix K) are referred to by the letter P followed by an identification number.

4.1. Minister for Housing and Local Government, Department for Communities and Local Government (DCLG)

Originally I assumed that any member of DCLG would toe the party line and reiterate the Government's position on the CSH. Namely: first, that the standard was developed in response to national carbon emission reduction targets and in recognition of the residential sector's contribution to the UK carbon budget; second, that by providing sustainability performance criteria that built on existing systems, the guidance was intended as a *"single national standard"* that would *"enable a step change in sustainable building practice for new homes"* (P1:4); third, that the CSH would complement Energy Performance Certificates (EPC)[1] providing information about the carbon performance of UK homes that could inform home-purchase decisions; and lastly, that whilst Code compliance was voluntary, builders were encouraged to follow Code principles to gain competitive advantage and as mandatory CSH phase-in was likely (P2). During the research process it became clear that not only was the incumbent Minister for Housing and Local Government[2] regularly replaced, but the CSH operated within a fast-changing policy environment, meaning that policy positions, regulations and guidance frequently changed.

In June 2008, the Zero Carbon Hub (ZCH) was launched to take operational responsibility for delivery of low and zero carbon new homes (P3). When the CSH was developed it was acknowledged that, in the words of Margaret Beckett MP *"the high-level definition [originally] set out in the [CSH] policy statement might not apply in all situations"* (P4: 6). Furthermore, feedback from the housing industry suggested that the CSH was not feasible for large-scale builds. Subsequently the industry-led body organised a consultation on the definition of zero carbon involving more than 500 housing organisations and professionals soon after the inauguration of the standard.

[1] Energy Performance Certificates: Certification scheme introduced in England and Wales on 1st August 2007 as part of Home Information Packs (HIPs) for domestic properties with four or more bedrooms. Over time this requirement was extended to smaller properties. When the requirement for HIPs was removed in May 2010, the requirement for EPCs continued.
[2] The Minister for Housing and Local Government office was held by Margaret Beckett MP (Labour) October 2008 – June 2009, John Healey MP (Labour) June 2009 – May 2010, Grant Schapps MP (Conservative) May 2010 – Sept 2012, Mark Prisk MP (Conservative) September 2012 – October 2013, Kris Hopkins MP (Conservative) October 2013 – July 2014, Brandon Lewis MP (Conservative) July 2014 – present. MP = Member of Parliament.

In December 2009, John Healey MP launched the consultation, which aligned the CSH with changes to Part L 2010 of the Building Regulations, and suggested a new definition of zero carbon to encourage uptake by the housing industry. He also put forward for discussion, a menu of (mainly off-site) allowable solutions (see Chapter 1) to enable lower on-site emissions targets to be set for house builders whilst preserving the zero carbon policy goal.

Healey stated, *"The Code has proved its worth but now is the time to make it a more user friendly standard for consumers. In the future, this will help drive uptake so people will save more money on bills and reduce the carbon footprint of new homes"* (P5; P6). At this time the CSH was already undergoing changes, which increased the level of confusion around building requirements.

DCLG Ministers believed uptake figures - only 8000 homes had been completed to Code level standards in the first three years of operation – to be too low, partly due to the complex and bureaucratic nature of the Code (P7). A primary concern was the definition of carbon zero and what this meant for house-building practices. When the CSH was first launched, zero carbon referred to net zero carbon emissions arising from a building over the course of a year, and all carbon dioxide emissions were required to be reduced to zero through on-site means. Both 'regulated emissions' (from heating, cooling, ventilation and lighting) and 'unregulated emissions' (from household appliances) had to be accounted for. However, the cost and impracticality of building to this definition, particularly on large sites, led to industry pressure for Government to find a new delivery approach.

In November 2010 updates to the CSH were announced by Grant Shapps MP. He proposed a streamlined Code to ensure that *"building standards can be used in a sensible way that suits the local situation"* (P8). This was followed by a more flexible definition of zero carbon homes in May 2011 (see Chapter 1). The Housing Minister suggested that this revised approach was *"fairer and reaffirm[ed] the Government's commitment to reduce regulatory and other burdens on the house-building industry…It also plays an important part in protecting the economic stability of the country"* (P9). Furthermore, reacting to a policy introduced by a Labour Government, Shapps also promised a wider regulatory review on *"the future role of the Code, alongside a wider rationalisation of housing standards"* (P8).

In 2010/11, the early development stages of Trinity Close Phase One, far from there being political consensus over the requirements of the CSH and UK house-building practices, the incumbent Housing Minister and DCLG civil servants continually worked through the practical, social and economic implications of the standard. Moreover, the leadership of DCLG and portfolio for housing was revised on an almost annual basis, making long-term political decision-making difficult. Whilst Trinity Close was built to the more stringent CSH definition of zero carbon, this section has shown how, in the months preceding completion of the development, industry concerns led to DCLG's requirements being revised (and arguably downgraded). It was against this changing political backdrop that the initiative was delivered.

4.2. Roger, Planning team - Broadland District Council (BDC)

When I met Roger, a senior figure in the BDC Planning team, he suggested that, in overseeing the planning team, his was *"a responsive, reactive role"* that provided a 'big picture' perspective of development across Broadland District. His role, he described, required not only the ability to weigh-up planning permission requests against the local development strategy and regulatory framework, but also the ability to rapidly implement edicts from Government relating to building standards or planning policy. He discussed how, according to Government growth targets, BDC are required to build 10,000 new homes within the Broadland District growth triangle by 2031. Whilst he considered himself a *"naturally a glass half-full"* [3] person, his concern about *"a potential housing crisis"* due to the economic downturn was evident when he discussed how housing construction in the local area was inadequate; *"there is clearly significant housing demand and at the moment levels of house building are very small… you're seeing somewhere between 5-10% of all the [planning] permissions that have been agreed actually being completed."*

[3] Glass half full: Colloquial term for an optimistic person.

Despite the need for pragmatism when making decisions about the potential numbers and location of new-build homes for the district, Roger became animated when describing how BDC was attempting to improve housing environmental standards. He stated, *"[BDC is] trying to create a policy framework, that may call for higher standards of design or it may call for policies that… determine what that development is going to look like"*. In response to these growth targets, local authority stipulations for green development, and interest from a large housing developer (Barratt Homes), Roger and the Rackheath eco-community steering group[4] expressed interest in developing an eco-town at Rackheath. Roger explained how the eco-community was intended to set Broadland District apart as a progressive council prepared to back innovative sustainable housing development. He described how he was *"involved in drawing up the Rackheath Code which was trying to enshrine [in local planning and environmental policy] what we saw coming out of the Rackheath eco-community"*. It was intended that the scheme would not only meet growth targets, but would act as a beacon of good practice for the housing industry.

When the Rackheath eco-community project stagnated (see Chapter 6), Roger and the TCSG pressed ahead with development of Trinity Close Phase One, as a pilot scheme aimed at assessing a CSH level six build. Appraisal of this trial, it was hoped, would inform local and national housing development, and would be useful for Registered Providers (RPs) of social housing given their ownership and management of *"a huge housing stock"*. BDC's aspirations for the exemplar were therefore; *"pretty simple, it was to please DCLG, please our own politicians and [to] get a Code six development on the ground"* that could be appraised. BDC aimed therefore to deliver carbon neutral housing that would meet the requirements of funders and regulators and would be accepted by existing Rackheath residents.

Roger described however, how these aspirations immediately led to tensions, as BDC councillors envisioned a fairly conventional construction style that would fit alongside existing properties in the area; *"[Council m]embers… wanted what they would describe as a traditional build. My problem with that is that I think in their mind traditional build is something that looks like it's from the 1980s… they wanted something that looked 'normal'."*

[4] The Rackheath eco-community steering group was dissolved in May 2010, when the political administration changed from Labour to a Coalition Government made up of Conservatives and Liberal Democrats.

Whilst BDC adopted a light-touch approach in determining the design and build specification, it was recommended that residents' everyday lives should not be disrupted. This led to some low-energy housing design options being excluded, as Roger discussed, *"Initially [WHA and DJH] were looking at a small biomass boiler, but there were problems with noise… and its functioning, so photo-voltaic panels were the solution… [But] we were very much reacting, rather than forcing them to go down a particular line"*.

Throughout our discussion, it became clear that Roger's experiences meant he held distinct views on the role of low-energy technologies in the home and the extent that residents should be involved in managing their everyday energy consumption. This position was reflected in support for homes that 'did the work' of reducing energy demand with minimal active householder engagement. He discussed how he increasingly believed that residents should be 'designed-out' of domestic energy management, *"I can remember walking into [low-energy] homes …and it was like a Boeing 747, a cockpit, so many dials and controls! … Some households thrive with that level of control, but it clearly doesn't work for all… I'm more and more of a view that it has to be a 'fabric-first' [only] approach and as little technology and control being given to the operators."* At the same time as advocating discrete low-energy technologies, Roger highlighted that residents had a responsibility to manage the sustainability of their lifestyles. He described how, in his opinion, householders should choose to behave in less energy-intensive ways; *"…You've also got to make a conscious choice about - How are you going to heat the house? Are you going to heat the house and have your windows open? … People have got to be thinking about the way that they're living and make those choices themselves. And there needs to be something to stimulate that…"*.

When I pressed Roger on what he felt would induce individual behaviour change, he argued that household finances would provide a strong incentive to reduce levels of electricity use. Domestic financial outgoings would, he considered, be felt acutely with elevations in fuel bills, particularly by households at the lower-end of the income spectrum subject to on-going welfare cuts[5]. He suggested, *"where [energy bills] hurt the pocket is going to be a driving force [for reducing electricity use further]"*. In this respect, he considered monetary incentives more powerful than encouraging behaviour change through social marketing; *"Do you want to reduce your carbon footprint just because*

[5] The UK Coalition Government's reform of welfare started in 2010. It aimed to save £18 billion a year from the social security budget by 2015.

your neighbour is, or … because actually you can't afford your fuel bill at its current rate?" Roger explained how the intended mechanism for behaviour change was through energy feedback to each household by In-Home-Display (IHD) units, in accordance with DCLG's stipulation for building electricity performance monitoring[6]. When prompted, Roger appeared sceptical of the long-term influence that this feedback would have on resident energy-related behaviour; *"The energy monitors were seen as that [incentive] … as a constant reminder… I haven't got one myself yet, and I'd love to get one because I think I'd be fascinated for the first two weeks… I want to have the experiment myself to see, does it change behaviour?"*

Roger revealed that he thought it imperative that householders are supported in order to understand the *"correct"* ways to interact with low-energy devices and IHDs, and to help to develop a *"low-energy community"* in the Close. He described how originally he had believed that less-energy intensive domestic practices would automatically result from simply living in a low-energy home; *"I imagined a low-energy utopia where everyone would love living in a low-energy environment… and sharing that common sense of living in a Code six development, and that behaviour change would happen across the board"*. Roger suggested that, whilst BDC commissioned Adapt, to provide a point of contact with the residents of Trinity Close and oversee electricity monitoring and intended resident feedback process, BDC's attention was largely focused on ensuring the design quality of the low-energy build. Whilst ideas were discussed around using the Feed-in-Tariff, received for on-site electricity generation, to incentivise community engagement, such proposals became infeasible in 2011/12 (during the period of research) when the tariff was cut[7]. Furthermore, Roger described an initial intention to recruit local 'energy champions' from Trinity Close, to share their experiences of living in a low-energy home and help induct other tenants, so that; *"if someone had a problem, or if someone didn't understand something, that they could go to their neighbour… developing a self-supportive community… [with the] collective desire to… live a lower carbon lifestyle"*. Roger acknowledged that such aspirations for behavioural change and community engagement were lost as all efforts became focused on gaining accreditation to CSH level six.

[6] The requirement to install building electricity performance monitoring equipment aligned with the Department of Energy and Climate Change's (DECC) proposal to install smart meters in every UK property by 2020 (DECC, 2011b).
[7] Electricity-generating technology from a renewable or low-energy source can be eligible for the UK Government's Feed-in-Tariffs (FiT) scheme. The scheme was originally launched in April 2010. Rapid uptake led to the resulting need for action to control costs. The generation tariff was subsequently reduced for solar photo-voltaic panels (DECC, 2015f).

Roger's senior role in BDC's planning department meant that he had to make difficult decisions when faced with conflicting needs for increased housing and sustainable development within the district. He considered the Trinity Close scheme as a low-energy housing exemplar that would drive up the standards of mainstream housing within the district. His approach to the build was informed by his personal experiences, which led him to favour fabric first properties as opposed to complicated technological builds. He was also influenced by DCLG's need to deliver an 'early win' on CSH level six, and to placate BDC local councillors by creating a traditional build that would minimally interrupt residents' everyday lives. Roger appeared somewhat divided in his framing of residents' engagement in domestic energy management; on one hand he considered that low-energy buildings did not require residents' involvement, on the other, he purported that householders needed education about how to interact with technologies and should make conscious individual decisions to be energy-efficient. The behavioural mechanism for such change was to be provided by residents receiving feedback on their energy usage, alongside energy and money saving tips. He acknowledged that as the initiative progressed, attention shifted away from behavioural change and towards gaining accreditation to CSH level six.

4.3. Dave, Development team - Wherry Housing Association (WHA)

When I met Dave, a senior figure in the Development team of Wherry Housing Association (WHA), the developer of Trinity Close, he showed me into the boardroom and proudly explained how WHA was considered as a *"fairly significant local player"* in the housing market of Broadland district. Owning thirty properties in Rackheath, partly due to inherited Local Authority housing stock, he explained that this meant *"… [WHA] has an interest in [the] community…because we sometimes own ten, twenty, or thirty percent of properties. [Our role is] not just providing properties, it's about providing services for our tenants and to a degree for the wider community…"*. Dave clearly felt responsibility for providing affordable properties of quality for WHA tenants and for enhancing community amenities.

Dave described how his remit spanned the entire development process. This included; identifying potential social housing development sites, appointing architects and obtaining planning permission, facilitating the tendering process, appointing a housing contractor and overseeing housing construction. It extended through taking possession of the site and *"handing the keys downstairs"* to his Housing Management colleagues to oversee the tenant rental process. As such, Dave considered that he had an enviable position that gave him control throughout the project; *"I'm lucky in that I tend to see [the development process] from cradle to grave… You have to take responsibility, you can't blame something on it happening before you got involved…"*.

When we began to discuss WHA's reasons for involvement with the Trinity Close scheme, Dave described how housing associations, as part publicly funded bodies, are uniquely positioned as forerunners in the uptake of national housing performance standards. He described how, *"Governments tend to use housing associations as a sort of tester of new technology… Historically it's been stuff like…using modern methods of construction… It's [the same for] the Code as well…[Housing Association properties] have to achieve Code three under Part L [of the Building Regulations]"* [8]. With some frustration, he explained how, when the Code was first introduced, it was *"not mandatory for private house builders"*. Consequently, Dave described how when BDC first approached WHA with the proposal to upgrade from the initial approved plan for a CSH level three affordable housing development to be built at Trinity Close, to developing twelve CSH level six units, he felt some trepidation as to the project's value given the extra investment that it would involve (P24). In addition, the development had to work within constraints presented by the physical site, which was not connected to mains gas supply. Despite this, WHA recognised the potential merits of involvement in the scheme. As Dave explained, there is a national shortage in social housing properties, *"We don't build enough social housing, so the more we build, the better"*. Dave was also keen for Trinity Close to inform WHA's future housing strategy; *"looking at these schemes obviously helps us… work out what we want to do in terms of going forward"*.

Dave described how the principal aspiration for the exemplar scheme was to gain accreditation to CSH level six, and how whilst there was some manoeuvrability in how the technical Code requirements could be met, WHA felt very much *"… bound by the Code… Certainly meeting Code [level six] was… the main driving force in this development"*. Influenced by previous retrofit experiences, Dave was sceptical of what he felt to be the prescriptive nature of CSH and frustrated by having to pursue a standardised vision of low-energy housing and definition of carbon neutrality. He described how *"We've been pushed down the Code route as a way of*

[8] The energy efficiency requirements of the UK Building Regulations are set out in Part L of Schedule 1 to the Building Regulations and in a number of specific building regulations (Planning Portal, 2014).

defining sustainability… because that's… the way the Government is going and certainly the way the Homes and Communities Agency (HCA) is going". At the same time, he questioned the feasibility of obtaining accreditation to Code level six, suggesting, *"you have this magical idea of creating homes which are carbon free, carbon neutral"*. Exacerbating this conflict, Dave explained how BDC had specified a particular design brief that aimed *"to produce a Code six scheme in a suburban village environment which involved fairly traditional construction and layout"*. He explained how this approach was intended to provide a locally acceptable aesthetic and enable learning from the 'one-off experiment' that could be applied by mainstream industry;

> *"[The Council] wanted [Trinity Close] to be suburban village housing rather than sort of mounds of earth buried in the ground with people living in them and having a very large glass frontage… they're fantastic, but they don't necessarily fit into commercial mass-scale housing"*.

Whilst WHA had previously been involved with a CSH level five development, Trinity Close provided Dave's first opportunity to manage a carbon-neutral housing scheme. As such, given a deficiency of in-house technical expertise, WHA worked closely with DJH and relied on external advisers to determine the build specification. Dave described this process as fluid, whilst ultimately dictated by Code requirements; *"We'd never done a Code six, and the contractor had never done a Code six, we were both, to be honest, learning… It was a case of saying 'we've looked at the options… and actually the best combination to achieve Code six, to get those credits, [is] to select this [technical specification]"*.

Whilst contemplating various technological options, WHA's options were ultimately restricted to a particular technical route. As Dave explained, *"[o]bviously super-insulation, so the fabric-first approach is there, and that gets you to Code four. But to then get [Trinity Close] to a Code five or six, you're looking at photo-voltaic panels and grey-water recycling"*. In addition to meeting Code requirements, Dave described how WHA were also faced with the challenge of ensuring cost-effective long-term maintenance and repair of the development; *"After year two, if it's a private house, the developer walks away, he says 'I'm done'. But for… housing associations, you have to maintain those properties for 20, 40, 60 years… For us the dream development is one that has no maintenance costs."*

As such, he intimated how even prior to Trinity Close being commissioned, WHA favoured a highly insulated, 'fabric-first only' construction approach;

"Renewable add-ons have a shelf-life of 15, 20 years and then they have to be replaced. Concentrating on… the u-values of the building [gives] a 90 year life of the property… So for us, you know, renewable add-ons were needed in this case to get to Code six, but… our preference is to focus on a 'fabric-first' approach to new build as a way of creating sustainable housing for the future".

A further requirement, stipulated by the funder DCLG, was that real-time building electricity performance monitoring should occur to measure electricity generation and consumption, appraise technological performance, and take forward learning to future builds. Dave stated that; *"quite rightly you don't just build a Code six and walk away. The idea was to monitor [technical performance] and…[householders'] use [of the properties] to get results… Hopefully we'll learn… about how we [can] build sustainable housing in the future"*.

Whilst Dave was adamant that the project *"was about creating a Code six carbon neutral [housing development], it wasn't about giving people free or cheap electricity"*, he was aware that some tenants experienced fuel poverty[9] in their previous homes and he did not want this to continue at Trinity Close. Indeed he explained how WHA was keen for tenants to save on their electricity bills where possible. This meant objectively appraising the low-energy technologies proposed by the housing contractor DJH; *"Some of the renewable technology [wouldn't] benefit tenants…as much as we'd like or where it would actually matter to residents, which is in their pockets"*. Dave also wanted to ensure that potentially vulnerable tenants were not overwhelmed by the technologies installed in their homes. He stated, *"what's good for tenants…obviously not all low carbon technologies are… their principle aim is not always to [work at a] cheaper cost…[and] some low-energy technologies are extremely complicated to use"*. To this end, Dave felt there was a case for not actively involving residents in the running of their low-energy homes and designing properties so that householders' everyday lives proceeded in a familiar and non-disruptive manner; *"It was also about designing [the scheme] in a way that had least impact on residents… trying to make [the design] fairly simple and [providing] a fairly traditional looking system"*. As such, he downplayed the technical specification of the scheme, suggesting, *"The technology in there isn't particularly mind-blowing is it? It's maybe slightly quirky having to deal with the thermostats and the under-floor heating, but it's not particularly… innovative"*.

[9] Fuel poverty: Being unable to afford to adequate heating. A household is fuel poor if a) income is below the poverty line and b) energy costs are higher than typical for household type (DECC, 2013a:11).

Dave described how residents were provided with an induction to their new homes in accordance with the discrete nature of the low-energy technologies (for example, residents were told that the mechanical ventilation and heat recovery (MVHR) system would operate automatically, but could be manually boosted using a pull switch in the bathroom and kitchen). He explained that WHA situated themselves as a trusted external advisor acting at distance, rather than a micro-manager of every households' daily energy budget, *"[w]e're not Big Brother, we don't tell people how to live their lives. As social landlords we provide people with a home and they can live in it and consume it as they wish really"*. This position manifested itself in the brief question and answer session provided by the TCSG for prospective residents prior to handover. Similarly, upon moving-in, key advice was provided to the tenants in relation to any demanding aspects of the house. As Dave explained, *"[w]e left sheets with people, explaining how to use [the thermostatic controls of the heating system], but we don't want to interfere in peoples' lives too much…"*.

Ultimately, the adopted tenant engagement approach was attentive to the needs of particular householders, *"It's a case of see how it goes for that individual in that property… If it's too hot, yes open windows"*. Whilst adopting a fairly hands-off management approach, WHA provided energy-efficiency advice to householders upon their moving in, which was followed up by an introduction to the IHD monitor delivered by Adapt. In addition, WHA encouraged residents to shift the timings of their demand for energy services to capitalise on 'free' solar generated electricity. As explained by a WHA neighbourhood officer, *"When I was in the properties with Dave, he was advising people that if it's a nice sunny day, you're making lots of electricity… You can't do everything at once, but you would be able to run your washing machine and when that was finished, use your cooker, to make best use of [the generated electricity]"* (PR.12).

Dave described how he anticipated residents would differ in their willingness to engage with the low-energy credentials of their new properties and to use the installed technologies as intended, restating how the main hook for tenant involvement would be reducing their fuel bills. He explained how Adapt was commissioned by BDC to use the electricity monitoring data to feedback to residents after the first twelve months of tenancy; *"[t]he point is really that we can, hopefully [by providing feedback], help some people to reduce their electricity consumption because they want to save money"*. Summing up, the interview concluded with Dave describing what he considered success at Trinity Close would constitute; *"[s]uccess will be, if it is a zero carbon scheme, if it meets the energy* *production as well as the energy consumption targets over a three year period… But really success is if people want to live there, and enjoy living there, and [there is] a stable community*".

As a senior figure in WHA, working in accordance with original planning consent for a CSH level three development, Dave had to balance BDC's aspirations for a traditional-looking low-energy housing scheme against national targets for developing more affordable homes, and the physical and infrastructural constraints of the site. In managing the development he also had to weigh up issues of quality, cost, longevity and tenant comfort. As WHA's first CSH level six scheme Dave saw the initiative as a potential learning opportunity, for which partnership working and building electricity performance monitoring were essential. From an early stage of the build process however, Dave was sceptical with the prescriptive nature of the CSH and questioned the feasibility of meeting carbon neutrality stipulations without disrupting tenants' everyday lives.

4.4. Tom, Senior Management - Dove Jeffery Homes (DJH)

When I met with Tom, a senior figure within DJH, he explained how their architectural practice uniquely situates the firm within the housing market; *"[w]e're very happy to get involved very early on in a scheme and put a lot of research and development work into [designing projects]"*. As such, the family company actively pursued housing projects enabling technical investigation and experimentation. The company's mission statement read as expected from housing providers striving to gain market advantage, stating how DJH; *"are continually looking to improve what we do, we strive to ensure best practice, cost effectiveness and sustainable development in all our operations, processes and practices"* (P10). Despite these ubiquitous corporate promises, discussions with the TCSG demonstrated confidence in the quality of the contractor's practices. For instance, an interviewee from BDC endorsed the company; *"I would say without DJH, the scheme wouldn't be as good as it is…they're very passionate… They go back quite regularly to visit [Trinity Close]"* (PR1). My observations of DJH practices on-site aligned with this statement.

Prior to Trinity Close, DJH's construction practices had been nudged in more 'sustainable' directions, by design criteria specified by statutory requirements of lower levels of CSH. Consequently, some familiarity of more sustainable house-building had developed as part of the performance of individual and company practices. Tom, stated, *"Generally speaking we do Code three, Code four… We've been building to the Code for seven or eight years and it's sort of a doddle really"*. Interviewing Tom at a Code level three housing construction site in Suffolk 18 months after construction of Trinity Close, my observations supported Tom's statement. DJH employees appeared to work together adeptly, drawing on skills and knowledge built up through repeated performances of particular techniques and actions. I also observed how Tom took a hands-on interest in managing the project and guiding his construction team through the build process. Whilst familiar with lower levels of the Code, Trinity Close presented the first opportunity for DJH to embark on a development with carbon neutral ambitions.

Initially, it proved problematic to converse with Tom, as I had to contend with our interview being postponed twice. Apologising, Tom explained how this was indicative of his hectic schedule. He explained how his role includes; winning new work, liaising with potential developers, researching and commissioning new materials and technologies, keeping abreast of legislative requirements, organising training for his construction team, overseeing the planning, architectural design and costing of schemes, obtaining planning permission, overseeing the construction process, and managing the after-care and defects service. It struck me that Tom's curiosity drive and determination had invariably influenced DJH's involvement with Trinity Close. He explained how; *"I loved the technical challenge of [Trinity Close]. It was… an existing Code three design scheme… there [were] massive issues with the layout and how things worked… and remits with regards to what things we could and couldn't do… It was just a very, very difficult scheme"*.

Tom described how despite risks associated with DJH's involvement in a 'one-off experiment', he was keen to be involved to enable modified practices to be tried and tested. He explained, *"Trinity Close was our first and only Code six to date… they're few and far between… when we did Trinity, it pretty much covered 30 percent of the Code sixes across the country"*. Whilst DJH's involvement would likely result in variable practice performances and outcomes, Tom hoped the trial would allow learning that could inform future housing construction. He stated, *"Nobody really knew what the outcomes were going to be. It was a learning experience for all involved… that was the point of it… [Were] we nervous about building Trinity Close? No because it was designed to be built as a trial scheme"*. As our discussion progressed, it became apparent that Tom's personal background had shaped his understandings of carbon neutral housing. He revealed that his interest in low-energy housing construction had first developed in the 1970s, *"I spent a lot of years in… Scandinavia and they know how to live neutrally… We didn't know anything about the Code back then. We didn't know anything about thermally enhanced living. I just found it very technical and very clean-cut the way they live."*

When I explored the ambitions behind DJH's involvement in Trinity Close further three key reasons for the firm's involvement were revealed. First, Tom's 'go-getter' personality and life experiences meant that he sought out involvement in the exemplar scheme. Second, a carbon-neutral build presented the opportunity for DJH to be a fore-runner in trialling more stringent Code levels, which Tom considered would be the trajectory for the mainstream housing construction industry. DJH therefore felt obliged to contribute to the industrial knowledge base: *"[w]e need to build carbon neutral homes. We need do it because we need to understand them. Well we've done our part towards that."* Third, DJH sought to showcase adoption of innovative materials, techniques and technologies as a unique selling point to separate their practices from other competitors. As such, their marketing material states how; *"[we] have been very excited by the opportunity to design and construct our first Code for Sustainable Homes level six rated development. We will continue to apply new and evolving technologies to our developments to help facilitate a greener lifestyle for our customers"* (P10).

Spearheaded by Tom and working within the constraints of the site, the DJH architectural team researched low-energy technologies for Trinity Close. They quickly encountered technical challenges, for instance, as Tom explained, the relative nascence of the low-energy housing market which limited available product information; *"[t]he biggest thing we found was ignorance in the market place, the ignorance of consultants. They'd be coming to you saying, "We've got this [product]". "Well what does it do?" "Oh I don't know… It gives you Code points""*. DJH was also acutely aware that the housing tenants had not deliberately sought to live in low-energy homes, and might not have a skill-set or interest that aligned with an energy-saving lifestyle, *"[w]e had the issue of tenure… lifestyle change, and trying to get people to live in Code six properties that were not, shall we say, eco-buffs"*. These considerations meant that DJH adopted a design approach that *"[tried] to simplify the technology so that there wasn't lots of gadgetry and things that were uncomfortable and not of the norm"*. Tom explained how the design had to appease different organisational objectives and *"work… for everybody"*. Importantly the design also had to adhere to the original, more stringent CSH level six technical specification[10]. He proudly explained how, *"We were working off the old Code, not the new Code, which is almost a Code five kind of project"*.

[10] Zero-carbon includes only the emissions covered by Building Regulations (heating, fixed lighting, hot water and building services). Emissions from cooking or from plug-in appliances are not addressed of this policy (P11, P12). In addition in 2011, the new concept of 'Allowable Solutions' was introduced to the CSH, which allowed for some carbon emissions not to be abated on site (see Chapter 1 for more details).

Tom described how initially DJH asked an energy consultancy to appraise potential housing designs for Trinity Close, but believing that their suggested routes forward did not balance the project's needs, it was decided to bring the architectural process in-house; *"[the consultancy] came up with four or five different options, but they were all so technical and so cutting edge, that they were just too far fetched… they weren't trying to cross their [ambitions] over with everybody else's issues"*. Ultimately, in terms of technical specification, DJH prioritised the following approach;

> *"[w]e moved forward with… a fabric-led solution that was a Passive house*[11] *product – windows, doors, external walls [were] structural insulated panels with extra insulation. I think the u values*[12] *were all low, sub one. Floor insulation, we had a thermal beta block floor, so thermal insulation, obviously that's the most important thing to deal with. Air tightness*[13]*, obviously as soon as you put the air tightness solution together, you've got to get MVHR [mechanical ventilation heat recovery]*[14] *because you've got ventilation issues with the air tightness… We were governed by the fact that there was no gas in the area [so] we then looked at having air source heat pumps [ASHPs]*[15]*. Well they're not a renewable technology… under the Code, so we needed to basically power those, or shall we say, offset the carbon of those, by using the PV [solar photovoltaic] panels*[16]*, which given the locations and facings of the buildings*[17] *were quite high in quantity."*

Additional low-energy thermal measures included triple glazing and under-floor heating with thermostatic controls, to provide increased control over room

[11] Passive house: A building for which thermal comfort can be achieved solely by post-heating or post-cooling of the fresh air mass, achieving sufficient indoor air quality conditions without the additional recirculation of air (BRE, 2014).
[12] u values: A measure of heat loss. It is expressed in W/m²k and shows the amount of heat lost in watts (W) per square meter of material when the temperature (k) outside is at least one degree lower. The lower the u value, the better the insulation provided by the material.
[13] Air tightness: The resistance of the building envelope to inward or outward air leakage. Excessive air leakage results in increased energy consumption and a draughty, cold building (Planning Portal, 2014).
[14] Mechanical ventilation and heat recovery (MVHR) system: An energy recovery ventilation system using a heat recovery ventilator, heat exchanger, air exchanger, or air-to-air heat exchanger which employs a counter-current heat exchange between inbound and outbound air flow. MVRV provides fresh air and improved climate control, while also saving energy by reducing heating (and cooling) requirements.
[15] Air source heat pump (ASHP): System that transfers heat from outside air to inside a building. An ASHP uses a refrigerant system involving a compressor and a condenser to absorb heat at one place and release it at another. They are sometimes called "reverse-cycle air conditioners". Heat pumps need electricity to run (Energy Saving Trust, 2014).
[16] Solar photovoltaic system: Employs solar panels composed of a number of solar cells to convert energy from the sun into direct current electricity using semiconducting materials. These cells do not require direct sunlight to work; they can still generate some electricity on a cloudy day. The cells convert the sunlight into electricity, which can be used to run household appliances and lighting.
[17] South facing roofs receive more radiation throughout the year and will produce the maximum energy output. The ideal roof will have an orientation 90° south. However a south-east and south-west orientated roof will still produce high solar yields.

temperatures. Tom described how each property was provided with a 'home-user manual' and a health and safety file produced by DJH for WHA, which provided operating instructions and contact details should the tenants experience technical difficulties. He explained that DJH delivered a demonstration to WHA's estates team that would provide sufficient information and technical skills to enable a basic level of technological repair and maintenance. Within the first week following hand-over, Tom described how he and Dave (from WHA) delivered an induction to the residents explaining how domestic energy management could be optimised. Part of this overview involved setting the heating thermostatic controls, which were initially programmed to operate between the technically optimum temperatures of 16°C at night, and 21°C degrees during the daytime. To maximise thermal insulation, tenants were advised that *"windows were supposed to be shut, the properties were meant to rely upon the MVHR… [and] doors [were] meant to be shut…"*. In Tom's opinion *"the homes [were] constructed to be used in a particular way [and] that way [was] explained to the residents [and] it [was] explained to the Housing Association"*. As such, DJH claimed that maximising energy performance at Trinity Close relied on educating the property managers and tenants to ensure correct interactions with the installed low-energy technologies.

Prior to the Feed-in Tariff[18] being reduced for solar PV electricity generation in August 2012, Tom described how BDC had proposed financial incentives to encourage individual residents to use less energy in their homes; *"There was mention of least electricity use bonuses… Personally, I don't agree with that, because if you want to [manage energy use within the home], you'll do it, and if you don't want to do it, you won't"*. Instead, he described how, with DCLG's backing, a smart metering system was installed in each property, capable of collecting real-time electricity monitoring data at an individual circuit level and for key appliances that tenants fitted with a 'plug bug'. Data were collated by the technology developer Green Energy Options (GEO) and Adapt was commissioned to analyse the electricity monitoring results. Households were provided with an in-home-display (IHD) unit (TRIO[19] developed by GEO) to support this system. Tom explained how he believed that the installation of a smart

[18] The Feed-in Tariffs (FITs) scheme aims to encourage the deployment of small-scale low carbon electricity generation. Between the start of the scheme in April 2010 and 3 June 2011 over 40,000 FIT installations were accredited, the vast majority at household level. The 2010 Spending Review made clear that the FITs scheme was to operate within spending parameters, and stipulated the need to make 10% (£40 million) savings to the scheme in 2014-15 compared with original projections (DECC, 2011).

[19] The TRIO In-Home Display (IHD) (since discontinued & TRIO II released) is web-enabled colour display that supports multiple Smart Energy Meters as well as Smart Home plugs and sensors, and is designed for smart-meter roll-outs where consumers want to take more control of their energy consumption (Green Energy Options, 2012).

meter in each property provided tenants the opportunity to better manage their energy usage; *"It doesn't hurt to install a smart meter… Our duty of care is that if we [can] provide something that could help [the tenants in managing their energy use], then we will do that."* As such, DJH envisaged the smart metering and IHD system would prompt less energy-intensive household practices.

Whilst neither Tom nor DJH had been previously exposed to the CSH level six standard, Trinity Close provided a learning opportunity, made possible by the scheme's explicit demonstration site status, which conveyed market protection. Although DJH employees had familiarity with CSH level three and four build techniques, Tom believed Trinity Close offered the chance to pioneer innovative building materials, technologies and techniques. He considered this would set the firm apart from similar housing contractors, and would contribute to the wider industry knowledge base. Faced with a nascent low-energy technology market, DJH invested much consideration into the selection of low-energy materials and technologies that would meet CSH level six requirements, TCSG's aspirations, and would minimally interfere with householders' daily lives. In so much as the residents were provided with a home user manual, given specific instructions on how to optimise the thermal and energy-efficient performance of their homes, and received a hands-on demonstration to help reduce electricity bills, discussion with Tom confirmed DJH's commitment to developing a scheme that worked for the residents. Ultimately however, Tom stressed that for DJH, *"Our goal was not to turn around and make a perfect development. It was to do a Code six scheme… [within set] parameters…"*.

4.5. Brian, Programme Manager - Adapt Commercial Limited (Adapt)

When I spoke with Brian and his colleague at Adapt's newly refurbished offices, he began by describing the consultancy's technical expertise within the built environment, which he explained was tailored to, *"looking at using renewables… quantifying carbon reduction and using metrics and monitoring"*. Recalling how Adapt was involved with the Rackheath eco-community project from its inception, Brian described how aspirations for the eco-town proposal and the subsequent design of the Trinity Close exemplar constantly evolved. Early on Adapt had sought to gain local community buy-in for the Rackheath eco-town which involved; completing a carbon footprint for the village, delivering an energy-based retrofit scheme (to bring 420 existing Rackheath homes -

included as part of the eco-community's 5,000 properties - up to Energy Performance Certificate level C), initiating the Rackheath community trust (P13), assisting with the Rackheath eco-community proposal (for which up to three consultants were seconded to BDC), and interpreting DCLG's eco-town requirements at a local level.

Despite having to revise Adapt's expectations in terms of scope of involvement following stagnation of the Rackheath eco-community, Brian explained how Adapt was excited to embark upon the Trinity Close scheme, albeit comprising twelve units instead of 5,000 properties. He saw the exemplar scheme as a unique opportunity to show-case CSH level six design and to appraise the benefits of low-energy technologies and energy monitoring equipment, which would not only bolster Adapt's expertise, but which could potentially have threshold influence across the mainstream housing construction industry. As he explained; *"When [pursuit of] Code [level] six was approved [at Trinity Close] there was eco-towns funding available and it was great to have such a demonstration site"*.

Whilst Adapt had initial involvement in researching carbon management strategies for the Rackheath eco-community, at Trinity Close their remit revolved more around the behavioural change of householders. We commenced our discussion however, by considering the materials and technologies necessary for the low-energy build, and as such, Brian revealed his support for a highly insulated, fabric-first only approach. Alongside recognising the importance of insulating existing 'thermally leaky' UK housing stock, Brian suggested that he favoured *"…[A] fabric first approach to building, and making things air tight… And helping people to understand that if you use [low-energy buildings] in the right way, then you consume less energy and it costs you less…"*. It soon became clear that Brian thought that low-energy housing was a matter of ensuring an energy-efficient build, but that any technical improvements could not be isolated from household behaviour post-occupancy. He was adamant that delivery of a 'technical-fix' alone could not be relied on to sustain a low-energy community at Trinity Close, or further afield. As he described;

> *"… I don't think we will meet our carbon reduction targets through technology alone… there will have to be some shift in behaviour. But it's not so well understood... It's difficult to implement and it takes time… You can have low carbon homes but you also need to educate the people inside them to behave in a low-energy way…"*.

According to Brian, resident engagement could adopt two strategies. On one side, in line with his preference for a fabric-first build approach, householders could be minimally involved with managing everyday energy demand at home, and rely on insulation to deliver energy-efficiency. He suggested that this strategy was advantageous as it prevented the 'misuse' of low-energy technologies and monitoring equipment. He explained how, based on TCSG's previous experiences, installed equipment was made as user-friendly as possible so as not to compromise householders' lifestyles, *"[t]here was a real attempt [at Trinity Close]… to provide as few buttons as possible to people so that they [couldn't] turn things on and off and mess with the technology."* Looking to the future, Brian suggested that the complete back-grounding of low-energy technologies would form the pinnacle of low-energy housing, but that this would require substantial technological development; *"[t]he ideal solution is that it all happens in the background…The question is will the technology catch up fast enough?"*

Whilst striving for the passive engagement of residents in energy demand management, Brian explained that this was not possible for Trinity Close, given operational requirements of the installed low-energy technologies. He stated that it was imperative therefore to ensure that tenants understood how to correctly interact with their new home. Householders were provided with the opportunity to ask questions about their low-energy homes at an Adapt presentation prior to hand-over. They were also provided with an induction to their home on move-in, focusing on introducing the monitoring equipment, the thermostatic control panel and heating system, and the operation of the MVHR system and a super-sealed home. Although Brian believed the ideal solution for low-energy housing was the passive-engagement of householders in managing their energy demand, he acknowledged that, in some instances, and for some residents, more active engagement would be demanded. He felt that this desire would be most acutely felt in relation to setting the temperature at home; *"…equally people want to be in control of the environment around them."* For this reason, he explained that it was imperative to instil understandings of the benefits and practicalities of domestic energy-efficiency.

In addition to providing householders with appropriate technical skills, Brian discussed the importance of implanting particular meanings around energy-efficient lifestyles, and encouraging residents to abandon unsustainable habits. He explained how one way to develop these understandings was through emphasising the financial benefits of a low-energy lifestyle. To make decisions about their energy usage, Brian believed that, households should be informed about their energy consumption, how this usage translated into household financial outgoings, and how much could be saved on the monthly electricity bill. He also believed that low-energy housing, particularly social housing, would receive greater political and commercial support with demonstrable household economic benefits;

> *"As much as people with an environmental slant would like to think that people will… cut carbon for the right reasons, in the end it's going to come down to costs… If the residents can see reduced bills, they'll be far more likely to support these kinds of developments… And so will the housing associations, and so will the house builders".*

When discussing routes for behavioural change, Brian remembered an early idea to use *"personal carbon trading"* as part of the Rackheath eco-community proposal. As he recalled; *"DCLG were really keen on [personal carbon trading]. So we [looked at the possibilities of]… collect[ing] data on individual residents or a households' personal carbon footprint [and having]… a management fee that would be variable depending on…carbon performance".* Ideas around the use of electricity monitoring, measurement and incentives to drive energy demand reduction, therefore existed from the outset of Trinity Close.

BDC commissioned Green Energy Options (GEO) to provide each Trinity Close home with an IHD to provide access to real-time monitoring data on household electricity consumption and generation. Brian explained that as well as using the results to undertake technological appraisal, it was intended to use these data to deliver tailored energy feedback for each household after twelve months of residency. He believed this energy feedback would provide *"an opportunity… to really encourage behaviour change and to inform people about their energy use".* Simultaneously, he recognised the proposed smart metering roll-out across the UK (DECC, 2011) as a potentially invasive intervention intended to provide energy suppliers with a controllable way of balancing energy supply and demand; *"a cynic might say 'well that's just something that will be used for the billing side of things but [it] won't actually engage with the households'".*

Brian considered that Adapt also had a responsibility to help householders optimise the timings of their appliance use to best capitalise on 'free electricity' generated by the photovoltaic panels. He suggested that, in line with the national smart metering agenda, Adapt needed to; *"[do] what we can to ensure that people understand how to use the energy [that the photovoltaic panels generate] effectively and [explain] the technologies that they need to enable them to do that."* He described how the demand-side response[20] concept extended outside of the household domain to the balancing of peak demand levels experienced by the National Grid; *"Can you prompt people to use energy at certain times of the day and manage their demand in a way that they can get the most out of the technologies that they've got? And on a bigger scale it's about getting the best out of the [National] Grid and managing expectations."*

Considering the practicalities of adjusting routines however, Brian described the difficulties that householders might experience in breaking long-established habits; *"[It's a question of when] to make best use of your energy… actually you do want [appliances] on during the day"*. Whilst advocating the rational use of feedback, and suggesting that new understandings could be prompted for residents' lifestyles to be more sustainable (in terms of less energy-intensive), Brian acknowledged that problems might be associated with such an approach. He recognised that household practices are often deeply ingrained and hard to change, and that personal preferences might override knowledge that patterns of behaviour could be performed in more sustainable and cost-effective ways.

For Adapt, involvement with Trinity Close developed out of work on the Rackheath eco-community proposal. The consultancy was subsequently contracted to first undertake a technical energy performance appraisal of the twelve CSH level six units, aimed at informing the selection of low carbon technologies in subsequent project phases, and second, provide the behavioural change element of the project. Brian understood electricity performance monitoring, analysis and provision of feedback as central to addressing both of these challenges. He was keen to appraise the low-energy technologies at the demonstration site, the results of which he hoped would instigate positive changes in mainstream housing construction. For Brian, ideally new homes would conform to fabric first principles, and residents would passively manage their energy demand. However, given the CSH level six requirements at Trinity Close, education was prioritised to encourage residents' correct operation of equipment, and promote awareness of the financial benefits of saving energy and shifting timings of

[20] Electricity demand-side response (DSR) is when consumers adjust the amount of electricity they use at particular times in response to a signal (OFGEM, 2014)

energy use. It was believed that this education would extend outside of the home to gradually modify societal norms and expectations.

4.6. Households 1-12 Trinity Close: WHA affordable housing tenants

Without exception, residents of the twelve Trinity Close households moved from within the Broadland district to their new homes due to a housing need and vulnerability, as opposed to identifying housing with low-energy credentials. Relocation was prompted by the need to improve existing housing circumstances (for instance to, minimise damp and cold conditions, ameliorate health requirements, increase comfort, gain space, and improve child-care arrangements). The majority of tenants heard about Trinity Close through word-of-mouth, or from contact by BDC in response to their position on the housing register. Indeed, one tenant had even campaigned against the Rackheath eco-community and proposed local housing development (H3).

Half the Trinity Close households previously lived in damp or energy-inefficient properties and were exposed to energy-inefficient building materials including solid walls, minimal insulation, single pane glazing and out-dated heating equipment. Such living conditions, forced these householders to develop particular routines and to hone skills for thermal comfort, such as wearing additional clothing layers or clustering in one room of the house at night to keep warm. Prior to moving to Trinity Close, the majority of householders (7/12) used old and second-hand electrical appliances that were, *"just what they ended up with"* (H6), and which were likely to be energy-inefficient.

Prior to the move, 5/12 householders acknowledged that they prioritised the timings, demands and cultural expectations of everyday life over environmental concerns or financial budgeting. Furthermore almost all households (10/12) claimed that energy or environment related decisions did not commonly feature in their everyday lives, and were unlikely to affect domesticity at Trinity Close. Despite financial constraints, only 2/12 households took purposeful action to save energy at home, for example by capitalising on lower electricity tariffs at night, switching off appliances running on stand-by, or turning down thermostatic controls. 5/12 households previously lived in shared accommodation and had not been responsible for paying utility bills. As a result they felt disconnected from the financial and energy implications of household doings. Some tenants were excited about potentially saving money on household electricity bills at Trinity Close; *"I'd already read* *about the environmental features that the homes were going to have… that definitely made me excited because I… very much try to keep my bills as low as possible"* (H4). Another family discussed how they planned to upgrade their electrical appliances at Trinity Close; *"What's the point of having old products that are like Cs and Ds that aren't going to run efficiently because that ain't going to go with the [eco-] house"* (H12). However, most householders planned to simply transport their existing lifestyles, routines and conventions to their new homes, without significant modification.

Despite community engagement activities, some residents were not aware that Trinity Close was a low-energy housing development until close to the hand-over date; *"[w]e didn't find out what was involved until we had to go for a meeting at Broadland Business Park"* (H9). This orientation presentation provided an overview of the low-energy technologies and continuous electricity monitoring arrangements that formed part of the conditions of the social housing tenancy. For some households, a lack of familiarity with the described technical measures led to them feeling overwhelmed. For instance, *"You could ask questions but we just sort of sat there and listened and thought 'Oh no!'"* (H6). Other householders, inspired by the description of their new properties, felt privileged and excited to be moving to Trinity Close, *"I felt really lucky that I was going to be in a brand new place … and for it to have all these features is a real bonus…for it to have all this environmentally friendly stuff in…. Yeah, I felt really excited"* (H3).

Section 4.1 describes how prior to the move, very few tenants described themselves as energy conscious or green-minded. Given that in 2008, only 18% of the UK public were categorised as 'positive greens' - citizens that are highly engaged and willing to act towards environmental issues - (DEFRA, 2008), if an attempt was made to segment the Trinity Close sample, the households in this study would be considered no less representative of the national population. Furthermore, many of the individuals and families in this research, had previously lived in 'leaky' energy-inefficient homes, and did not have access to, or prioritise purchase of, energy-efficient electrical appliances. Whilst the minority of householders actively managed their routines to minimise electricity consumption, for the most part, the tenants were not 'energy conscious' and rarely considered the financial or environmental implications of their everyday activities. For most tenants, Trinity Close presented a long-awaited answer to a housing dilemma, as opposed to the pursuit of a low-energy utopia. Whilst some residents bought-in to the green ethos of the development and found the opportunity to optimise their carbon performance exciting, the vast majority wanted to simply relocate their existing lifestyles to their new abode without interruption.

4.7. Summary: Planned (non)-interventions in housing practices at Trinity Close

This chapter has adopted a distinct approach whereby technologies and behaviours have been understood as intertwined and embedded in social practice. This contrasts with dominant, but reductive, research approaches used to study low-energy housing, which either examine the design decisions lying behind particular energy-efficient materials and technologies, or interrogate the values and choices underpinning individuals' energy-consuming behaviours. Instead, introducing the key actors at Trinity Close, their everyday contextual positioning, and their expectations and assumptions for the housing intervention, has produced more nuanced insights into the diverse everyday doings occurring at the Rackheath CSH level six site. These activities, built up over many years, and made up of constituent meanings, assumptions and understandings, particular skills and abilities, and materials, tools, and physical infrastructures, combined to represent the practices of the six principal actors involved with Trinity Close.

The professional practitioners' vision of change broadly coalesced around a techno-rational paradigm whereby it was agreed that installation of energy-efficient materials and renewable technologies would reduce the overall energy demand of the Trinity Close housing development. Further the TCSG relied on models and assessments conducted by DJH, and WHA that predicted that the selected design measures would deliver carbon-neutrality across the twelve housing units. This revised design and construction was intended to deliver required energy reductions predominantly without the active involvement of tenants; a view to which many of the residents also subscribed. To the extent that residents were considered, it was anticipated that particularly motivated individuals could be encouraged to monitor feedback on their domestic electricity usage, and would be incentivised to revise their consumption levels by reduced utility bills.

At the same time, each of the six emblematic actors put forward subtly different aims and objectives for the Trinity Close initiative. For instance, the Minister for Housing and Local Government wanted to demonstrate the economic, social and environmental benefits of building to CSH level six. Roger from BDC sought to determine a sustainable growth strategy for Broadland district, whilst Dave from WHA aimed to determine a suitable design for affordable housing that was cost-effective, easy to maintain and would deliver comfort for residents. Tom from DJH saw involvement in Trinity Close as an opportunity to set the housing construction company apart from their peers. Brian from Adapt sought to trial highly energy-efficient design and construction methods alongside engaging household residents in electricity demand management using monitoring and feedback techniques. Prospective residents to Trinity Close hoped that their move would not disrupt their daily routines, and would ensure comfortable and affordable living.

As such, rather than Trinity Close being a project in which all involved parties were unified, and where there was consensus on the implementation approach, the initiative was contested from its outset. Although some extended rationality approaches to understanding domestic energy consumption do give space to context (see Chapter 2), this finding supports the understanding that techno-rational approaches are not neutral or context independent as is often claimed. Rather, the aims, ambitions and objectives of the initiative were conditioned by the dominant practices in which the Trinity Close principal stakeholders engaged. That the involved actors' activities underpinning the Trinity Close initiative were not abstract, but determined by real life contexts, supports the need to employ a SPT-based methodological approach. It also raises the question of what these contextualised understandings and particular ways of doing mean for re-establishing housing practices in less energy-intensive directions.

In practice terms, the aim of implementing CSH level six at Trinity Close was to enhance the environmental sustainability of social housing infrastructure by inserting low-energy technologies and energy-efficient building materials into the everyday practices of housing professionals. As such, the practitioners researched, installed, operated and maintained new building fabric and equipment intended to deliver codified energy-efficient homes. These practitioners required new ‘competences’ delivered through training courses or learnt ‘on the job’. They also had to embrace new ‘meanings’ around housing, such as recognition that the respective developments were built to achieve carbon neutrality, rather than economic profitability.

Whilst the CSH and Trinity Close initiative sought to intervene in the professional practices of housing construction, simultaneously the development sought to keep household practices largely intact (i.e. non-intervention in household practice) (Macrorie *et al.*, 2014). It was assumed that only particularly motivated householders would reflect on the energy implications of their daily domestic routines, and that residents' everyday practices would proceed as normal around the newly installed technologies. In addition, Trinity Close was designed to look as 'normal' as possible so as not to challenge cultural expectations around domestic living and energy.

Applying a SPT framework through this introductory empirical analysis has revealed the techno-rational approach of the initiative as too narrow, given that it primarily relied on technical-fixes, and if considered at all, individuals' actions were assumed to be rational and malleable by information and/ or incentives. This understanding of change fails to attend to how housing practices are mediated through societal culture, formal institutions, politics, economic structures, as well as by materials and infrastructures. Even at this early stage of planning the Trinity Close initiative, it is possible to suggest that SPT therefore recasts the intervention (and the CSH standard informing the initiative) as radical in some (material) parts, but not in others (e.g. failing to challenge expectations around what energy is used for in daily domestic life). This SPT based analysis also raises questions of whether it is possible to intervene in certain elements of practice (e.g. technical/ building changes), without disrupting the practice as a whole.

This chapter has demonstrated how a wide spectrum of different sets of actors – ranging from national government, to local housing associations, to private consultancies, technology manufacturers and social housing tenants – were involved in shaping the emergence and maintenance of low-energy housing-related practices at Trinity Close. The assumptions, approaches and existing routines of the TCSG, in particular, have been shown as crucial in determining the design and implementation of the Trinity Close scheme. SPT has thus far predominantly focused on practices within the home and their consequences for resource demand (see Chapter 2), however this chapter has highlighted that these practices cannot be fully understood without an appreciation of the other diverse practices with which they are entwined. This shifts the analytical focus to include policy, public sector and commercial housing practices, which are just as crucial, if not more important, than understanding how energy is embroiled in domestic routines (Macrorie *et al.*, 2014a).

Finally, the TCSG believed that the CSH standard and their governing decisions and actions, were 'outside of' and acted upon professional and domestic housing practices (even if attempting to maintain the *status quo*). These professional practitioners envisioned that implementing codified housing design would straightforwardly lead to carbon-neutral behaviours and outcomes, thereby creating a carbon-neutral development. In contrast, SPT suggests that actors and their practices cannot be isolated, and that practitioners cannot be separated from the context within which they operate because context emerges from practice. This raises the question of whether (as often assumed in policy documents and much academic work) it is possible to govern practices from an external position, without invariably becoming implicated in those practices.

These claims and questions will be further explored in the following two empirical chapters of this thesis.

Chapter 5. Appraising low-energy interventions in housing-related practices: Outcomes of the Trinity Close initiative

The techno-rational approach informing implementation of Trinity Close, described in Chapter 4, relied on inserting energy-efficient technologies and materials into the design and construction practices of professional practitioners, in order to shift their outcomes in less energy-intensive directions. At the same time, the Trinity Close Steering Group (TCSG) sought not to disrupt everyday domestic life by keeping household practices largely intact (i.e. non-intervention in household practice). This dual strategy was underpinned by an institutional confidence in the Code for Sustainable Homes (CSH) standard, the implementation of which, it was envisioned would appropriately modify environmentally unsustainable professional and domestic housing practices. This chapter will appraise whether and how, if at all, these aspirations were met. Alongside determining whether the initiative was successful according to the terms of the TCSG and their funders, this chapter will investigate whether it was possible for the TCSG to intervene in some parts of housing practices and not others. It will also investigate whether the initiative organisers could act outside of the practices in which they sought to intervene.

To begin, the chapter provides a brief overview of secondary data that quantifies building energy performance results for Phase One of the housing initiative (Monahan, 2014) (Section 5.1). This review is supplemented by primary data from the professional interviews. It is suggested that whilst the housing development was accredited to (the revised) CSH level six standard fulfilling the objectives set out by the scheme's funders, there are reasons to question the merits of the adopted techno-rational approach.

Analysis then draws on a range of data sources from mixed-method research (see Table 3.1) to explore how the initiative shaped household heat comfort practices, and associated projects (Section 5.2). The chapter proceeds to show that the accreditation process obscures wide variation in energy demand at a household level and that certification to the CSH standard serves to reinforce expectations of 'normal' energy usage at home. I show how although the TCSG sought to maintain the domestic *status quo*, even when the low-energy homes worked as intended, their modified material qualities reconfigured household (heat comfort) practices, with wide repercussions for tenants' everyday lives.

Reporting on analysis of the professional practitioner interviews, Section 5.3 next explores whether implementing CSH level six standard enabled the deliberate targeting of housing design and construction practices, and analyses the extent to which these practices could be standardised and shifted in less energy demanding directions. Finally, Section 5.4 responds to the questions posed at the outset of this chapter. I ask whether it is possible to intervene in a single practice alone, and whether the adopted governance position and approach adopted by the TCSG and professional practitioners was conducive to achieving environmentally sustainable transformations in housing practices. In response, it is suggested that Social Practice Theory (SPT) needs to expand beyond its current position, to think about how practices relate to one another in networked configurations.

5.1. Trinity Close Phase One building energy performance results

For the TCSG, the primary objective for the Trinity Close housing development was to attain CSH level six accreditation, as one of the first carbon-neutral, new-build, social housing, developments in the UK. As explained in Chapter 4, Phase One of Trinity Close was designed and constructed in accordance with the initial definition of the housing standard. According to this definition, zero carbon referred to net zero carbon dioxide emissions arising from a building over the course of a year, requiring all carbon dioxide emissions to be reduced to zero through on-site means. Both 'regulated emissions' (from heating, cooling, ventilation and lighting) and 'unregulated emissions' (from household appliances) had to be accounted for. As discussed in Chapter 3, at the time of construction in May 2011, this definition changed to permit allowable off-site solutions and to omit unregulated emissions. In addition, the accreditation process did not consider the properties post-occupation, and this way, the sustainability appraisal was very much based on an assessment of the building as a house, as opposed to a lived-in home. When Phase One of Trinity Close was completed in mid September 2011 therefore, the Code assessors considered the development in terms of the new definition of the CSH. Against the requirements of this revised standard the completed development was successfully awarded CSH level six certification.

In order to gain more insight into how, and to what extent, the twelve Phase One properties addressed their sustainability objectives, Broadland District Council (BDC) (leading the TCSG) commissioned a report designed to evaluate the electricity performance of the Trinity Close homes post-occupancy. This review was undertaken by an external research consultant - Dr. Jennifer Monahan (Monahan, 2014) - based on data downloaded from monitoring equipment installed in the properties by Adapt and supplied by Green Energy Options (GEO). As discussed in Chapter 4, this monitoring programme was intended both to inform the technological appraisal process and future design of new-builds in Broadland, and to provide householders with feedback on their electricity consumption. Whilst this monitoring equipment was *in situ* for two years, due to data collection issues, Monahan's evaluation drew on available household energy consumption data collected during the first year of occupation (between 11th October 2011 and 30th December 2012). The categories of monitoring data and monitoring intervals at which data were recorded are described in Chapter 3. Wherry Housing Association (WHA) also provided annual meter readings taken for the electricity consumer unit and photovoltaic (PV) system in each property.

5.1.1. Gaps in electricity performance monitoring

The electricity monitoring process led to 'patchy' results with all of the twelve homes collecting data for each category to differing degrees (see Table 5.1) and with significant gaps throughout the monitoring period (see Figure 5.1). Complete data across all twelve homes was only available for the initial two weeks of the monitoring (11th - 22nd October 2011). One home had 100% data coverage, five homes had 60% data coverage, five homes had less than 50% data coverage, and for one home, data collected covered only 24% of the period (Monahan, 2014: 6). These limitations meant some households were over-represented during the winter months, resulting in overestimation of energy consumption. Others were over-represented during summer, leading to underestimation of energy demand (Monahan, 2014).

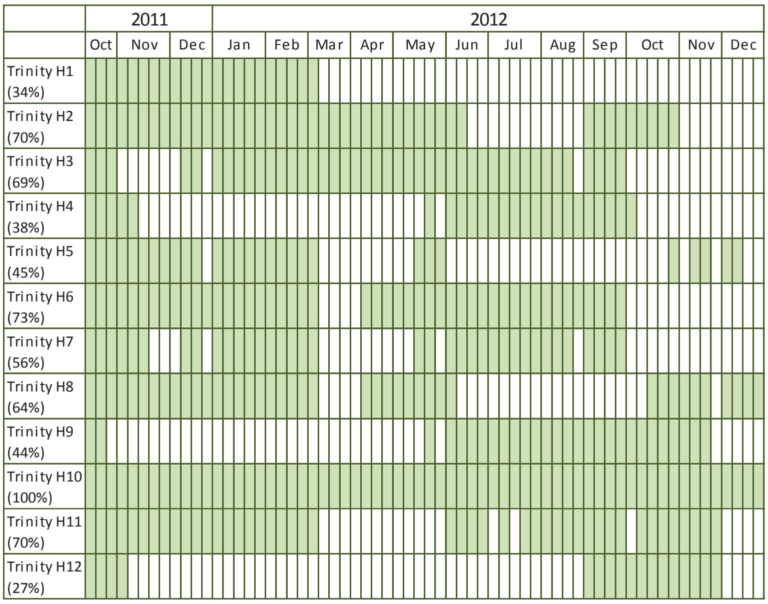
Gaps in data were attributed to the monitoring units failing to maintain connection to the Internet. As discussed by a senior management figure from GEO, in addition to the variable reliability of wireless communications, the units going offline was attributed to a combination of technical malfunctioning and undesirable user responses:

> *"There's [a fault] between the system and the… router, which can be temperamental, so it needs resetting from time to time. [That's] something that we can do from [our offices and] something that the user can do as well, but if they're not well versed in it, or not that interested in it, they don't necessarily know that the information is not being collected [and they don't report the fault]"* (11, GEO).

	Trinity H1	Trinity H2	Trinity H3	Trinity H4	Trinity H5	Trinity H6	Trinity H7	Trinity H8	Trinity H9	Trinity H10	Trinity H11	Trinity H12
Category data												
Cooker	√	√	√	√	√	√	√	√	√	√	√	√
Lights 1	√	√	√	√	√	√	√	√	√	√	√	√
Upstairs Lights	√	√	√	√	√	√	√	√	√	√	√	√
Sockets 1	√	√	√	√	√	√	√	√	√	√	√	√
Sockets 2	√	√	√	√	√	√	√	√	√	√	√	√
Heat Pump	√	√	√	√	√	√	√	√	√	√	√	√
Immersion	√	√	√	√	√	√	√	√	√	√	√	√
Underfloor Heating	√	√	√	√	√	√	√	√	√	√	√	√
Solar	√	√	√	√	√	√	√	√	√	√	√	√
Plug Bug Data												
Baby		√										
Television			√	√					√	√		
Toaster	√		√	√				√				
Tumble dryer									√			
Entertainment								√				
Kettle	√	√	√	√				√	√			√
Microwave	√	√	√	√					√			

Table 5.1 – Categories of electricity consumption data collected at Trinity Close

(Source: Adapted from Monahan, 2014: 5)



Shaded bars = electricity monitoring data available. % = percentage data availability for each household.

Figure 5.1 – Electricity percentage data coverage for Trinity Close properties

(Source: Adapted from Monahan, 2014: 7)

Monitoring did not take place for the mechanical ventilation and heat recovery (MVHR) systems (Chapter 3). Only eight households partially used the PlugBugs (Chapter 3 and Table 5.1) and it was not possible to know with certainty, from either the quantitative data or qualitative data, what appliances these devices monitored. PlugBug data were therefore excluded from the analysis (Monahan, 2014). Additionally, whilst data during the main heating season (November to March) were largely complete for nine of the homes for the first season, they were limited to just one home for the second season, preventing accurate analysis. Together, these data collection issues meant that results produced from data analysis were limited to 'estimates at best' from which 'any conclusions [could] only be suggestive' (Monahan, 2014: 6). To enable more comprehensive data analysis therefore, annual meter readings taken by Wherry Housing Association (WHA) for the electricity consumer unit and the photovoltaic (PV) system in each property were also drawn on. These data provided one year's grid electricity consumption and PV electricity production. Combining the meter readings with the GEO data provided some insight into how the twelve Trinity Close homes used their property and their electricity implications. However, data limitations meant that it was not possible to undertake a full technological appraisal.

TCSG and funders DCLG organised electricity performance monitoring to form part of the initiative's design, procurement and construction strategy, to inform future housing development in Broadland district and the house-building industry more broadly. Monitoring devices were also installed to enable provision of tailored energy performance feedback reports to each of the Trinity Close residents. The intention here was that feedback would enable motivated households to choose to adjust their domestic routines and behaviours, in order to maximise household electricity savings and to contribute to minimising household financial outgoings. As described by a senior figure from WHA:

> *"…there have been … problems … we all thought it was all going to work… and it's proven that it is hellishly difficult to have monitoring of energy consumption in houses to the degree that we wanted to break it down … Maybe we were… over ambitious?"* (7, WHA).

Whilst the TCSG acknowledged technical difficulties, monitoring faults were predominantly blamed on perceived misunderstandings and misuse by households.

These factors led the TCSG to agree to use a more 'user-friendly' and reliable monitoring system in future schemes. As the WHA interviewee elaborated, *"the only option is to look at maybe a much simpler monitoring system like… one that literally flashes up and down when you're using lots of electricity…"* (7, WHA). More fundamentally, receipt of below anticipated monitoring data prevented the intended quantitative technology appraisal and dramatically undermined the planned behaviour change mechanism of provision of householder feedback. Brief reports summarising household energy demand and providing simple tailored recommendations for electricity savings were developed relating to this period. However, the data was only analysed, and reports delivered to respective householders, in November 2014, by which time many tenants questioned their usefulness (Section 5.2).

5.1.2. Energy production and consumption at Trinity Close

During the monitored period, the PV system installed at Trinity Close generated 51,610 kWh of electricity, 10% more than initially estimated by the TCSG (Monahan, 2014: 12) (see Table 5.2). In this respect, the housing development surpassed expectations. Whilst design of the Trinity Close properties assumed that the PV generation would produce a significant amount of electricity, the TCSG did not known whether this would align with the households' annual power demand or how much the PV generation would offset electricity from the National Grid. Arguably, planned levels of PV electricity generation were intended to offset, and not to challenge or modify, embedded expectations of domestic energy use.

The annual energy demand for each household was estimated from available GEO data. With no net metering installed, it was (crudely) assumed the difference between metered grid supplied electricity and estimated annual energy demand would have been supplied by the PV system. The average annual metered grid electricity consumption for Trinity Close was 5767 kWh[1] per year, ranging from 3468 kWh (H4) to 8042 kWh (H10) per year (Monahan 2014: 10) (see Table 5.2). As average energy consumption for households in the UK for this period was 16,100 kWh per year, lower for the East Region (15,500 kWh per year), (ONS, 2013), the homes at Trinity Close clearly demonstrated significantly lower energy consumption compared with national and regional averages. However, when comparing PV generation with grid electricity

[1] kWh: The kilowatt-hour is a unit of energy equivalent to one kilowatt (1kW) of power expended for one hour.

demand (see Table 5.3) only one home (H4) was net energy self-sufficient over the course of the year. Trinity Close households H7, H8 and H9 were also close to net energy self-sufficiency for the year (Monahan, 2014: 13).

	Annual units of grid supplied electricity Consumed (metered) kWh	Estimated total annual electricity consumption (GEO[2]) kWh	Estimated difference between grid supplied and annual total consumption kWh
Trinity H1	5462	8172	2710
Trinity H2	7151	7927	776
Trinity H3	4752	6466	1714
Trinity H4	3468	4287	819
Trinity H5	6914	10367	3453
Trinity H6	6017	7635	1618
Trinity H7	5408	7047	1639
Trinity H8	4243	6450	2207
Trinity H9	4418	5206	788
Trinity H10	8042	10353	2311
Trinity H11	5914	7665	1751
Trinity H12	7410	7817	407

Table 5.2 – Annual household electricity consumption at Trinity Close (27th September 2011 - 26th September 2012)

(Source: Adapted from Monahan, 2014: 11)

	Grid electricity supplied kWh/year	PV power produced kWh/year	Grid electricity minus PV kWh/year
Trinity H1	5462	4143	1319
Trinity H2	7151	5159	1992
Trinity H3	4752	3731	1021
Trinity H4	3468	3860	-392
Trinity H5	6914	4885	2029
Trinity H6	6017	3368	2649
Trinity H7	5408	5206	202
Trinity H8	4243	3768	475
Trinity H9	4418	3880	538
Trinity H10	8042	3434	4608
Trinity H11	5914	4983	931
Trinity H12	7410	5194	2216
Total	69199	51609.9	17589

Table 5.3 – Grid electricity and PV generation for Trinity Close

(Source: Adapted from Monahan, 2014: 13)

[2] GEO = Estimated total annual energy consumption (Grid + PV generated electricity) was estimated by calculating average daily energy consumption from the GEO monitored data multiplied by 365 days to give an estimated annual total energy consumption. Note this extrapolation is not accurate, the over representation of winter months in the GEO data set is likely to over-estimate total energy consumption.

The estimated proportion of PV generated electricity consumed directly by Trinity Close or exported to the National Grid, also demonstrated a large range between households (8%-71%) (site average 39%) (see Figure 5.2). Monahan (2014: 14) recognises that whilst this could be a consequence of the poor dataset, households at home during the daytime used a higher proportion of PV generated power (e.g. H10, H1, and H5), compared with unoccupied households during daylight hours, or householders that were more conscious of how they could modify their practices to be energy saving (e.g. H9 and H4). Monahan's calculations also estimated that the PV systems had contributed approximately 23% of total annual energy consumption at Trinity Close, ranging from 5% to 34% for the individual households (see Figure 5.3). Again this large range was in part attributed to the limited data set (*ibid.*).

Monahan (2014:16) estimates average household energy demand for Trinity Close to be 21kWh per day (approximately 0.26 kWh per m^2 of floor area per day)[3]. However, she emphasises the wide range in daily average energy consumption identified between the different households, from 12 kWh per day (H4) to 29 kWh per day (H5) (Table 5.4). This equates to households varying in their energy demand by a factor of 2.4. Normalising by floor area to provide a fairer comparison, and considering the daily average kWh energy consumption by m^2, she reveals that larger homes did not have greater energy consumption, as expected. For example, H5, the largest of the homes, had an equivalent daily average consumption per m^2 to two of the smallest homes (H3 and H8, both flats).

[3] Monahan (2014: 16) calculated this figure from the GEO data assuming a total metered energy use of 89,392 kWh for a total of 365 days and a gross internal floor area of 930m^2. This figure was based on analysis of gross energy consumption of properties of different characteristics (type, size and number of occupants).

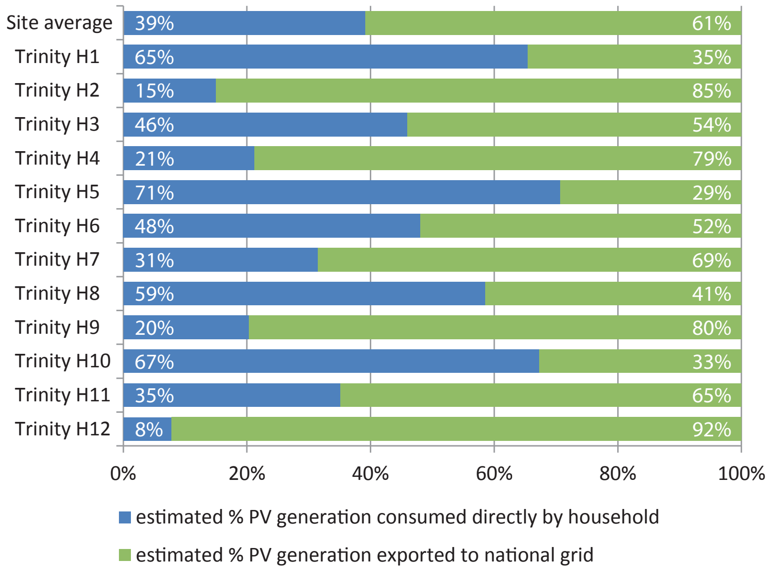


Figure 5.2 – Estimated proportion of PV generated power consumed directly and exported to the National Grid at Trinity Close

(Source: Adapted from Monahan, 2014: 14)

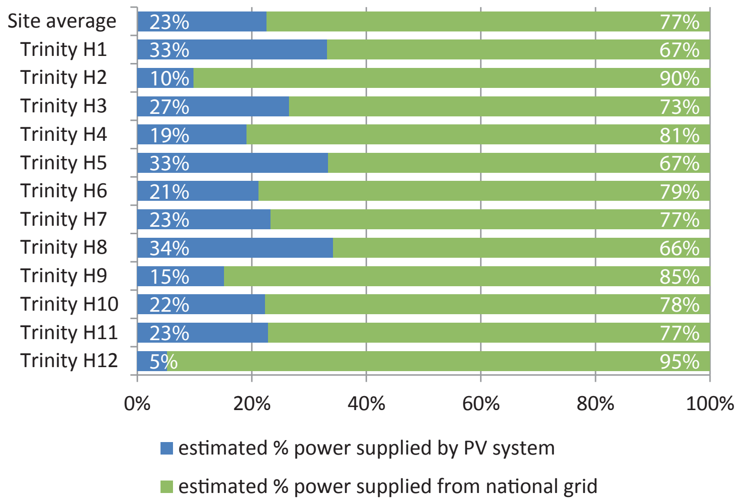


Figure 5.3 – Estimated proportion of total annual household energy consumption supplied by National Grid and PV system at Trinity Close

(Source: Adapted from Monahan, 2014: 15)

	Average daily energy kWh	Minimum daily energy demand kWh	Maximum daily energy demand kWh	Standard Deviation	Sample Variance	Number of days with metered readings	kWh per day per m²
Trinity H1	22	3	58	8	61	236	0.29
Trinity H2	22	3	44	5	27	312	0.25
Trinity H3	18	5	30	3	11	289	0.27
Trinity H4	12	3	15	2	2	161	0.18
Trinity H5	29	3	55	9	76	199	0.27
Trinity H6	21	6	49	7	45	323	0.31
Trinity H7	19	3	42	6	35	238	0.22
Trinity H8	18	8	35	4	19	288	0.27
Trinity H9	14	3	27	3	12	193	0.22
Trinity H10	28	6	58	8	62	411	0.42
Trinity H11	21	4	45	7	51	308	0.24
Trinity H12	21	13	27	4	14	27	0.24

Table 5.4 – Statistics for average daily household energy demand at Trinity Close

(Source: Adapted from Monahan, 2014: 17)

Recognising the incomplete dataset, which likely overestimated annual energy consumption by heating and hot water energy demand, when considering how energy was used in the Trinity Close properties, Monahan (2014: 18-20) collated the monitoring circuit data into four end use categories. These can be understood in terms of household practices.

- Heating (and hot water use): including Heat pumps, Immersion heat and Under-floor heating
- Lighting: including Lights 1 and 2
- Appliance use: including Sockets 1 and Sockets 2
- Cooking: Electric oven

The analysis clearly demonstrates the variation found both for overall energy consumption (Figure 5.5) and for patterns of energy consumption (Figure 5.4) across the twelve homes. By percentage, heating and hot water constituted the largest energy use for all of the homes (ranging from 46% (H12) to 71% (H4). However, H4 also had the lowest energy consumption overall. In contrast, H10 had the highest overall energy demand with appliance related energy double the site average, and heating-related energy almost 80 kWh/m²/year (site average was just below 60 kWh/m²/year).

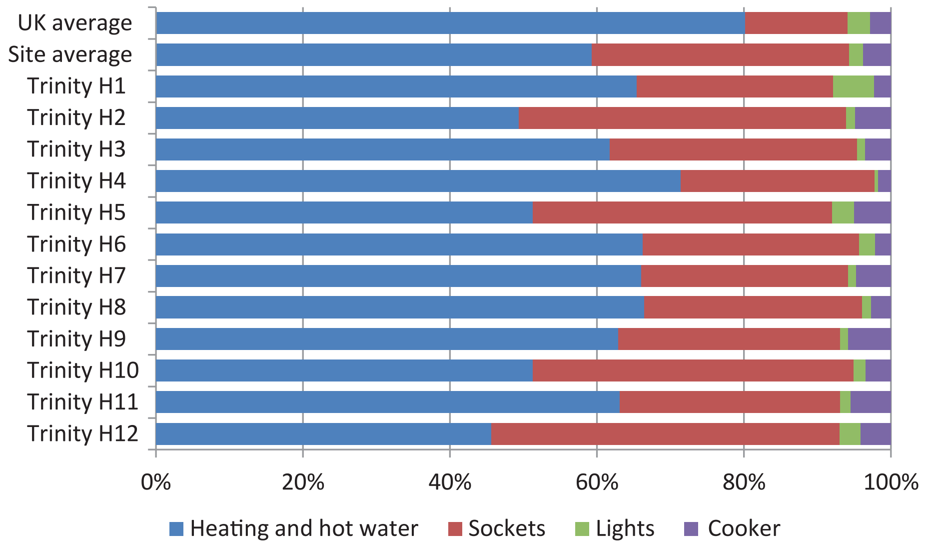


Figure 5.4 – Percentage energy consumption by end use for Trinity Close properties normalised by area (m^2)

(Source: Adapted from Monahan, 2014: 19)

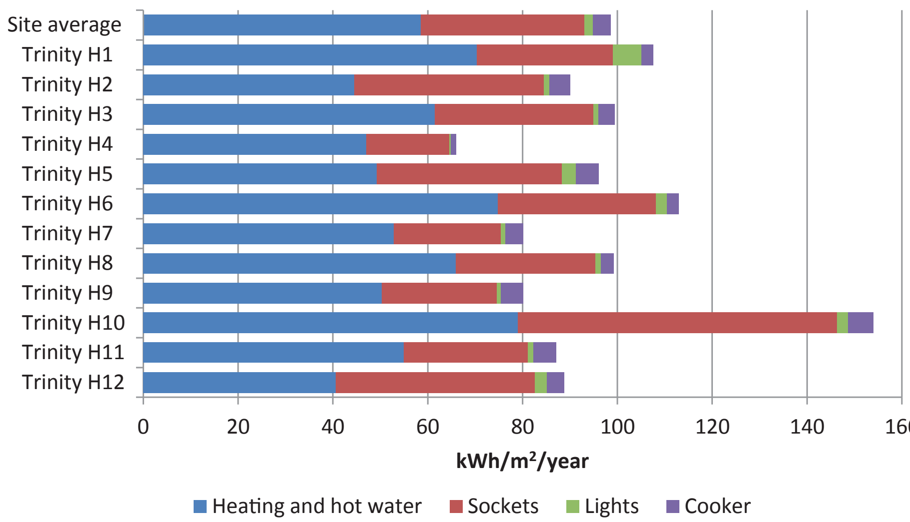


Figure 5.5 – Annual energy by end use for Trinity Close households and site average

(Source: Adapted from Monahan, 2014: 20)

As opposed to the TCSG's implicit assumptions that householders' routines and actions would respond similarly to their new low-energy properties (i.e. by being minimally affected), energy demand results were highly variable. It was also recognised that the quantitative assessment could not offer an explanation as to the demand levels or variability shown. Whilst the TCSG's initiative did not seek to understand householder practices, Monahan's report adopts a techno-rational understanding that, '[e]nergy demand is highly variable and closely related to both behaviour and appliance ownership' (2014: 25). Furthermore, as homes are built to be more thermally efficient, socket-related energy consumption will become more important for determining the overall energy performance of the home. Not surveying or talking to householders, and failing to observe householders' daily practices as part of the Trinity Close initiative - a fundamental component of this research – is shown to be a critical omission for interpreting the monitored energy consumption (and production) data. Householder practices, and not just the technical specification, are shown to be crucial to determining and understanding the overall energy performance and associated carbon emissions of a residential property.

The final consideration of the quantitative energy performance appraisal was whether Trinity Close operated as a carbon-neutral housing development during the monitored period. To answer this question the grid electricity consumed by Trinity Close was converted into carbon emissions. The Trinity Close homes were estimated to be responsible for 34.2 tCO_{2e} emissions from grid supplied electricity (69,199 kWh – see Table 5.3)[4]. The PV system generated 51,610 kWh of zero carbon electricity during the same period, offsetting 75% of the total energy requirements (offsetting 25 tCO_{2e}). This resulted in a net carbon balance of 8.7 tCO_{2e} (Monahan, 2014: 21). According to the original definition of CSH level six therefore, the Trinity Close development did not result in zero net carbon emissions (DCLG, 2010) (see Figure 5.6).

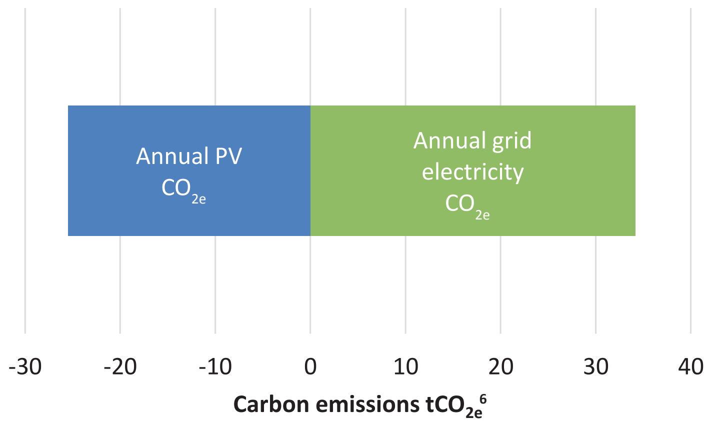


Figure 5.6 – Annual carbon balance for Trinity Close[5]

(Source: Monahan, 2014: 21)

[4] For 2011-2012 the average emissions factor for UK Grid electricity was 0.49 kg CO_{2e} per kWh delivered. Source: DEFRA (2012).

[5] Carbon dioxide equivalency is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of CO_2 that would have the same global warming potential (GWP), when measured over a specified timescale (generally, 100 years).

[6] CO_2e = Carbon dioxide equivalent.

However, in accordance with the new regulatory definition, zero net carbon is now defined as the annual dwelling carbon emissions (in units of $kgCO_2/m^2$/year) from regulated energy end uses only (see Chapter 3) (ZCH, 2012). Regulated energy end uses include space heating and cooling, water heating, ventilation and lighting. Monahan (2014: 21) explains that assuming regulated energy constituted 61% of overall energy consumed at Trinity Close (21 tCO_{2e} (42211kWh)), the PV system offset 100% of emissions associated with regulated energy. It was only in accordance with this update to the CSH standard that Trinity Close met both CSH level six and the regulatory definition of zero carbon.

In summary, the Trinity Close development achieved its remit of obtaining certification as a CSH level six scheme, and indeed was one of the first social housing schemes in the country to gain this sustainability standard. However, this assessment did not take into account the WHA tenants and the energy implications of their household practices. In light of this, electricity performance monitoring was commissioned by TCSG in order to: a) determine the preferred technological specification of future new-build housing development projects in Broadland district, b) provide learnings for the housing industry more broadly and c) provide tailored energy feedback reports to the Trinity Close residents with the intention that motivated individuals would choose to adjust their routines to save energy and make financial savings. This monitoring programme however produced 'patchy' data. Data limitations were attributed to technical faults, and misuse and misunderstandings by residents, which reinforced the techno-rational assumptions behind the scheme's design. Furthermore, key electrical circuits were not monitored (e.g. MVHR, PV net metering), and monitoring of household temperature and humidity (to gain an understanding of householders' thermal comfort) was overlooked by Adapt.

An evaluation of data covering the first year of tenancy, completed by an independent researcher, whilst acknowledging that findings were 'estimated and not conclusive' due to data limitations (Monahan, 2014: 2), established the following. First, the homes at Trinity Close demonstrated significantly lower energy consumption compared with national and regional averages for the year, attributable to the 'thermally efficient construction, the air-source heat pump (ASHP) system and the contribution of the PV system' (Monahan, 2014: 25). Second, the installed PV system(s) at Trinity Close generated 10% more electricity than originally anticipated by WHA and Dove Jeffery Homes (DJH). 39% of this power was estimated to have been used by the twelve households (with the remainder being exported to the National Grid); leading to the PV system contributing an average of 23% of the total annual energy demand of Trinity Close. Indeed, without deliberately seeking to reduce household energy expectations or challenge energy requirements, the PV system produced enough electricity to offset 25 tCO_{2e} of the 34 tCO_{2e} produced during the course of the year by the development. Despite this, the Trinity Close homes failed to achieve carbon-neutrality (as originally defined by the CSH standard, and as originally intended in the scheme's design) resulting in net carbon emissions of 8.7 tCO_{2e}. It was only when adopting the new zero-carbon definition - which only accounted for regulated emissions - that the scheme could be considered carbon-zero.

Quantitative energy performance measurements alone provided an opaque picture of how householders' domestic practices led to particular energy consequences, underlining the need for more qualitative research in this area. The results revealed that heating and hot water usage (bathing/washing) constituted the largest energy use for all the homes (ranging from 46% (H12) to 71% (H4)), validating the focus of this research on domestic heat comfort practices. Most crucially, there was a huge variation in all categories of household energy demand. Arguably, as homes become more thermally efficient, household energy demand - particularly socket-related consumption but also heating related energy use – gain importance in determining building energy performance. As such, it is vital to determine how this energy demand is 'made up', and to understand whether, and the extent to which household practices (resulting in domestic energy demand) could be transformed in less energy-intensive directions.

According to the building energy performance assessment, even when evaluated according to the TCSG's own techno-rational objectives, the Trinity Close initiative is found to be deficient. As such, there is a need to explore energy-related household practices in more detail.

5.2. Stability and change in the elements of household (heat comfort) practices

This section will explore the reasons behind household variability in energy demand at Trinity Close, by 'zooming in' (Nicolini, 2009) on the composition and performance of domestic heat comfort practices, and their association with linked bundles and complexes of household practice (Shove *et al.,* 2012). Whilst heat comfort practices form the focal point of this analysis given their contribution to the overall household carbon footprint, it would be equally possible to study the elements and contours of any other domestic practice.

The initiative is analysed as an explicit non-intervention in household practices whereby implementation of the Code for Sustainable Homes (CSH) sought not to disrupt the everyday lives of the Trinity Close tenants, nor to distinctly challenge accepted cultural norms around energy usage in the home. To explore whether and how, if at all, the practice elements of domestic heat comfort changed, analysis is framed by the first (of three) mode of practice intervention outlined by Spurling *et al.* (2013) and Spurling and McMeekin (2014) – that of *re-crafting practices* (see Chapter 2). This way of intervening in practice is defined as 'reducing the resource intensity of existing practices through changing the elements that make up those practices' (Spurling *et al.*, 2013: 10). Taking each element in turn, i.e. stuff, skills, images (Shove and Pantzar, 2005), an assessment is made as to how the constituents of heat comfort practices are modified, replaced or remain stable at Trinity Close. Analysis also considers the extent to which links between the three practice elements are made, reaffirmed or broken, and with what implications. In so doing, the composition and dynamics of household heat comfort practices at Trinity Close are ascertained.

Analysed data sources include: (i) initial and (ii) repeat semi-structured interviews and audio-tours with the householders; (iii) research diaries completed by the residents on their domestic heat comfort practices; (iv) interpretation interviews during which householders discussed their research diary entries and a data plot produced from tracking the living room temperature over a two week period; and (v) results from an exercise where householders guessed the percentage contribution to domestic energy demand of various household practices.

5.2.1. The 'stuff' of household heat comfort practices

This section considers how the low-carbon technologies and energy-efficient features encountered at Trinity Close modified how residents maintained their heat comfort. In contrast to understanding the installed equipment as autonomously delivering reductions in energy demand - as largely assumed by the TCSG and as underpins the CSH standard – here the material composition of the properties is understood as but one element of domestic practice. This material element of practice interacts with householders' competences and understandings. The evaluation therefore considers how energy-efficient materials and low-carbon heating technologies are involved in the carrying out of everyday heat comfort practices, and associated home-making projects, with implications for domestic energy demand. It is recognised that material elements in domestic heat comfort practices extend well beyond provision of a heating system and insulated building fabric to include supporting infrastructures. It is also acknowledged that personal thermal comfort is maintained in many more ways than simply by switching on/off the heating and keeping room temperatures within a recommended range (see Chapter 2). Whilst focusing on discrete material improvements to the Trinity Close building fabric, this account explains this diversity of ways by which household heat comfort can be maintained.

As described in Chapter 4, the TCSG considered that installing energy-efficient building materials and renewable technologies in the Trinity Close homes would automatically deliver optimal energy-efficiency results upon installation. Although the TCSG expected some technical 'teething problems'[7] following construction completion, particularly during the first couple of months following move-in, faults were commonly experienced, particular with the ASHP and under-floor heating system. Faults ranged from equipment not having been turned on, to refrigerant gas leaks, to excessive heat retention due to the super-insulation and triple glazing (see Table 5.5). These technical malfunctions forced the technical features of the home to enter the residents' discursive consciousness (Giddens, 1984), and sometimes had severe implications on the spatial and temporal organisation of residents' everyday lives. Residents had to either adapt to temperatures outside of their usual thermal comfort range or postpone, curtail, or abandon the planned undertaking of particular activities. However, even when the materials and technologies worked *in accordance* with the intentions of the designers, architects and housing contractors, the modified material qualities of the home reconfigured the composition and performance of heat comfort practices. This had potential wider repercussions for everyday domestic life.

The inserted energy-efficient features of the Trinity Close properties actively configured the householders and their practices, by encouraging heat comfort (and associated household practices) to be undertaken in certain ways, and not in others. Discussions

[7] Teething problems: Short-term problems that occur in the early stages of a new project.

with tenants revealed that far from everyday life proceeding as per normal, adjustments were required to be made in order to fit around the new technical configuration of the home. As such, the social neutrality of energy-efficient building materials and renewable technologies assumed in the implementation of the CSH standard (critiqued in Chapter 2) was far from applicable at Trinity Close. The TCSG had predominantly assumed that the tenants at Trinity Close would passively interact with the energy-efficient features of the home, and that only particularly motivated individuals would actively seek to change their established routines. However, for all households, the installed materials and technologies could not be considered as passive artefacts because they were actively and continuously incorporated into everyday household practices. For example, new interactions were required with the heating system and thermal materials of the home for different times of the day, seasons, and activities.

Appendix M demonstrates how many of the institutional assumptions around technical operation were not realised in the householders' everyday heat comfort practice performance. As shown, many householders demanded to be more actively involved with the set-up and maintenance of their home than assumed by WHA and Adapt. Householders also often contested using the installed energy-efficient technologies in institutionally prescribed ways, as they did not mesh with householders' expectations and routinised practices. For example, as opposed to maintaining a super-sealed environment, tenants would open windows and doors for ventilation and to manage their thermal comfort. Some tenants used the mechanical ventilation and heat recovery (MVHR) system as a conventional ventilation fan or blocked the air vents to prevent draughts, disrupting the required transfer of warmed air between rooms.

A particular point of contestation was the recommended setting of room thermostats to a temperature range of 16-18°C at night and a maximum of 21°C during the day to achieve the most efficient operation of the ASHP under-floor heating. Data logging of the living room temperature for nine of the twelve households undertaken during 22nd March 2013 and 15th April 2013 (a snowy period), demonstrates that all monitored households commonly exceeded these maximum requirements (see Table 5.5). As opposed to programming the heating according to regular household activity patterns, several tenants also relied on the convenience of switching the heating on and off as required, sometimes forgetting to turn it off. As explained by H3 when reviewing the temperature plot;

> Interviewer: *"Well the coldest it's been was 19 degrees and the warmest was 25.5".*
> Interviewee: *"Woah! That's hot"! [laughs]*
> Interviewer: *"Yeah, sauna-esque. [laughs] So that was at 10.30pm at night, so maybe you had some people around"?*
> Interviewee: *"Yeah that will probably be – I have a habit of falling asleep on the sofa so if I put the heating on for a little while and then I go to sleep, then it just gets hot".*

In contrast to keeping the ASHP continuously running, as advised, during the summer months several tenants turned the unit off because it was too hot, or they did not run the ASHP because they thought that they could save money on electricity bills. Finally, some households brought in supplementary heating technologies to circumvent using the ASHP, which was unfamiliar and potentially inefficient (Section 5.2.3).

Temperature comparison*	Trinity Close properties								
	H1	H2	H3	H4	H6	H7	H8	H9	H11
Minimum	17	19.5	19	18	18.5	15.5	16.5	19	18.5
Maximum**	24	26	25.5	23	23	24	24.5	25.5	26.5
Mean	21.00	21.48	21.50	20.19	20.72	19.46	21.12	21.59	23.50
Standard Deviation	1.39	0.87	1.05	0.63	0.98	1.46	1.25	1.19	1.48

Shaded cells = Exceeded recommended room temperature range.
* Temperatures recorded in the living room of nine participating households at five-minute intervals between 22/03/2013 - 15/04/2013. ** Maximum temperature considers both daytime and night-time temperatures.

Table 5.5 – Comparison of living room temperatures recorded at Trinity Close

In summary, the TCSG framed the installed energy-efficient materials and renewable technologies as 'bounded entities' (Shove *et al.*, 2014: 113) that could be inserted into the tenants' housing structure and everyday lives very discretely, and with limited upheaval. Some initial technical snags[8] were experienced. However, even when the Trinity Close homes worked as intended, the modified material qualities of the home reconfigured the composition and performance of householders' heat comfort practices (and associated practice bundles and complexes). Some householders were not content to be passive actors, contesting the institutionally prescribed settings and operation of the equipment, and sought convenience when managing their heat comfort. The unintended reconfiguration of these domestic heat comfort practices, in contrast with

[8] Snag: Unexpected or hidden obstacle or drawback.

institutional expectations of technological acceptance, had broad repercussions for both building energy performance and for tenants' everyday lives.

5.2.2. The 'skills' of household heat comfort practices

As described in Chapter 4, the energy-efficient features and renewable technologies of the Trinity Close properties were designed and installed so that they appeared discrete and minimal engagement was required from the residents. Where the TCSG required the tenants to use their property in a specific way, technical instructions aimed at delivering optimal performance was provided through a number of different channels. These included: an initial presentation prior to handover, an induction by WHA and DJH delivered within the first week following move-in, a visit by a heating technician (during which the heating system thermostatic controls were set), and provision of a home-user manual. Based on review of household interviews, audio-tours, research diaries and interpretation of temperature data logs, five dominant householder responses were exhibited in response to provision of this explicit formal instruction and as the tenants gained (or failed to develop) the skills to manage their thermal comfort in their new home. These responses were not mutually exclusive and are further described in Appendix N.

First, 75 percent of householders retained the institutional advice provided. For example, one diary entry rehearsed information received during the induction, although how this householder was able to put this information into practice was less clear;

> *"Triple glazing means better insulation so heat stays once it's here. Under-floor heating means fast evenly distributed heat. Heat source pump keeps a constant supply of fresh air coming in, heating it with the old warm air as it leaves [and] meaning no drop in temperature. Ventilation in bathroom and kitchen prevents condensation and stuffiness. Draft excluders round front door stops cold drafts. Extra insulation in walls keeps temperature constant"* (H3C).

Second, 33 percent of tenants refrained from actively becoming involved with the energy-efficient features of the Trinity Close properties because they did not understand the advice or equipment. One householder described how in her opinion a disorganised induction process had resulted in most of Trinity Close being confused as to how to optimally set-up the thermostatic panels. She explained:

> *"When you first move in you've got so much going on in your head, you don't take in what you're being told… When [WHA and DJH technicians] first came around, I think there were about six of 'em', and they're all talking to you… and then one of them tries to show you the heating… That's why people got confused and they didn't know what they were doing… It was just totally baffling"* (H10A).

Tenants overwhelmingly found the home-user manual to be inaccessible and complicated leading 66 percent of households to disregard the explicit technical instructions provided. When one household was asked how the heating system was explained to them, they responded that they would have found a demonstration on how to incorporate the technical operation of the heating system into their practice far more useful:

> *"When something goes wrong, you've got to know a little bit about the equipment rather than thinking I've got to look through this [manual] [flicks through, and casts manual to one side]. You know, you just don't want to be doing it [flicks through again]. I mean it's nice to have, but it'd be even nicer to know how the equipment works and what you can and can't do"* (H12A).

As a consequence of a perceived flawed induction process, for (at least) the first two months following move-in, confusion reigned at Trinity Close as to the best ways to set up and operate the heating system. 17 percent of households turned off their heating system as they were afraid that it would break, or cost too much too run. Similarly, 50 percent of households avoided changing the thermostatic controls initially set by WHA and DJH, even if the pre-set timings or temperatures did not mesh with their domestic practices. As one tenant described:

> *"I don't change anything with the heaters, I don't change anything. I don't touch the thermostats at all… I don't understand them, so I don't want to break it and then have to pay for it… Yeah, I've been shown how to use them, but they're so complicated, everything is so complicated, and [WHA] just expect you to know"* (H1A).

Third, 58 percent of households ignored the manual and gradually became more familiar with the thermal properties of the new home through trial and error, even though they had been advised by WHA and DJH to refrain from touching the installed equipment once it had been set-up. These householders felt strongly that they needed to have a practical understanding of how their heating system worked alongside knowledge of what to do in an emergency, should the equipment suffer a technical fault. As one resident commented, *"I'm not worried by all of this technology, I'm quite happy to fiddle around and I don't think it's going to bite and go bang or anything [laughs]"* (H3A). All households drew on tacit understandings of the thermal qualities of the home and of technical operation, cumulatively developed from their previous domestic experiences and embedded through long-term practice performances. For example, one tenant described how she was used to modifying her clothing to manage her thermal comfort, as she had not previously been able to adjust her heating thermostatic controls with her 'conventional' gas-fired heating system. In her thermal comfort diary, she discussed how:

> *"… the main thing I normally do [to keep warm] is that I change my layers of clothing, because I don't adjust temperatures because I've never had the option to wherever I've lived, and I've never seen the need to. So even though I can, I choose not to"* (H4B).

Whilst this example led to greater energy-efficiency, another couple described how they had assumed that, as with their previous home, the heating system was separate to the hot water system and could be switched off to save electricity. In fact, the Trinity Close properties were fitted with air-to-water system intended to both distribute heat and provide hot water to the properties, and as such, the system should have been left on. They described how:

> *"We assumed that [the ASHP] would do your heating and then switch off. But apparently there's an… immersion heater in the loft, which is maintaining your water [temperature]. So [the heat pump] is effectively always running… We assumed that if you didn't have your heating on, it wouldn't work. But it doesn't work like that"* (H5A).

Fourth, 91 percent became aware of the passive thermal design of the properties through their experiences of everyday life at Trinity Close. It was only through repeatedly performing modified heat comfort practices (and associated bundles/complexes of domestic practices) that householders really understood what it was to maintain thermal comfort in their new low-energy properties. This 'learning through doing' was often the way in which received formal information and instructions came to resonate and have meaning as part of everyday domestic life. For example, one tenant described how she came to realise that the insulation in her apartment led to heat retention:

> *"[It was]… much better than I'd thought it'd be because all the windows were always closed and I was always wearing jumpers... And I sort of realised that it just doesn't get cold as much if you have the heating off, [the flat] just retains the heat so well"* (H9A).

Another householder described how she had learnt to shut her internal doors to keep the heat in, to enable the underfloor heating to warm up quickly, and to help the ASHP to work more efficiently:

> *"Sometimes I notice when the heating is on, [the thermostat] takes a bit of time just to go up by one degree, but overall if I keep all the doors… shut [it] does warm up and it does keep the heat in"* (H4C).

Fifth, as well as individual householders being able to hone the ways in which they managed their thermal comfort through repeated practice, increasing competence was gained from other household members, neighbours in Trinity Close, as well as friends, family and colleagues living outside of the development. These interactions, which shaped the ways in which heat comfort practices were managed, reinforce the social and shared nature of practice. By seeking advice from more experienced and accomplished practitioners within and outside the Close, and observing their modified practice performances, householders often became more competent at managing heat comfort in their low-energy homes. For example, one householder, unsure about how to operate her heating system, and forced to run her house at below her thermal comfort preference, asked her neighbour for advice and was shown how to use the equipment. She described:

> *"The neighbours… said that [in summer] you stick [the heating] on 17 [degrees] but you have to have the doors and windows open all the time because it gets so hot, so that's what I'm hoping [laughs]… They said you have to keep [the heating] on 17 [degrees] 'cos if not, it freezes up, and they said that's the down side of it… They said [the homes are] brilliant, but …they won't be any cheaper than normal houses…"* (H6B).

In this way too, shared learning through collective practice performance was also capable of reinforcing non-optimal heat comfort practices (in terms of energy-efficiency) and potentially detrimentally shaping household understandings.
In summary, whilst the TCSG believed that provision of user-information and a short demonstration would enable householders to use the installed materials 'correctly' (i.e. to deliver optimal energy-efficiency), Trinity Close tenants reacted differently to the induction and had many different relations with their modified material environment. Five different responses were noted: (i) the information did not mesh with tenants' everyday lives and the tenants found it irrelevant, (ii) tenants were confused as to how to operate the installed technologies, (iii) residents drew on tacit understandings to experiment with operating the installed devices, (iv) residents made the technologies work for them by adjusting, and learning from, their practice performance, and (v) householders operated the installed technologies and managed their heat comfort practices collectively. This diverse range of knowledge and competences led to the installed materials and technologies being used differently (institutional compliance/ passive operation/ not being used/ experimentation /subversion) and to the focus practice of heat comfort being managed in various ways. Invariably, this had implications for energy and carbon emissions.

5.2.3. 'Images' of household heat comfort practices

The onus for reducing and/or offsetting domestic electricity demand was predominantly placed on the work of the installed energy-efficient materials and renewable technologies. To the extent that meanings of domestic energy-related practices featured in the design and implementation of the Trinity Close housing initiative, they were conceived as drivers or motivating factors that would encourage householders to correctly use the installed energy-efficient materials and renewable technologies (see Chapter 4.). Treating the new tenants as individual rational decision makers, the TCSG envisioned that feedback on household electricity usage would prompt electricity-saving behaviours. It was assumed though, that only residents wanting to save money on domestic electricity bills, or who had particularly green credentials, would respond to this feedback. Whilst 42 percent of households held particular opinions about economising, green living and self-sufficiency, these beliefs only became meaningful through the performance of everyday household practices, such as maintaining household heat comfort levels. Importantly, far from normal domestic life continuing unchanged in the Trinity Close properties, the initiative led to the householders developing strong opinions and emotions regarding the way the homes, the TCSG, and the initiative shaped their everyday lives.

As opposed to the individualistic framing of home-users underpinning the design of Trinity Close, there was constant renegotiation as to whose 'ways of doing' heat comfort should take precedence. One interviewee described how regular disagreements would take place at home in relation to setting the thermostatic controls:

> *"Myself, I find [setting the thermostat] a nightmare, the wife does all that. She goes along and turns all [the room thermostats] up, and I go behind her and turn them all down because I'm hot [laughs]"* (H5A).

Householders would also take intentional actions to modify the internal temperature of the home or to provide materials that could warm family members and invited guests. For example, one householder described how she ensured that her visiting mother would not feel cold, whilst maintaining efficient use of the heating system,

> *"My mum came around that day and I saw her rubbing her hands a bit. I looked at the heater and it hadn't kicked in. She has a wood-burning fire so she's used to instant heat. But I knew that she wasn't going to stay long, so if I [had] turned [the under-floor heating] up that wouldn't have impacted her. So I made her a hot drink and shut the doors so she felt warmer"* (H4B).

In contrast to the TCSG's assumptions that motivated tenants would respond to receipt of energy feedback as a behavioural change mechanism, residential energy demand was rarely considered in terms of units of electricity, carbon emissions, or even cost implications. When asked whether expenditure on electricity had increased or decreased over the course of their tenancy at Trinity Close, the majority of householders were not aware of their monthly financial outgoings on electricity. Tenants also had minimal awareness of the average percentage contribution made by heating to household energy demand in the UK.

> Interviewee A: *"I'm going with 30% on heating"*
> Interviewee B: *"I'm going to take 10% from off of the heating and make that 20%…"*
> Interviewer: *"Okay so these are the answers"*
> Interviewee A: *"I told you heating would be high didn't I? Crikey"!*
> Interviewee B: *"Oh"!* [shocked]
> Interviewer: *"So this is an average [UK] home… you can see that heating is nearly 70%"* [of the overall energy demand].
> Interviewee B: *"Yeah heating, I suppose it does [use] a lot [of energy]"* (H7B).

Furthermore, whilst concern about expenditure on household electricity bills forced some residents to use the heating system less, the cost of heating the home was overshadowed by the need to carry out domestic life at a suitable temperature, which varied dependent upon the practice in which residents were engaged. Indeed, saving money was but one meaning among many that shaped and structured heat comfort practices. Whilst 50 percent of households found it interesting to monitor their household electricity use (when the monitor was operational), the majority of tenants were constrained in their ability to modify their heat comfort practices and associated bundles and complexes of practice (e.g. doing the laundry). Instead, domestic heat comfort was managed to meet familial and cultural expectations surrounding everyday domestic life, conventions of comfort and convenience, and to fit with the structure and timings of contemporary life. One householder described how she felt she could not modify when she washed and dried her clothes to take advantage of solar generated electricity:

> *"I just found it interesting to see what was different [using the energy monitor]… I don't think I could have done anything any different. Although ironing and using the washing machine, it's better to put that on in the day when the sun's out and shining on the solar panels. But sometimes that's just not possible, it just doesn't fit in [because I'd need to hang the washing out to dry and I'd be at work]…"* (H3A).

Similarly, ensuring convenience in heat comfort management proved critical for 33 percent of households. 42 percent of tenants became frustrated by the lack of instantaneous heat provided by the under-floor heating (which took time to heat the hot water pipes, particularly if room temperature fell below 18 degrees Celsius). Reviewing a tenant's research diary it became clear that he manually overrode thermostat settings to switch on the under-floor heating whenever he felt that it was required. He coupled this action with either opening or closing the windows to warm up or cool down. He also frequently left the windows open whilst at work during the day and upon encountering a cool environment on his return, would react by closing them and immediately switching on the heating. He described this highly inefficient heat comfort practice in terms of its ease and convenience.

> *"6pm Front Room. Just come home. Too cold. Wanted to feel warmer. Turned heating on & closed windows [i.e. had windows open all day whilst at work]"* (H8B).

42 percent of households also discussed how the way that they used the heating system was structured by an overriding perceived need for comfort, even if this meant consciously breaking institutional rules. For example:

Interviewer: *"So would you sleep at a warmer temperature then in the bedroom? Would you have [the heating] running throughout the night"?*
Interviewee: *"Yeah"*
Interviewer: *"So do you have any thoughts about that in terms of energy use"?*
Interviewee: *"Umm probably once I'm in bed I actually don't need [the heating] on. But then it's just you think 'oh it's cold' and you want it on, but once you're under the covers, you probably don't need it on"* (H9B).

Interviewee A: *"I'm afraid we don't play by the rules. If we're hot, we open the door, if we're cold the heating goes up to 25 degrees".*
Interviewee B: *"Yes and we stick [the electric heater] on [laughs]…".*
Interviewee A: *"The heating, as far as I'm concerned, if I'm cold, I'll turn it up, my home, I'll do what I want"* (H12A).

In fact, only 58 percent of households perceived that they made changes to the ways in which they maintained their thermal comfort by decreasing operation of the installed heating system, turning down the thermostat and/or attempting to maintain a thermally efficient environment at Trinity Close. These residents tended to have either experienced faults with the ASHP which had led to higher than anticipated electricity bills (for 50 percent of households e.g. quote 1), were intimidated by a heating system that they could not operate, and that was not familiar to them (33 percent of households e.g. quote 2, 3), or actively sought to save money on heating bills (58 percent of households e.g. quote 4). For example tenants described the following:

1. *"[Our neighbour] had the same problem when she first moved in. She got a £600 odd electric bill and there's only her there and she's never actually there…but that was all to do with the heat pump..."* (H7C).

2. *"I do find it frightening that heating…I think, 'oh, I mustn't touch that, something's going to blow…'"* (H6A).

3. *"I don't trust it, I don't like it. I'd much rather have a radiator, or because I'm old fashioned, a coal fire. I love coal fires [laughs]… I just don't like not sitting in front of something that produces heat… which is another reason why we've got that [halogen fire] because it glows [laughs]"* (H5A).

4. *"When I first moved in I would open windows to ventilate, but now I try not to open them as I don't want to lose too much heat [laughs nervously]… I'm very tight with my money... It's definitely warmer here, and I'm definitely noticing a difference with the electric bills as well…"* (H4A).

However, 25 percent of households revealed that their heat comfort expectations had increased in their insulated Trinity Close homes, potentially driving up heating energy requirements. For example, one tenant described how she had become used to warmer indoor temperatures, had adjusted her clothing to wear lighter layers throughout the year, and felt cold when visiting friends in their thermally 'leaky' homes:

> Interviewee: *"Now I'm a real wuss*[9] *when I go to other people's [homes], I'm like "Have you got any slippers?" Because I don't even use slippers any more… here"*.
> Interviewer: *"So do you adjust your clothes here? Do you think you're wearing lighter-weight clothes"?*
> Interviewee: *"Yeah, yeah"*.
> Interviewer: *"Okay, is that throughout the year?"*.
> Interviewee: *"Yeah, yeah"*. (H11C)

Another tenant described how she had become less tolerant to the outdoor temperature at work, and she consequently wore more layers of clothing when she was outside:

> *"Because I work outside… I've even noticed that since I've been living here in the winters I get a lot colder at work… Now when I go to work I have to put on one more extra layer and I certainly do feel a lot colder, because I've been living in a place that's a lot warmer"* (H4C).

Householders had strong emotional attachment to particular heat comfort experiences. In addition, rather than being impartial to the installed technologies and material set-up

[9] Wuss: Colloquial term for a feeble person.

of the home, as assumed by the TCSG, the technological specification of the home, and its implications for heat comfort, prompted strong feelings. As everyday domestic life at Trinity Close suffered disruptions and challenges, 50 percent of households also became increasingly sceptical and resentful towards the organisers of the initiative. The previously discussed issues manifested themselves in a breakdown of trust between the householders and TCSG. Householders' opinions included: feeling like they had been unfairly subjected to trialling an innovative housing design (42 percent of households, e.g. quote 5); feeling that their electricity bill savings did not outweigh the challenges of domestic life at Trinity Close (50 percent of households, e.g. quote 6) and doubting the technical expertise of WHA and DJH (42 percent of households, e.g. quote 7). They also included, frustration at not being provided with energy feedback or long-term support (66 percent of households, e.g. quote 8), and feeling the need for institutional communications to be more transparent and responsive (50 percent of households, e.g. quote 9).

5. *"No I don't think this [development] has been put here to benefit us. I feel like this is an experiment, it's an experiment and it's gone wrong"* (H1C).

6. Interviewee A: *"… If I knew that [the homes weren't going to be as cheap to run as promised] I wouldn't have bothered. I'd have waited for…"*.
   Interviewee B: *"An old council house"*.
   Interviewee A: *"Yeah an old council house…"*.
   Interviewer: *"And why is that"?*
   Interviewee B: *"Other than the electric, I don't think it's worth it"*.
   Interviewee A: *"It's not cracked up to what it's meant to be is it"?* (H2C)

7. *"I was actually going to get [my friend (an electrician) to check the technologies] because I didn't trust the people from Wherry or Dove Jeffrey, who'd fob me off with more bull that things are working properly, because I honestly don't think they are. I think they've spent too much money on these places, and they're not prepared to sort the problems out… I think they've over spent and they've just left us to it"* (H5A).

8. *"I thought we were going to have… someone come back to [us] and say, "look this is what [electricity] you've used and that month was particularly high" or " that month was low"… I thought that we'd be educated a bit more, guided a bit more, supported a bit more"* (H11C).

9. *"But you know [sighs]. When the crunch comes to crunch [the TCSG] don't want to know do they? I mean how many times have we rung up now about the monitors cause they're not working? …And then the equipment don't work, and then something else goes wrong…"* (H12A).

Finally, 88 percent of households were aware of the TCSG plans to build fourteen mixed units to CSH level four in the second development phase of Trinity Close (see Chapter 6). These plans incited vehement reaction from 63 percent of households. Concerns included that: existing householders' experiences and views had not been incorporated into the design of Phase Two Trinity Close (75 percent of households, quote 10), institutional attention would shift to phase two and existing residents' technical concerns would not be resolved (34 percent of households, quote 11), and decreased environmental sustainability requirements for Phase Two undermined the first phase of the initiative (75 percent of households, quote 11). Some tenants were concerned about the increased costs of building social homes to more stringent sustainability criteria (25 percent of households, quote 12), whilst 38 percent of households wanted to complete a house exchange to the planned Phase Two properties to make their everyday lives more comfortable (quote 13).

10. *"…That does make me wonder why, when they said that they were going to build this brand new [Rackheath] eco-village, are they not building any more [carbon-neutral] houses? Because these ones have turned out so crap!.. The time hasn't been taken to listen to us, our opinion on it, because we didn't build [the development] and we don't understand it, [our views are] not valid"* (H1C).

11. *"I think if these are all meant to be eco-homes why can't they carry on building them [for Phase Two]? And I think before they start building them they should correct all the problems with these [homes] … Everybody said it, you know, it was meant to be eco-homes all down here, and if they're now not going to be, what was the point of putting these ones here?"* (H2C)

12. Interviewee: *"People do need homes, like more social housing".*
    Interviewer: *"And do you think that they should be built like these homes"?*
    Interviewee: *"I just think that it costs them so much to build them and I just don't know whether it is cost-effective. You know, for how much it costs them, I think*

they said 70% more than just to build a normal house - all the equipment and all the technology!" (H11C)

13. *"The way of how life would be better in those properties compared to here… If I got offered to live in one of those places, I would take it rather than living here. I would go into a Code four house… because everyday living would be a lot more private, everything would be in your day-to-day life more comfortable"* (H4C).

In summary, whilst the TCSG thought that 'normal' domestic life would continue unchanged at Trinity Close, residents held strong views about their heat comfort practices and the installed technologies which were vital in shaping everyday practices at home. Taking a close look at the meanings of heat comfort management, this section has demonstrated that far from the TCSG's assumptions that individual residents would make profit-maximising decisions about their energy consumption, electricity use associated with heating was bound up with prevailing practices and conventions that sustained 'normal' household life. Energy-related heat comfort practices were also structured by past experiences and future visions. This meant that electricity demand and heating use was highly variable. Indeed electricity demand was perceived by 50 percent of tenants not to have decreased, even in their thermally-efficient properties (Section 5.1).

Rather than autonomous decision-making, understandings of heat comfort practice performance were developed and adjusted in constant negotiation with members of the household, neighbours and friends/family. Importantly, householders also held strong opinions about the TCSG, their organisation of the initiative, and the planned second phase of the development. Here, issues of transparency, trust, communication and inclusion were shown to have both partially configured domestic life, and to have shaped delivery of the TCSG's objectives.

5.2.4. The Trinity Close initiative as an intervention in practice

Analysing the changing elemental composition of householders' heat comfort practices, and associated domestic practice bundles and complexes at Trinity Close, has demonstrated that the TCSG's ambition of non-intervention in household practice was an unrealistic goal. Investigation has shown that 'introducing new practice elements necessarily has knock-on effects on other elements, which often play out in unexpected ways' (Macrorie *et al.,* 2014a: 103). As such, when seeking to gain accreditation to CSH level six, the TCSG's narrow focus on energy-efficient and renewable technologies intended not to challenge how electricity was used in the home or disturb established domestic life, was likely to run into difficulties. In addition, behavioural change attempts, by targeting householders' attitudes and values through reflection on provided energy feedback, had limited and short-term results, and led to a wide range of unexpected, and sometimes negative, understandings of the technology, initiative and its organisers.

Attempting to maintain the integrity of conventional household practices in the low-energy homes, the techno-rational design and implementation of Trinity Close Phase One failed to account for how elements of domestic practices were interrelated and would have knock-on effects on other practice elements, and/ or connected practices. Building on Spurling *et al.,* (2013) and Macrorie *et al.,* (2014a), these observations shift attention from a narrow focus on only technology or behavioural aspects of housing practices, and open up opportunities for intervention in other practice elements (see Chapter 7). They also suggest that 're-crafting' the elements of individual practices, may be unlikely to succeed unless interrelations occurring between practices are considered.

5.3. Shifting housing design and construction practices

In this section, the Trinity Close initiative is analysed as an explicit intervention in housing design and construction practices whereby implementation of a Code for Sustainable Homes (CSH) level six scheme, sought to deliberately shift the professional practices of BDC, DJH, WHA and subcontractors in less energy-intensive directions. To explore how, if at all, the housing design and construction practices were replaced by less-resource intensive alternatives, analysis is framed by the second (of three) modes of practice intervention outlined by Spurling *et al.,* (2013) and Spurling and McMeekin (2014) – that of *Substituting Practices* (see Chapter 2). This way of intervening in practice is defined as 'replacing less sustainable practices with more sustainable alternatives' (Spurling and McMeekin, 2014: 11). This might involve encouraging defection from unsustainable practices, and recruitment to more sustainable alternatives. For example, when the Code for Sustainable Homes was first launched, higher code levels were to be phased-in as mandatory requirements for the construction industry to meet over the long-term, encouraging a shift from energy inefficient house-building, to more sustainable methods and materials. Alternatively, more sustainable versions of existing practices might be encouraged. For example, the original standard specifies that, when designing new-build homes, a significant proportion of energy demand should be provided by low and zero carbon energy sources, as opposed to the National Grid. CSH level six also requires that facilities for tumble-drying be replaced with in-built air-drying amenities (DCLG, 2010).

An assessment is made as to how low-energy housing design and construction practices were initiated at Trinity Close, how professional practitioners were recruited to this standardised way of building homes, and whether the performance of this alternative practice could be sustained. Analysis draws on interviews held with professional practitioners directly involved with the housing development, which were conducted after eighteen months of tenant residency. It is argued that in order to govern the sustainability of housing design and construction practices, it is crucial not only to intervene in practices-as-entity but to also generate opportunities to reproduce sustainable practices through more or less faithful performances over the long term (Macrorie *et al.*, 2014a).

5.3.1. Generating environmentally sustainable housing construction practices

In practice terms, the aim of the Trinity Close initiative was to enhance the environmental sustainability of social housing infrastructure by inserting new energy-efficient building materials and renewable technologies into the everyday working practices of housing design and construction professionals. As discussed in Chapter 4., the professional practitioners involved on the Trinity Close project researched, procured, installed and learnt to operate and maintain a wide range of new materials, equipment and devices in order for the housing development to meet the technical specification of CSH level six. The housing professionals also required new skills and competences, delivered through training courses or learnt on the job. In addition, they needed to embrace new understandings and meanings associated with low-energy house building.

Whilst the CSH provided an explicit roadmap for implementing low-energy housing and construction at Trinity Close, it proved difficult for the professionals to modify their embedded 'ways of doing', as they came up against distinct challenges. First, the low-carbon technology market was fast evolving, with new products becoming available each week, making it difficult for DJH to select, and understand operation of, materials and technologies most appropriately placed to meet CSH level six requirements. As discussed by Tom, a senior management figure in DJH:

> *"…You'd be two weeks into [designing with] a [particular] product and all of a sudden something would come out that was better, so we had to put a stop date on what we [were] researching".* (PR9, DJH)

Additionally 'low-[energy] housing meanings lagged behind the newly acquired technical devices and materials' (Macrorie *et al.*, 2014a: 100-101). For example, Tom from DJH described how it took time for the project team to switch from an economics-driven logic to a sustainability-driven housing construction rationale when, *"[Code level six] properties cost one and a half times more money to build"* (PR9, DJH) than conventional houses. In addition, clarity about the requirements of the CSH standard and confidence in its codified technical approach increasingly waivered during the construction project. In particular, DJH increasingly believed that the CSH was too technically prescriptive, and supported an urgent review of the standard:

> *"[With the CSH] you're driven down a path, a path that you have no choice in. And… that needs to be looked at in a bigger way, not at a scheme-by-scheme level, but it should be looked at at a government level".* (PR9, DJH)

> *"With CSH…that really focuses on the individual house and you can bump your score up with, what I think are some pretty superfluous points, you know, if you've got the right planting and that sort of thing… But I think it's really important to take account of the whole development".* (PR1, BDC)

> *"…The CSH and the requirement for carbon-neutral living run in two separate tangents. I don't think they are compatible with one another… There [are] products on the market that will give you much better results, that don't fit with the Code".* (PR9, DJH)

Prior skills and experience – learnt through engagement with 'thermally leaky' conventional builds and lower Code builds – could also no longer be relied upon', but proved difficult to move away from (Macrorie *et al.*, 2014a: 101). One of the senior management representatives of DJH described the amount of work involved in encouraging this shift away from established energy-inefficient house-building practices:

> *"It's not just the end result and what was produced [i.e. accreditation to CSH level six], it was everything that was involved in getting there…every nut and bolt… It took a lot of work to get there...[But] they all came in on it, all the people that work for us. At the start they were like, 'What's this about?' …By the end they were all on board with [the project]. They were all doing their little bit…".* (PR10, DJH)

By focusing intently on the promise of technical solutions, and aiming to insert more energy-efficient materials and devices into professionals' construction practices performed at Trinity Close, the initiative (in adhering to CSH level six requirements) largely overlooked competences and meanings associated with energy-efficient house-building. For example, it became clear when talking with a senior management representative from WHA that minimal training was deemed necessary for WHA personnel, with the exception of training provision for the grey-water-recycling (GWR) system:

> *"…We're a big rural housing association… so the only bit of kit that is unusual is the grey-water-recycling system… DJH are providing two years maintenance on them and they're also providing training for our plumbers to get their head around them".* (PR7, WHA)

And yet, the majority of householders described how technical faults had arisen at Trinity Close (Section 5.2), and expressed concern that none of WHA, DJH, Adapt or their technicians were confident as to how to operate, or could advise the residents on the installed materials and equipment (at least initially). In this way, new materials themselves often also struggled to align with the requirements of the CSH standard (Macrorie *et al.*, 2014a: 101). For example, one resident explained how:

> *"To be honest, none of them know how the equipment works. You ask, 'How does this work?' and they say 'Well I don't know'. And you even get the people who installed the stuff to come and show you how things work, and even they don't know how the things work!… They put the technology in, and they don't even know how to use it, so what is the point of that?"* (H12A)

In order for new low-energy housing construction practice entities to be generated and sustained, prerequisite practice elements needed to come together and be integrated.

Placing focus on only altering one element in isolation (i.e. materials, without tackling associated meanings and competences) has been shown to be insufficient, in that it led to a failure to realise and sustain deliberately modified housing construction practices. Just as shown for householder practices (Section 5.2), such a narrow techno-rational approach is deficient by 'failing to account for knock-on effects on other practice elements, or from connected practices' (Macrorie *et al.*, 2014a: 103). Arguably, as well as highlighting opportunities for intervening in other practice elements, this analysis further underlines that 'attempts to replace the elements of individual practices may be unlikely to succeed unless wider systems of practice are taken into account' (*ibid.*). This observation is developed in the following section.

5.3.2. Developing low-energy systems of housing construction practice

In addition to attempting to generate more environmentally sustainable housing construction practices through elemental reconfiguration, the Trinity Close initiative can be understood as an attempt to insert a whole set of interconnected low-energy practices into the housing system (Macrorie *et al.*, 2014a: 104). Trinity Close acted as a flagship scheme intended to investigate, and demonstrate, how low-energy housing could be developed (Chapter 4.). It was hoped that the uniquely positioned trial would inform future builds in Broadland district (particularly the proposed Rackheath eco-town), and would encourage low-energy house-building practices to be taken-up more broadly by the housing industry. As explained by a member of the district council and a BDC councilor:

> *"Plans at the time were to develop a CSH level six scheme using different green technologies to enable us to find out what works and doesn't work in order to help inform the [Rackheath] eco-community proposal. As it turns out Trinity Close were the only homes to be built at the time".* (PR6, BDC)

> *"If nobody does it [builds social housing to CSH level six], you'll never know. Someone has to be bold enough… Hopefully that information [gathered from the trial] will be of use to other developers".* (PR4, BDC)

The effort to construct new systems of practice was also enshrined in the CSH standard itself, which contained stringent specifications for exactly how CSH level six compliant properties could or should be achieved. Several interviewees involved in the design and construction of Trinity Close described how the build specification for the twelve units was constrained by the Code requirements and assessment procedure. As discussed by Dave from WHA in relation to the final technical specification for the properties:

> *"I don't think there was any real alternative on that site to get Code six, that was the governing factor, I don't think there was any other way that we could have achieved Code six on that site without PV panels, when we dismissed the district heating system and biodiesel route... Obviously super-insulation, so the fabric first approach is there, and that gets you to Code four. But to then get it to Code five or six you're looking at PVs and grey water recycling".* (PR7, WHA)

Likewise, Tom from DJH described the rigorous assessment procedure associated with the CSH accreditation process, particularly given that Trinity Close was designed in accordance with the original Code definition (Chapter 3):

> *"We were one of the only larger contractors to work to the old Code, which I mean we had BRE [Building Research Establishment] looking at those documents for… six and a half months before [Trinity Close] got a certification... And they couldn't find any fault in what we did, which I think was a big issue for them, because they've changed the Code on the basis that it was kind of unachievable".* (PR9, DJH)

Working to the CSH accreditation process - comprising point-allocation for different sustainability categories and generation of an energy rating in accordance with the Standard Assessment Procedure (SAP) - not only provided the housing professionals with the competence required to ensure they could meet CSH level six; it also determined compatibility with the new system of practice. The standard therefore 'sought to generate connections between housing-related practices and practitioners that would encourage the professionals to move away from conventional build approaches, and simultaneously construct a new system of low-energy housing practices' (Macrorie *et al.*, 2014a: 104).

However, instituting new systems of practice proved to be challenging and as noted, unsurprisingly, Trinity Close encountered issues. As revealed in Chapter 4, the development architects and quantity surveyors in DJH came up against difficulties when attempting to source appropriate technologies. Without the necessary (low-energy) competences, the professional practitioners struggled to source and receive advice on, specified building materials, an issue that was exacerbated by the nascent UK low-energy housing supply chain. Reflecting on the difficulties experienced when attempting to source suitable technologies in the UK, Tom from DJH outlined how he thought that the low-energy housing market and associated supply chain should be encouraged:

> *"[The housing industry] might need a kick-start initially to have more developers building to better carbon values at which more products [i.e. houses] will be sold. Once more products are sold there'll be more R&D [research and development] into [technologies and materials] at which point the products will become cheaper".* (PR9, DJH)

Similarly, one of the planning officers from BDC raised concerns about how the CSH standard connected with, and appeared to act counter to, recent planning policy-making practices advocating growth. He commented:

> *"With the NPPF [National Planning Policy Framework] being produced last year by this Government … the main thrust of sustainability is economic sustainability … approve [new housing developments], build things [and that'll get the country moving] …".* (PR1, BDC)

In this way, dependencies and interconnections with policy-making and market-related practices had distinct implications for the low-energy housing system as defined by the CSH standard (Macrorie *et al.*, 2014a).

Despite these initial challenges however, as the Trinity Close initiative proceeded, new systems of low-energy housing practice began to emerge. Using photo-voltaics (PV) as an illustration of his argument, a senior management representative from DJH described how the range of available low-energy technologies and materials had increased since the design stage of Trinity Close: *"You only need to look at the time we went to the eco-show five years ago, there were six stands of [PVs], and you go there now there's a whole hall full of 'em"* (PR10, DJH). This product and supply chain development had been accompanied by a decrease in cost per unit: *"You look at the cost of PV two years ago and the number of products on the market, and now its a third of the price"*

(PR9, DJH). Interviewees also discussed developments in the number of accredited properties (particularly at the lower spectrum of CSH code levels), and growing professional knowledge and experience with the energy performance of buildings. For example, an interviewee from Adapt discussed how their skill-based had broadened from a sole focus on monitoring:

> *"Evaluation of monitoring is something that's been part of our core skill base… evaluating carbon emissions and the carbon impact of various things… More recently our focus has been to demonstrate that it's not only the energy consumption in buildings once they're built that's important, but also the embodied carbon in building materials".* (PR2, Adapt)

In addition, a senior planning figure from BDC described how he believed that the Trinity Close exemplar project and proposed Rackheath eco-community, had encouraged other low-energy housing developers to seek to build in Broadland, raising the accepted standard of housing development. He described how:

> *"…One of the massive benefits that's arisen from the eco-community… is [to have developed] an ambition for a higher standard of development… Without the eco-community at Rackheath, I don't think we'd have got 'Beyond Green'*[10] *… If 'Beyond Green' delivers even half or three quarters of what it says it will deliver, then it will raise the bar again… It will be very difficult for a developer to say 'Oh well I'm doing something fairly bog-standard around the corner'".* (PR8, BDC)

These developments demonstrate how in order for the housing professionals to adopt and successfully perform their new low-energy housing construction practices-as-entities, a system of practice capable of supporting and maintaining them, also needed to develop and be sustained (Macrorie *et al.*, 2014a).

This analysis supports findings from Sections 5.1 and 5.2 that highlighted institutionally unanticipated variability in domestic heat comfort practices, and demonstrated that it is impossible to intervene in one element of practice without necessarily affecting

[10] Beyond Green Developments have been approved by BDC to develop a new-build sustainable development at Beeston Park, northeast of Norwich. The development plans to combine principles such as proper streets, 'walkable' centres and a mix of housing types with contemporary sustainable design including very low carbon energy infrastructure and measures to conserve water (Beyond Green Developments, 2011).

connected elements and inter-related practices. It was also revealed that housing professionals' practices, and the outcomes of their interventions, could not be considered in isolation to household practices as they were intricately meshed together. Building on these findings, this section has revealed that housing design and construction practices are embedded within, and dependent on, broader systems of practice. As such, attempts to intervene in any single practice (e.g. energy-inefficient housing design and construction practices), or to ensure non-intervention in practices (e.g. maintaining the 'normality' of contemporary household heat comfort practices), will invariably encounter resistance, and lead to unintended effects as the initiative's effects radiate out across interconnected systems of practice (Macrorie *et al.,* 2014a). Flows between practices are then highly significant as they determine the extent that sustainability interventions can operate smoothly and achieve desired objectives. As such the flows and dynamics between practices deserve greater attention (see Chapter 6).

Whilst studies of whole systems of practice are only recently gaining ground[11] within academia and have yet to be taken-up as an analytical tool in policy circles (Chapter 2), these findings reinforce the importance of examining whole systems of practice, as opposed to narrowly focusing on single practices in isolation. They also underscore how networked practice relations and dynamics mean that no single actor can ever be in sole charge of reconfiguring a system of practice, or steering it in a particular desired direction (Macrorie *et al.*, 2014a). Not only are practice elements transformed through their integration into individual practices, relations between practices, and the ways that bundles and complexes of practice intersect at any one moment, also determine how practices develop over time (Shove *et al.*, 2012: 114).

Rather than seeking to maintain or modify specific practices-as-entities in and of themselves, a 'systems of practice' approach demands identification of the layout of the 'mesh of interconnected practices' (Macrorie *et al.*, 2014a: 105) relevant for the intervention in question. Second, it advocates understanding, and potentially modifying, the relations and circuits of reproduction (Shove *et al.*, 2012) operating between interconnected practices. As opposed to making isolated attempts to insert low-energy materials into housing contractors' construction practices, interventions in housing practices should be undertaken with reference to shifting cultural conventions, an evolving low-energy technology supply chain, and supportive infrastructure

[11] Gaining ground: Making progress.

planning decisions (Macrorie *et al.*, 2014a). Chapter 6 picks up this line of enquiry by analysing the Trinity Close initiative using a 'systems of practice' perspective. Chapter 7 concludes by considering the distinct implications of this approach for the governance of low-energy housing initiatives, and for broader transformations towards environmental sustainability.

5.3.3. Recruiting and keeping low-energy housing construction practitioners

As discussed in Section 5.3.2, as the Trinity Close initiative progressed, low-energy housing practices-as-entities were nurtured and supporting systems of practice began to emerge within Broadland district and the UK. The professional practitioners at Trinity Close also grew in their competences as they worked with low-energy materials and technologies, inducted and supported the residents, resolved maintenance issues, and established the post-occupancy building energy performance analysis. As the professionals performed low-energy housing and construction practices, they therefore developed informed understandings as to what was required to meet CSH level six, gained insight as to the benefits and limitations of the standard, and gradually established what these practical experiences meant for the development of future housing schemes in the district. Despite this showcase scheme however, the second phase of Trinity Close was downgraded to a CSH level four scheme, reflecting substantially reduced sustainability requirements. In addition, low-energy housing practices have thus far failed to gain a stronghold within the UK; the CSH standard has not been mandated and attention has, for now, shifted towards economic development and away from innovations in low-energy housing infrastructure. Trinity Close must therefore be understood, essentially, as a 'one-off' experimental project (Lovell, 2007b), as the housing design and construction practitioners were prevented from repeating their newly acquired low-energy practices (Macrorie *et al.*, 2014a).

The primary objective for the TCSG for Trinity Close Phase One was to attain CSH level six accreditation, as one of the first carbon-neutral, new-build, social housing, developments in the UK. Described in Section 5.1 this appraisal failed to take into consideration the properties as lived-in-homes, obscuring variation in residential energy demand. Aptly described by Dave from WHA, the TCSG's electricity performance monitoring scheme at Trinity Close sought to develop this assessment by appraising the balance between solar electricity production and energy demand by the residents over an intended three-year period. If the scheme could be considered as carbon-neutral when taking into consideration how the residents used their homes over the long-term, it would truly be successful. However, the electricity performance monitoring encountered difficulties. These meant that quantitative analysis of these results only took into consideration one year of 'patchy' data and feedback was undertaken three years after tenant handover. As such, TCSG's assessment criteria shifted from a purely numeric building energy performance calculation, to account for residents' experiences of life at Trinity Close. It also shifted from a focus on individual properties to consideration of the whole Close, and of Rackheath, as a residential community:

> *"Success will be, if [Trinity Close] is a zero carbon scheme, if it meets the energy production as well as the energy consumption over a three year period [pause]... But really, success is if people want to live there and enjoy living there and [there's] a stable community".* (PR7, WHA)

As described in Section 5.1 substantial variation in annual domestic energy consumption was revealed between properties (although significant levels of solar electricity were generated across the site). This meant that only one home (H4) – a notably energy aware household that deliberately sought to reduce electricity payments - was operationally carbon neutral. This largely unexpected disparity between anticipated and realised energy savings indicated to the TCSG that - taking into account technological teething problems - how tenants' everyday lives intersected with the material fabric of the homes was critical to overall energy performance. As Dave from WHA put it:

> *"If [Trinity Close] were a magic or perfect zero carbon scheme, [then carbon neutrality] would be in balance. … But I think the reality of people's lives… meant that it might be zero for one property but not for another. So there are clearly some variations".* (PR7, WHA)

In line with techno-rational approaches, 50 percent of interviewees continued to hold the opinion that ensuring carbon-neutral homes post-occupancy would stem from the installation of energy-efficient building materials and renewable technologies coupled with users' technical compliance and selection to reduce their 'wasteful' energy habits (as prompted by information provision and incentives).

However, insights into the significance of tenants' household practices and routines within low-energy homes gleaned from Trinity Close Phase One, took the TCSG beyond these assumptions and presented the TCSG with two new potential governance routes. On one hand, 50 percent of interviewees began to understand the importance of household practices in broader sociological terms. They argued that far from residents considering a low-energy home in the same way as their previous conventional 'thermally-leaky' house, to achieve a carbon-neutral status post-occupancy necessarily demanded 'behavioural change' and required householders be provided with continuous education and long-term support (quote 14). Additionally, developing carbon-neutral housing was thought to require changes to patterns of domestic routines as opposed to a focus on altering specific energy consumption actions (quote 15), and broader changes in societal values and cultural norms (quotes 16 and 17):

14. *"If you're trying to change a person from 'I just want to whack to heating on' to having a different lifestyle, you can't just give them a new property and send them on their way, you do have to hand hold them… Now I realise that better than I did before".* (PR5, WHA)

15. *"People aren't just moving into a house like you normally do… if there's technologies in there, you do need education, you need guidance and you need help with it. And even just with things like when's the best time to put your washing on, when should you have your windows open, when should you dry your clothes? All the practical things that people on a day-to-day basis need to know".* (PR1, BDC)

16. *"People need to develop a social conscience about energy use. It needs to be like knowing to wear a condom or not smoking which is now considered anti-social. It needs to be considered to be an irresponsible act and there needs to be increased awareness about energy use".* (PR4, BDC)

17. *"[Behaviour change] takes a long time, you have to try and get it embedded in something cultural…".* (PR3, Adapt)

These learnings led to the TCSG contemplating different potential strategies for optimising low-energy housing performance. For example, one interviewee discussed wanting to explore how residents' health needs affected domestic energy demand (PR6, BDC). Another interviewee expressed his desire to explore how tapping into existing village relations, and establishing new connections, could develop more of a low-energy community and help induct new residents (PR1, BDC). This potential strategy was reinforced by the opinion that *"actually developing that community to be self-supportive and [establishing] a collective desire to achieve together and live a lower carbon lifestyle together"* (PR8, BDC) could have offered potential long-term energy, carbon and social benefits.

On the other hand, 50 percent of professional interviewees suggested designing-out occupant involvement and adopting more of a 'fabric first' approach to housing construction, *"where really well insulated homes [are built] and there isn't a great deal of technology"* (PR1, BDC). The latter option captured a greater number of professionals given: i) maintenance issues associated with add-on technologies (quote 18), ii) difficulties ensuring the 'optimal' use of installed technologies (quote 19), iii) prohibitive costs of building to the CSH level six standard (quote 20), and iv) support of the fabric first approach by other Registered Providers (RPs) of affordable housing (quote 21):

18. *"For us the dream development is one that has no maintenance costs. …Reducing your heat loss, making your u values fantastically low is great because it… reduces maintenance [costs] because bricks and internal walls don't generally require much maintenance. They'd [only] need the odd skim every 20/30 years".* (PR7, WHA)

19. *"I think we've also learnt that the addition of green technologies is not always the answer, mostly because residents can find them difficult to use and complicated to understand even with a lot of help and support".* (PR13, BDC)

20. *"…looking at the cost from a Code four scheme and taking it to a Code six, the price is incredible really and will make certain schemes unviable…".* (PR1, BDC)

21. *"I would go with the housing associations, because… all of them say, super-insulated house, one add-one technology, level four, job-done. It's cost-effective, savings to residents, that's it".* (PR6, BDC)

Despite learnings acquired from experience of Trinity Close Phase One, the TCSG were constrained in their ability to apply their recently acquired knowledge in subsequent performances of housing design and construction practices. The professional practitioners quickly recognised a failure of the techno-rational paradigm to take into account householders' practices, appreciating that these practices were critical to building energy performance and were shaped by broader social trends and institutional and infrastructural patterns. There was also an overall desire amongst BDC to engage with householders. However, broad shifts in the UK political administration, associated regulatory changes, and the economic downturn acted to prevent pursuit of this option (Macrorie *et al.*, 2014a) (see Chapter 6). These substantial and inter-related practice shifts together turned attention away from low-energy construction and attempts to nurture low-energy householders, and towards more profitable house-building techniques. The results were that the TCSG's original ambitious aim – to achieve the highest CSH level six – were abandoned for Phase Two of Trinity Close in favour of building to Code level four, which is only one step above statutory building requirements.

Instead Phase Two Trinity Close was designed to comprise fourteen properties that would be constructed using: *"…a fabric led solution [which] is fundamental to allow a passive carbon emissions and energy reduction…to achieve Code Level four"* and was proposed by the developer as a method that would be *"more efficient than using renewable technologies to reduce the energy demand"* (P24:11). This technical specification however significantly reduced the energy and carbon credentials of the Phase Two properties in comparison to phase one Trinity Close. Instead of seeking to obtain carbon-neutrality, energy-efficient materials and technologies were to feature: super-insulation, double glazing, air source heat pump (with programmer, room thermostat and weather compensator), extract fans from the kitchens and bathrooms, and 100% low energy lighting only (P25). On the basis of these design decisions, the BDC planning department deemed that, in accordance with district planning and national requirements, *'appropriate conditions [had]…been used to ensure an energy and water efficient form of development'* (P26).

In addition, despite learning to the contrary, householders were 'designed out' of the development and expectations around everyday energy 'needs' were not challenged. This was epitomised by the decision not to provide residents with feedback on their electricity consumption or undertake building electricity performance monitoring for the Phase Two properties (although meter readings were taken by WHA at the start and end of one year of tenancy). Together these resolutions translated into pursuit of a more fabric-first housing design approach, abandoning 'add-on' technologies, and a continued emphasis on minimally impacting householders' everyday lives (Macrorie *et al.*, 2014a).

Regardless of what the TCSG had learned from the first phase of development, the new design and construction practices that they had acquired, and the new systems of practice that they helped to construct, the housing professionals involved in Trinity Close were therefore unable to replicate CSH level six low-energy housing design and construction practices in Broadland district. Whilst I am in agreement with Spurling *et al.* (2013) that practices-as-entities form a more appropriate target for sustainability interventions than practices-as-performances (described in Chapter 2), this case demonstrates that practices-as-performances must not be overlooked in the effort to achieve lasting practice change (Macrorie *et al.*, 2014a). Although Phase One Trinity Close provided an opportunity to intervene in the housing practitioners' construction practices-as-entity, without the ability to repeat and hone their skills, apply their newly acquired understandings, and work with modified materials and technologies, these low-energy house-building practices could not be more or less faithfully reproduced over the long term. With limited opportunities to build carbon-neutral housing in the near future, the TCSG risked losing out on the progress made in Phase One in reshaping elements, and reconfiguring housing practices and their linkages.

However, 'a shift in performance also requires broader systemic change' (Macrorie *et al.*, 2014a: 107), and as this analysis will go on to show (Chapter 6) opportunities to replicate and refine modified practice performances were clearly linked to broader cultural practices, policy-making practices and practices of the economic market. The housing professionals in this study and their practices, represented only a small component of the broader system of housing practice. Consequently, shifts in this system shaped the professional practitioners' 'context of action' (Shove, 1998) so that it became almost impossible for them to apply the institutional learning gleaned from Phase One Trinity Close, and the further reproduction of honed low-energy housing practices was prevented. In short, as discussed by Macrorie *et al.* (2014a), whilst the housing construction practice-as-entity began to be modified away from techno-rational approaches and in less energy-intensive directions during Trinity Close Phase One, the limited scope for the professionals to repeat and refine these modified practices, threatened their continued longevity.

5.4. Developing a relational understanding of housing practices

The Trinity Close development succeeded in achieving certification to CSH level six, one of very few housing developments in the UK to gain this sustainability standard. However this chapter has shown that rather than the technical design and associated instructions for tenants standardising low-energy household practices, wide variation in household energy demand resulted across the twelve households during the first year of tenancy. This variation in domestic energy demand has substantial implications for achieving carbon emissions reductions from new-build housing.

In addition, DCLG and the TCSG believed that ensuring energy-efficient technical design of the properties and providing professional support during the construction project would automatically shift house-building practices in less-energy intensive directions. Instead, this chapter has shown that such a transformation required not just the introduction of new materials, but also demanded modified ways of thinking about and managing the building processes, as well as new skills and abilities for interacting with the materials and tenants post-occupancy. These non-material requirements were frequently overlooked. Furthermore, the professional practitioners were not provided with the opportunity to embed their modified house-building practices through repeated performance.

This chapter has demonstrated how it proved difficult for the TCSG to isolate and target individual practice (e.g. shifting housing-construction practices in less energy-intensive directions or standardising household heat comfort) due to intricate connections and dependencies leading to unintended, knock-on effects. In response to the question posed at the start of this chapter, I have found that neither a) re-crafting practice elements or b) seeking to shift a practice form sufficient approaches to socio-technical transformations for sustainability. Indeed, this chapter has highlighted how it is often not possible to isolate and intervene in a single practice, without affecting linked practices. As such it is imperative to expand current SPT thinking to think about interventions in practice in more relational and systems-based terms. Chapter 6 takes up this challenge.

Chapter 6. A 'systems of practice' approach to low-energy housing: Reframing Trinity Close.

This chapter completes the Trinity Close story by analysing the initiative as an intervention in a whole 'system of [housing] practice' (Shove and Walker, 2007, 2010; Pantzar and Shove, 2010; Schatzki, 2011; Shove *et al.*, 2012; Watson, 2012; Spurling *et al.*, 2013; Spurling and McMeekin, 2014; Macrorie *et al.*, 2014a&b (see Appendices O and P)). Here I extend the conceptualisation of 'systems of practice', and appraise the potential for applying this concept to the governance of low-energy housing. I do this by contextually appraising the Trinity Close initiative and implementation of the Code for Sustainable Homes (CSH). This extends existing SPT thinking, which whilst having introduced some concepts and terminology to understand the organisation and dynamics of inter-related practices, has to date minimally conceptualised, and applied, systems of practice (see Section 2.4).

The majority of research on socio-technical change has adopted an applied and problem-orientated approach, which whilst embracing different disciplinary traditions, has failed to engage with social or critical theory and commonly falls short of realising anticipated change (Day and Walker, 2013) (see Chapter 2). Decades of social research has shown how change processes are underlain by complex and dynamic relations between heterogeneous entities. These entities include: social conventions; political standards and regulations; economic markets; infrastructures and technologies, that are distributed across time and through space (Watson, 2012). Chapters 2, 4 and 5 demonstrated that abstract assessments of the performance of particular technologies and materials, large-scale surveys of factors influencing individual decision-making processes, cost-benefit modelling and randomised control trials can only ever capture a narrow slice of this socio-technical complexity.

Chapter 5 revealed how it is not sufficient to pay sole attention to the connections between co-evolving practice elements, or to the trajectories of isolated practices. Similarly, studying how housing design and construction practices shifted in less energy-intensive directions at Trinity Close, revealed that housing practitioners' doings were intricately linked with each other as well as with: district planning and development principles; the availability of products on the green technology market; infrastructural availability; and a range of governmental policies. These results echo developments in the literature which increasingly recognise that '… meeting the sustainability challenge will require innovation at a *systemic level* to fundamentally change the way things are done and how societal needs are created and met' (Hargreaves *et al.*, 2013: 402). Given the requirement for a revised approach to understanding, and attempting to affect, socio-technical change that takes into consideration how practices 'interlock' (Spurling *et al.*, 2013; Spurling and McMeekin, 2014), this chapter sets out a relational systems of practice framework. This approach demands first, that attention is paid to whole practice systems as opposed to single practices, their elements, or practitioners that carry them. Second, it calls for a greater focus on the ways that practices interrelate, form links, and can break apart. Third, a systems of practice approach broadens the temporal and spatial focus conventionally allocated to practice studies.

Identifying that conceptualisations of systems of practice have been insufficiently developed, Section 6.1 uses two concepts from arrangement theories and the sociology of translation (Callon, 1986): problematisation(s) and enrolment/ de-enrolment in heterogeneous networks. Applying these notions, and extending existing SPT understandings, Section 6.2 analyses the development of inter-related practices at Trinity Close over a ten-year period, drawing on data from the documentary review (listed in Appendix K), as well as from professional and householder interviews. Low-energy housing developments in Rackheath (Norfolk) are analysed as a system of housing practice that sequentially adopts five configurations according to contrasting problematisations. I use the notions of enrolment and de-enrolment to analyse fluidity in practice system configuration, and to account for how practice 'bundles and complexes' (Shove *et al.*, 2012) can disband from a network, as easily as they are enrolled. Recognising the importance of connections between practices in determining these problematisations, I develop a typology of practice relations. Based on this analysis, Section 6.3 sets out a conceptual framework for systems of practice. Whilst arising from an examination of low-energy housing in Rackheath, this conceptual framework has wider applicability to a range of socio-technical sustainability challenges. Section 6.4 provides a chapter summary.

6.1 Extending SPT using relational concepts from arrangement theories

Chapter 2 described how SPT has all too often concentrated on isolated practices, mundane doings at a household level associated with 'inconspicuous consumption' (Gronow and Warde, 2001), and has overlooked novelty in practice. More recently, particularly due to a growing desire to use SPT to understand systemic change, practice theorists have begun to consider how practices relate to one another as part of wider networks and systems (see Section 2.4, particularly Section 2.4.3) (Shove and Walker, 2007, 2010; Pantzar and Shove, 2010; Schatzki, 2011; Shove *et al.*, 2012; Watson, 2012; Spurling *et al.*, 2013; Spurling and McMeekin, 2014; Macrorie *et al.*, 2014a&b). However, there remains much work to be done to fully conceptualise practice systems, relations between networked practices, and dynamics of practice system change (see Section 2.4.4).

In light of the limited amount of research conducted within the SPT community on systems of practice, their workings, and their implications for the governance of the socio-material world and sustainability, I contend that there is a need to supplement the existing SPT theoretical tool-kit. I argue that existing SPT concepts need further development to better enable the relations and dynamics between networked practices to be investigated and for this understanding to be applied to governance interventions. In Section 6.3, I explain how the systems of practice framework put forward in this thesis takes forward existing discussion of connected practices and their relations (described below).

Burgeoning (largely conceptual) research on practice systems and relations has emerged in recent years. Using the notion of 'circuits of reproduction', Shove *et al.*, (2012: chapter six) consider how elements, practices and links between practices are generated, renewed and reproduced. They use this term, alongside understandings of 'bundles' and more tightly knit 'complexes' of networked practices, to understand how practice performances relate to each other, and to identify 'forms of cross-referencing through which practices shape each other' (*ibid.*: 17). Networked practices and their relations are considered (in rather mechanistic terms) as 'anything other than a single practice' (Shove, 2015: 12). Further the authors avoid describing connected practices as a system as it is suggested that this term is 'borrowed' from the socio-technical systems literature and has a positivist history (*ibid.*).

Focusing on mobility practices, Watson (2012) stresses the importance of systems of practice and their relations and dynamics for the governance of practice and transition to a de-carbonised transport system. He argues that systems of practice not only present opportunities for indirect governance interventions but that positive feedback dynamics could enable processes of change to 'become self-extending' (p.488). Despite these important contributions, Watson fails to set out in detail precisely how systems of practice come into existence, operate and change, and could provide greater discussion of the nature and significance of practice relations. Spurling *et al.* (2013) and Spurling and McMeekin (2014) highlight the importance of affecting how practice interlock for governance interventions, however they omit description of how boundaries can be defined around interlocking practices.

Pred's concept of 'dominant projects' - inter-linked practices that in combination 'require that participating individuals expend their labour power or in some other way engage themselves in activity in a given manner, at a given time and place' (1981: 16) – has also influenced systems of practice research. This concept has helped to understand why some practices capture devotion from carriers and resources (including time and space), reproducing dominant societal institutions. Whilst this notion is helpful for understanding how practices structure society, it does not fully explain why some practices (as opposed to others) come to be influential. Acknowledging this work, Schatzki (2011) turns his attention to practice relations that he argues hold networked practices together to form 'systems', 'constellations' and ultimately the practice 'plenum'. He argues that in order to understand how practices network and how these connections can potentially be reorganised in order to encourage socio-material transformations, it is essential to understand practice relations. He commences this line of enquiry by beginning to describe different types of practice relation and their modes of action (see Section 2.4.4).

Given the limited research on systems of practice to date, there is a need to extend the existing conceptual framework of systems of practice. I do this here by drawing on notions from arrangement theories (the most notable of which is Actor Network Theory (ANT) – described in Section 2.3.2), which provide a 'way in' to analysing networked practices and their inter-connections. Four characteristics of arrangement thinking have overlap with practice-based understandings of socio-material life. First, arrangement theories understand social life as an interrelated 'configuration of human, non-human, material and abstract entities' and importantly, 'the nature of the assemblage is made in the *interaction* and association of these diverse elements' (Day and Walker, 2013: 19, 20, emphasis in original). Second, both require a broad conceptualisation of action through time and across space (Day and Walker 2013: 23; Schatzki 2011; Røpke and Christensen, 2012). They also conceptualise assemblages as dynamic. This prompts questions about how elements (and practices) come together, become entangled, and can disaggregate or be exchanged (McFarlane 2009).

Third, contingency and variety arise from networked relations for both concepts (Day and Walker, 2013). As Powells (2009) points out, often the actors and actants 'enrolled' in networks have more capacities than realised (Callon, 1986; Latour, 2005), generating unanticipated effects. Each actor or actant is also simultaneously enrolled in many networks, resulting in a multiplicity of socio-technical relations, and increasing the contingency of change processes. Lastly, whilst SPT and arrangement theories share the concept of distributed agency, they adopt different understandings of the enactment of agency (see Section 2.3.2). Whilst actor network theorists allocate the same level of agency to non-humans and humans, SPT contends that materials only have agency through their being used and meanings being attributed to them.

However, arrangement theories have limitations. McFarlane and Anderson (2011) and Jacobs (2012) note that because the approach traces which actors and actants are involved, how they come together and stabilise, it is not good at understanding what might be absent from a network. Additionally, in focusing on a particular assemblage, the approach can overlook wider structures within which networked entities operate (Day and Walker, 2013). ANT has also been criticised for merely providing a descriptive account of endless chains of association and failing to explain 'why some possibilities for reassemblage are actualised over and against other that are suppressed or excluded' (Brenner *et al.*, 2011: 235). In drawing on arrangement theories to help analyse systems of practice, it will be important to bear these critiques in mind.

Having determined how SPT and arrangement theories are commensurate and highlighted differences between the two approaches, I home in on the ANT concept of Sociology of Translation. In particular, I contend that problematisation and enrolment/de-enrolment are useful for understanding the changing configurations of networked systems of practice. As Callon's (1986) influential paper described (see

Section 2.3.2), scallop conservation research at St. Brieuc Bay emerged, enrolled certain actors and agents, and was only sustained, due to a particular problem-nature of the network. When those issues changed, configuration of the network altered, actors and agents de-enrolled, and the network ultimately disbanded. In this way, Callon suggests that the problematisation 'possesses certain dynamic properties: it indicates the movements and detours that must be accepted as well as the alliances that must be forged' (1986: 206). Similarly, here I suggest that problematisations of the Rackheath system of practice emerge from networked practice relations, which are consequently critical to sustainability transitions and deserving of attention. In the next section, I apply these concepts to understand how different practices came together as part of an evolving system of low-energy housing-related practice at Trinity Close.

6.2. Five problematisations configuring Rackheath housing initiatives

This section describes five problematisations that shaped low-energy housing initiatives and practices in Rackheath, Norfolk. The analysis considers the various planned and enacted ways of doing practices related to low-energy housing in Rackheath, as an evolving system of (housing) practice. After Callon's (1986) definition, problematisation is used to describe how particular challenges led housing-related practices in Rackheath, their elements and the practitioners carrying them, to interlock in particular configurations. The five described problematisations, to some degree, artificially divide the network of practice bundles and complexes, because change is ongoing. However, understanding the evolving nature of low-energy housing initiatives in Rackheath, and implementation of the CSH, in this way, enables appraisal of the entangled practice relations and dynamics that continuously shaped this system of housing practice. Moreover the five problematisations were inductively generated through analysis of household and professional interviews, and the document review.

Throughout this analysis, different types of practice relations are gathered (highlighted in bold), and later typologised (Section 6.3.3). I contend that this is important because the five different problematisations are emergent from the practice relations, and understanding these continuously dynamic relations provides a way to potentially intervene in the networked configuration of the system of practice. The identified problematisations track the changing form of the low-energy housing system of practice in Rackheath across a period of almost a decade. They also take into account events not just occurring within Trinity Close, but also: local protest in the Rackheath area, regional planning policies, national building regulations, European Directives, and international economic markets. Paying attention to these problematisations and networked entities and understanding the characteristics of different practice relations, is shown to be crucial for the governance of low-energy housing-related practices, and for sustainability transformations more broadly.

6.2.1 The need for an increased (affordable) housing supply

Origins of Trinity Close stem from as early as 2004 when the Barker Housing Review prompted the United Kingdom's (UK) Labour Government to acknowledge consistent under-investment in housing, particularly in affordable homes (P27). Consequently, in October 2006, Greater Norwich was designated a new Growth Point and plans were agreed for 33,000 new homes in the area by 2021 (P28: 32). This review rendered a national deficiency in housing 'thinkable… calculable, and amenable to deliberated and planful initiatives' (Miller and Rose, 2008: 28). To meet these targets, DCLG established the Greater Norwich Development Partnership (GNDP) to coordinate a strategy for sustainable growth (P29). These commitments to sustainable growth in the region reveal the first problematisation, or governance logic (Foxon, 2013), informing housing initiatives in Rackheath. Even at this early stage, actors and their practices - previously unacknowledged in the governance of Trinity Close - were being enlisted in the assemblage of housing-related practices, defined by the need for affordable housing, associated growth targets, planning policies and funding.

As explained by a senior figure in Broadland District Council (BDC)'s planning department, these growth targets prompted a raft of regional planning policies for the area. The interviewee suggested that this was a "top-down" (PR8) approach to governance. Alternatively, implementation of this agenda can be understood as a strong, uni-directional link from the governing practices of DCLG to those of their designated service providers. The planner described how,

> *"The Joint Core Strategy and the Greater Norwich Development Plan jointly look at what the housing need is in this area. Under the Labour government that was very*

much a top-down "You will provide X number of homes in this area"… Afterwards each Local Authority starts to look at… how are we going to distribute those homes within this area? … The planning policy documents…start to draw that forward" (PR8, BDC).

This linkage between central and local housing governance practices was not only **emergent** in generating new planning objectives, reallocating capital and prompting formation of a new formal institution (GNDP), it also triggered a **cascade** of housing-related practices to be undertaken to deliver the required urban and rural growth. After the GNDP committed to sustainable growth, in early 2007 the CSH standard was made operational (P1, P2). As described in Chapters 1 and 3, this standard had a history that was not mono-causal. It formed part of a swathe of carbon mitigation measures affecting many sectors, mandated by the UK Climate Change Act (UK Government, 2008). In specifying environmentally sustainable housing, CSH attempted to **standardise** the way in which new homes were to be designed, built and lived in. Whilst met with scepticism from the housing industry, DCLG encouraged home-builders across the country to follow CSH principles.

Anticipating a mandatory requirement for new builds to be carbon-neutral by 2016 (P1; P30), the house-building industry paid careful attention to the launch of the CSH, yet few construction companies wanted to depart from their established ways (Monahan and Powell, 2011). This reluctance demonstrates the difficulty of dislodging housing-related practices that have become tightly interconnected with other supporting practices, for instance: financial practices, manufacturing practices, supply-chain links, building repair and maintenance, tenant management, and infrastructural design. These embedded relations acted to **reinforce** the stability of associations between established practices, and to constrain practice change. In this first problematisation strong practice links did not just originate from government practices and policy. Equally forceful relations resisting change were established between housing industry associations, contractors and suppliers, and the services and materials on which they relied.

To help transform housing construction practices, the Government launched the Zero Carbon Hub (ZCH), an organisation with the objectives of 'creating confidence during change, reducing risk and obstacles, and disseminating practical guidance' (P31). The ZCH's remit was to **enable** environmentally sustainable house-building practices to become established by 'mobilising knowledge' related to the CSH standard (Faulconbridge, 2012). To further encourage adoption of the CSH, housing associations were required to trial CSH to level three (Lovell and Smith, 2010; P32). This stipulation is understood as a 'public demonstration' or 'public **experiment**' (Barry, 2001; Bulkeley and Castán Broto, 2013). As explained by a senior figure in Wherry Housing Association (WHA),

> *"Governments tend to use housing associations as a sort of tester of new technology… the Code came in for [us] on a mandatory basis years before it came in… for private house builders"* (P7, WHA).

It was then with a requirement to provide more affordable housing in Broadland, the housing industry pre-empting increasingly stringent environmental requirements, and with commitment from the Homes and Communities Agency (HCA) to **demonstrate** the viability of CSH, that in early 2008 WHA gained planning approval for twelve affordable homes to be built to CSH level three in Rackheath (P33).

Studying how the Trinity Close affordable low-energy homes came to be commissioned, has begun to demonstrate how different practice relations of varying force, nature, number of connections, and direction, shaped how housing-related practices, elements, and actors were brought together in Rackheath. As evolution of this housing-related system of practice is analysed, it is useful therefore to consider how different relational ties and connections generated particular problematisations. It is also important to understand how these problematisations concurrently held this system of practice together in distinct configurations, and with what effects. Section 6.2.2 provides a more detailed discussion of different practice relations and their effects, distinct problematisations, and particular configurations of the studied system of practice.

6.2.2 Ensuring large-scale green growth within Broadland District

Following the Stern report on the Economics of Climate Change (Stern, 2006), which highlighted the role of a plan-led system on economic growth, and in response to forthcoming carbon reduction budgets enshrined in the Climate Change Act (UK Government, 2008), in March 2007, the Labour Government announced plans to build five eco-towns as part of the New Growth Points (NGP) programme (P34).

To be eligible for DCLG funding, eco-towns were required to meet a number of criteria. The proposed development as a whole had to be zero-carbon and between 30-50% of total housing had to be allocated for affordable homes (P35: 6). Presented with an opportunity to turn designated expansion in Greater Norwich into socially and environmental beneficial growth, BDC collaborated with a large-scale housing developer, Barratt Developments Plc. (Barratts), and their low-carbon consultant, the Low Carbon Innovation Centre (Adapt). Together they developed a concept statement proposing an eco-town at Coltishall (eight miles north-east of Norwich). There was a desire to pursue high environmental standards for prescribed new homes in the area, as described by a Local BDC Councillor,

> *"We want to be better than just statutory building requirements in Broadland. We want to promote the construction of energy-efficient units for residents, and [to] work with and encourage… local housing associations to [build more environmentally sustainable developments]"* (PR4, BDC).

This proposal redirected BDC's planning team from a focus on developing affordable homes towards collaborating with Barratts in *"being one of the front runners in looking at energy-efficiency across large-scale developments…"* (PR1, BDC). It was thought that this potentially lucrative eco-housing scheme would not only **demonstrate** the viability of building to CSH level six, but would showcase BDC as a progressive council and transform DCLG targets into a sustainability opportunity. When the Coltishall eco-town proposal was announced however, the perceived detrimental influence of mass-housing provision on the landscape led to vociferous criticism (Manns 2008). Sceptical of the eco-town's environmental credentials, a community campaign group, Stop Norwich Urbanisation (SNUB), formed in objection to development and sought to **prohibit** local house-building. As described by a resident involved in protests against the eco-town,

> *"I'd known about [BDC being involved in building eco-homes]… because we all done protests and things… 'cos they were talking about putting practically a whole new village down here… I know that people weren't happy"* (H1A).

Housing development practices were **contingent on** local consultation outcomes, and unanticipated levels of contestation forced Barratts, BDC and Adapt to reposition the scheme. In August 2008, Rackheath was recommended as the revised location as it was closer to Norwich city. To help embed the eco-town in the local Rackheath community, the design made provision for a £1.3M eco-community education centre and community trust. In addition, the eco-town strategy promised to ensure 870 existing Rackheath households[1] would meet at least Energy Performance Standard grade C[2] (P36). In this way, the housing-related practices of existing residents were 'adsorbed' (Deleuze and Guattari, 1987) by planning, architectural and consultancy practices, and held in a configuration determined by pursuit of large-scale green growth within Broadland district.

Design of the eco-town was distinctly moulded by the UK Government's commitment to develop renewable technologies and roll out smart meters by 2020 (DECC, 2009). Energy-related projects were to include a biomass energy centre and a community heating network. In addition, renewable technologies and energy-efficient building materials were to be installed in each property. The eco-town was also to use energy monitoring systems to appraise technological performance, and occupants were intended to receive feedback and incentives designed to encourage domestic energy demand reduction. Whilst later abandoned when the idea decoupled from the eco-town assemblage, a senior Adapt consultant described how,

> *"… We were talking with… developers [about] personal carbon trading… and [DCLG] were really interested in that… We were looking at… collect[ing] data on individual residents or households' personal carbon footprint and [having]… a [variable] management fee… depend[ant] on… individual carbon performance"* (PR2, Adapt).

Competitive practice relations also shaped the low-energy housing assemblage at Rackheath, as Barrett Homes, BDC and Adapt sought to develop a winning eco-town bid that would receive DCLG funding. As the Adapt consultant proudly explained, when in July 2009 the Eco-towns Planning Policy Statement (PPS) was published, Rackheath topped the Government's list of proposed eco-towns for suitability,

[1] 870 existing households were included in the Rackheath eco-town proposal in order to meet the minimum population specified by the Eco-town Planning Policy Statement (PPS) of between 5,000 and 10,000 units.
[2] Energy Performance Certificates were introduced in England and Wales on 1 Aug 2007 as part of Home Information Packs (HIPs) for domestic properties. When the requirement for HIPs was removed in May 2010, the requirement for EPCs continued.

> *"[DCLG] gave it the highest energy or carbon or sustainability rating of all of the proposals that went in! [Proudly] Which… triggered BDC to put in a programme of development for Rackheath"* (PR2, Adapt).

This section has discussed how attempts to turn housing targets for Greater Norwich into socially and environmentally beneficial growth changed the Rackheath development agenda from prioritising affordable homes to developing an eco-town. The problematisation shifted from coalescing around affordable house-building practices to a configuration geared towards large-scale green development. Section 6.2.2 has also discussed how connections between practices were broken, and new practice relations were established and reinforced in the development of the Rackheath eco-town. This underlines the importance of practice-relations in terms of how different housing-related practices became connected, and continually shaping the networked configuration adopted by the housing practice system in Rackheath. The suggestion that 'elements have no significance except in relation to their neighbours, or the structure of the system as a whole' (Law, 2000: 4) potentially has merit here in suggesting that relations are at least as, if not more, important than the constituent practices of a networked system.

When considering why the studied housing system of practice changed configuration, different relations between practices have been revealed including: new regulations, funding streams, and opportunities to demonstrate energy-efficient technologies. Analysis has revealed how, for the Rackheath housing initiative, change originated from any point in the practice system – for instance, from residents objecting to development, to European Directives demanding national carbon emission reductions. Additionally, it has been shown that practice relations are continuously dynamic, can occur concurrently and can work together in different ways at different times. These relational processes led to the emergence of different problematisations. Contrasting the need for more affordable housing in Rackheath (Section 6.2.1) with the challenge of large-scale green growth (Section 6.2.2), has demonstrated how these different problematisations had implications for the sustainability of housing-related practices.

6.2.3 Demonstrating codified low-energy housing construction

Whilst the GNDP envisaged that Broadland district would *"trailblaze"* (PR6, BDC housing officer) new methods of housing construction by pioneering one of the first UK eco-towns, by late 2009 the proposal was encountering difficulties. Suffering from the **chaotic** effects of the international financial crisis[3], a downturn in the UK economy dramatically affected the housing construction sector as land prices fell and mortgage lending declined (Property Wire, 2009). Implications of this 'credit crunch' for construction in Broadland, were described by a senior member of the BDC planning team, *"I think there is a potential housing crisis… You're seeing somewhere between 5-10% of all the [planning] permissions that have been agreed actually being completed"* (PR8, BDC).

The economic downturn, coupled with local opposition to development, **prohibited** development of the Rackheath eco-town, as the housing developer became less prepared to embark on experimental projects. As described by a local councillor,

> *"Barratts say that they're not in a position to build [the eco-town] as the cost of the land doesn't justify the return… They're the main land-owner so [things have] stalled for the moment. Plus we've had lots of local objection"* (PR4, BDC).

This reversal illustrates the 'powerful forces (human and non-human) that keep [commercial housing-related practices] in place'(Lovell and Smith, 2010: 461) and **reinforce** lock-in to the trajectory of building energy-inefficient houses (Berkhout, 2002; Unruh, 2002). It also shows how development of the eco-town was inherently linked with economic practices and was continuously open to change by political and economic intervention, 'including that affected deliberately or inadvertently, and with unintended as well as intended consequences' (Lovell and Smith, 2010: 465).

With Barratts reluctant to progress the eco-town, a new strategy was required. Pressure from DCLG to **demonstrate** the merits of the CSH, altered the form of the Trinity Close housing system of practice configuration from a large-scale eco-town to a pilot of twelve CSH level six homes. However, the original CSH level three planning

[3] The collapse of Lehman Brothers, a sprawling global bank, in September 2008 almost brought down the world's financial system. Huge taxpayer-financed bail-outs were used to help the industry recover. Even so, the ensuing credit crunch prompted the worst recession in 80 years (The Economist, 2013).

permission constrained the design of the exemplar. As senior members of the BDC Planning Department and WHA described,

> *"When the eco-community bids were put in… DCLG was saying, "this is great, but we need some early wins! We need to see some Code six development coming forward very quickly, so Ministers… can point to stuff on the ground … and we can say this is a successful development"* (PR8, BDC).

Consequently,

> *"[WHA] were approached by the council who was leading the plans on the Rackheath eco-community… They said, "look as part of that [project] we can access funding from the [DCLG]… to [upgrade] the current scheme at [Trinity Close] to a Code six [development]". [It was] a kind of benchmark, a trial really to look at what [could] be done in terms of providing energy-efficient homes"* (PR7, WHA).

WHA's recruitment to building carbon-neutral homes shows how the objective of conducting a CSH level six pilot was translated from DCLG and BDC to the housing association (Callon, 1986). Opportunities for involvement on the new pilot scheme **created** practice links that did not exist before and modified the previous intention of building an eco-town in Rackheath. Not now required to implement the biomass burner, district-heating scheme or to build houses *en-masse*, Trinity Close was intended to test (or **experiment** with) how low-carbon technologies and energy-efficient materials would work at an individual house level. This appraisal was intended to help define requirements for future low-energy builds in Broadland district. As described by a BDC housing officer,

> *"Plans… were to develop a CSH level six scheme using different green technologies to enable us to find out what works and doesn't work, in order to help inform the eco-community [and future builds within Broadland district]"* (PR13, BDC).

And by one of the first residents,

> *"We all knew … what we could we be getting ourselves into. [These homes have] never been built before … [WHA and Adapt] told us that we were going to be*

> *guinea pigs really because the equipment was all new, it had never been put in these houses before, so that's why we're being monitored for so many weeks…"* (H12A).

The main reference point for the design of Trinity Close was pursuit of Code level six points, which served to enrol and mobilise particular practices, elements, and their practitioners to building a **standardised** housing exemplar at Trinity Close (Callon, 1986; Rodgers *et al.*, 2009). This point system influenced selection of renewable technologies and energy-efficient building materials for the development (**contingent relations**)(Chapter 4), however even at this stage, some of the professional practitioners felt the CSH requirements to be somewhat arbitrary and bureaucratic. As outlined by a BDC planner and a senior manager from DJH,

> *"With CSH… it really focuses on the individual house and you can bump your score up with… some pretty superfluous points… if you've got the right planting and that sort of thing... But I think it's really important to take account of the whole development"* (PR1, BDC).

> *"Trying to balance the Code and ticking all the boxes… it's a lot of box ticking! Trying to balance [that with a] good product [i.e. a well designed house] – I'm not sure that they're in line with each other…"* (PR9, DJH).

In addition to the pursuit of CSH points the Trinity Close technical design and tenant engagement strategy were informed by other practice relations. First, the TCSG's previous experiences of low-energy housing shaped the design process. BDC, WHA and Adapts' previous experiences of building or retrofitting low-energy housing had highlighted the importance of occupant technology interactions in determining building energy performance. Monahan and Powell (2011) appraised a small BDC development in Lingwood (Norfolk) and highlighted the need to question how households use new technologies, alongside how eco-homes and the technologies within them affect behaviour and service expectations. Similarly the Visible Energy Trial, with which Green Energy Options (GEO) and Adapt were involved, revealed limitations of monitoring feedback in 'changing user behaviour' (Hargreaves *et al.*, 2010). As discussed by a senior figure at GEO,

> *"[We] found… you can give people too much [information] too soon, and they get scared… "Woah, crikey! What the hell's going on here? … I don't understand it!"… Also [the monitor] starts off in the kitchen… and gets pushed to the back of the house"* (PR11, GEO).

These experiences can be understood as **cooperative** relations that underpinned and supported the design and tenant management approach informing Trinity Close. Despite these ties raising concerns around householder engagement, a techno-rational evidence-base commended a technical design strategy that sought to largely limit active tenant involvement in energy demand management.

Second, the nascent low-carbon technology market restricted some technological aspirations for Trinity Close. For instance, whilst the TCSG opted to install the GEO Trio energy monitor, limited connections established between housing design and construction practices and the green-technology industry restricted how much this device became embedded in the Trinity Close housing-related system of practice (see Section 5.1.1). As asserted by the GEO representative,

> *"Unfortunately [GEO Trio] was one of the first systems that we had… they were quite difficult to maintain… but back [came BDC] saying "It's the only option on the market…, so we'd rather have something than nothing"…On that basis, we did go ahead"* (PR11, GEO).

Similarly, whilst a personal carbon-credit system was initially supported by DCLG, this option was soon ruled-out due to a lack of available technology. Described by two Adapt consultants,

> *"When we proposed [personal carbon budgets] there were very little supporting tools... So how do you create a network?… How do you work out the [carbon] baseline? ... How do you get people to buy into it?"* (PR3, Adapt).

> *"We've put energy monitors into homes [at Trinity Close], but clearly the technology <u>now</u> if we could do it, would be a lot slicker than it was then"* (PR2, Adapt).

The restricted ability to form connections with suitable products had a **prohibitive** impact on the Trinity Close pilot design and in determining how best to enlist new tenants into the low-energy housing agenda.

The third set of practice relations shaping Trinity Close Phase One were initiated by TCSG's concern around the long-term financial viability of carbon-neutral homes. When the Government launched the Feed-in Tariff scheme for domestic-scale renewable energy generation (P38)[4], this consequently resulted in the decision to install large amounts of solar photo-voltaic panels with the aim that electricity export payments to the National Grid would offset future installation costs. *In lieu* of using personal carbon credits, the income stream offered by the Feed-in Tariff offered a communitarian way to incentivise, and attempt to **enable**, residents to pursue sustainable lifestyles. Described by a BDC housing officer,

> *"Feed-in Tariffs [were intended] … to incentivise [residents] as a community to reduce their energy use… The more energy they saved, the more money they got back from the Feed-in Tariff. Then they could do something as a community, like… go on a trip"* (PR6, BDC).

Seemingly an indirect link to the low-energy housing objectives of CSH level six, the domestic Feed-in Tariff clearly intersects with the low-energy housing system of practice at Rackheath. This finding is supported by research demonstrating how non-energy policies relating to security, health and safety, education and employment can, due to indirect practice relations, have major implications on residential energy demand (Spurling, 2014).

In February 2010, the design and approach for Trinity Close having been finalised, DCLG awarded BDC £10.2 million to build twelve homes to CSH level six at Trinity Close (P37). These homes were to incorporate the latest low-carbon technologies, have an energy performance monitoring scheme, and be embedded in the local community by means of a retrofit programme and community trust.

[4] In April 2010, Feed-in Tariffs were introduced by DECC as the main financial incentive to encourage uptake of renewable electricity-generating technologies. Most domestic technologies qualified for the scheme, including solar electricity (PV) (roof mounted or stand alone).

The different configurations adopted by housing-related practices in Rackheath (compare Sections 6.2.1, 6.2.2 and 6.2.3) reveal how a system of practice is continually shaped and reconfigured. Practices enmeshed by the proposition of a Rackheath eco-community continually 'jostled' and 'collided with' those deeply established within the conventional housing market (in which house-building posed less risk and construction was cheaper) (Bourdieu, 2005). This led to the target system of practice being pulled in unanticipated, non-linear directions, away from large-scale green growth and towards the development of a CSH level six scheme.

That the Rackheath large-scale green growth proposal was inherently linked with economic practices, which ultimately led to a dramatic shift away from the eco-community agenda, demonstrates that 'would-be governors' of housing-related practices (Macrorie *et al.*, 2014a) are simply part of these 'ongoing entanglements' (Garud and Gehman, 2012: 983). In contrast to the linear vision of change put forward by TCSG (see Chapter 4), would-be governors of housing-related practices should not anticipate total control over policy interventions.

6.2.4 Appraising the low-energy housing development

Whilst construction of the pilot got underway, in May 2010, the UK Labour Prime Minister resigned, prompting an election. David Cameron subsequently formed a Coalition Government composed of members of the Conservative Party and the Liberal Democrats. This change in political administration had repercussions for the eco-town agenda. Keen to distance themselves from Labour's policies and give local authorities more autonomy, in July 2010, the new housing minister, Grant Shapps MP, cut eco-town funding by fifty percent (P37). Writing to local authorities he stated,

> *"[Funding] awards will be subject to achievement of milestones, and completion of a value for money and sustainability audit on projects. Additionally I want to ensure that localism is a real feature of these schemes"* (P40).

Anticipating a retraction of eco-towns policy and continuing to suffer from the economic downturn, this weakening of practice relations around the notion of large-scale green growth prompted a **cascade** of outcomes. Barratts de-enrolled from the Rackheath eco-community proposal, and by March 2012 the eco-towns planning policy statement was abolished (P41), breaking all ties to this ambition. A housing officer at BDC confirmed that this resulted,

> *"…because of change of Government… and… eco-towns weren't really delivering. The new Government wanted to move away from the eco-towns idea because it was a Labour idea, although… they're basically morphing [the concept] into garden cities[5] now"* (PR1, BDC).

Alongside this shift in policy, as the conventional housing industry continued to place pressure on the Government, there was official recognition that it might not be *"cost-effective, affordable or technically feasible to meet the zero carbon homes standard in all cases solely through measures on the dwelling itself"* (P42: 7). Connections between house-building practices and the CSH were weakened, and confusion grew as to the actual requirements of the standard. Housing associations too began to question pursuit of CSH, particularly given potential long-term maintenance costs associated with CSH level six properties. A senior figure at WHA revealed growing doubts around pursuit of CSH,

> *"There's a debate in the housing association's technical sector about how good the Code for Sustainable Homes is as a definer of sustainable housing… There's a school of thought that says [it] isn't the best way of providing sustainable housing..."* (PR7, WHA).

By September 2011, the first phase of Trinity Close had been completed (to the original definition of carbon-neutral), accredited to Code level six, and tenant hand-over had occurred. Almost immediately, a number of technical issues arose, notably with the energy performance monitoring system and the ASHP (see Chapter 5). Exacerbating these problems, several suppliers were forced into administration (for example, the grey water recycling system (GWR) company) and some systems were withdrawn from market (for example, the GEO Trio electricity monitoring system). The breaking of these practice connections prompted further deliberation as to the merits of building more carbon-neutral homes in Rackheath. As described by a senior figure in WHA,

> *"If I was a council… I would want to look at what works, what didn't work... [Trinity Close Phase One] worked, it provided social housing, it has achieved Code six, but there's a price that comes with that… Do we just roll out [that design saying]*

[5] DCLG defines Garden Cities as 'liveable, viable, modern communities with the resident at the centre of planning… [and] important considerations around local support, scale, connectivity, delivery arrangements, and land' (P39: 6).

"We want Code six on the rest [of new build homes in Rackheath]"? Or do we say, "… actually Code six has its limitations" … The [main] issue is [that] housing associations… have to maintain those properties for 20, 40, 60 years" (PR7, WHA).

In October 2011, DECC published a review of Feed-in Tariffs for small-scale solar PV[6] (due to unexpectedly high uptake), approximately halving the available tariff (P46). Retraction of this vital funding stream, added pressure for TCSG to abandon the low-carbon technologies planned for the second phase of the housing development. As explained by a concerned housing officer from BDC, it also meant that the electricity industry benefited from any electricity generated at Trinity Close as opposed to WHA or their tenants,

"Since Feed-in Tariffs were scrapped, [housing associations are] not getting anything [back] because [any generated electricity not used] is being lost to the Grid. [The properties] may be carbon-neutral, but actually, there are no [financial] benefits for the residents" (PR6, BDC).

Taking into consideration the equipment malfunctions, a decline in the political backing of decentralised renewable energy generation, and the variation in energy monitoring results (see Section 5.1.1), a Councillor from BDC described how a new low-energy housing strategy **emerged** - TCSG opted to 'design-out' residents for the second phase of Trinity Close,

"…if the technology is there [for Phase Two], we [TCSG] should definitely make use of it. The more advanced the technology, the more people will work with it and accept it. Technology takes the thinking out of energy saving" (PR4, BDC).

Reflecting on findings from Trinity Close Phase One, and researching Government-backed demonstration schemes such as AIMC4[7] (which sought to deliver Code level four homes using fabric-first solutions), UK housing associations began to lean more towards fabric-first only housing construction. As discussed by a senior figure in WHA,

[6] With a total installed capacity of 250kW or less.
[7] AIMC4: The Application of Innovative Materials, Products and Processes to meet the Code for Sustainable Homes level four energy performance is a partnership of companies, created to research, develop and pioneer the volume production of the low carbon homes for the future (P43).

> *"If I was doing that scheme again… I'd get rid of the PVs, I'd stick a solar thermal panel on the roof and I'd get rid of the grey water recycling system. I'd see if you could get away with traditional extract fans and trickle vents, as opposed to MVHR… [Such a] scheme wouldn't have got Code six, would probably have got Code four, but [it] would be easier to maintain and… would [be] an easier scheme for residents"* (PR7, WHA).

Responding to complaints from tenants regarding the live-ability and affordability of the first twelve homes (see Section 5.2), BDC's advocated design approach shifted from pursuit of higher Code levels, towards one perceived as less onerous and more economical. BDC worked with Adapt on an advisory document recommending fabric-first only construction (P48), and it was decided to build Trinity Close Phase Two to CSH level four. This reconfiguration of the Trinity Close assemblage can be understood as the partial de-enrolment of governing and house-building practices, their practitioners and elements, from the carbon-neutral goals defined by the CSH standard. As explained by a BDC housing officer,

> *"We have generally accepted that a fabric first [only approach] should be considered before sticking on additional technologies to reduce energy use"* (PR6, BDC).

With the prospect of Code level four being mandated for all new builds, this loss of confidence in the CSH was increasingly expressed across the housing industry. The Home Builders Federation (HBF), epitomised industry views that it would not be able to adjust house-building practices in time to meet CSH level four's planned introduction,

> *"…The home building industry does not yet have a sufficient understanding of how best to achieve such a performance standard – requiring a 44% improvement on the emission levels permitted under Part L 2006 of the building regulations… It will be a good 18 months before [research] work is complete and the relevant post occupancy evaluation available to inform future investment decisions"* (P52: Point 36).

As shown in this section, **constitutive** practice relations making up the Trinity Close initiative were subject to continuously ongoing disruption and breakage as well as re-linkage. In many instances, erosion of links between practices was unanticipated and **chaotic**, leading the Trinity Close assemblage to be reconfigured with unintended consequences. I have discussed the weakening of practice relations in terms of - the retraction of the eco-towns proposal, growing industry confusion around the codified requirements of CSH, lower than anticipated technical performance, and residents' dissatisfaction with their domestic experiences at Trinity Close. Subsequent new and modified connections between practices meant that Phase Two emerged as a very different initiative to the first phase of the initiative. As such, practitioners and their practices can be enrolled by, and de-enrol from, different configurations of systems of practice according to particular problematisations.

In addition, this section has shown how seemingly indirect practice relations also acted to shape the Trinity Close assemblage. For instance, reduction of the small-scale Feed-in Tariff shaped the design of the pilot scheme and its successor. This presents the opportunity to 'govern [practices] at distance' (Foucault, 1977; Rose and Miller, 1992; Rydin, 2007, 2012).

6.2.5. Developing a housing strategy for Broadland District

An embodied carbon study completed for Trinity Close Phase One partially informed the second phase of development (P47). However, operational difficulties with the monitoring equipment and poor clarification of responsibilities for analysis (see Section 5.1.1) **prohibited** energy performance results from contributing to the design of Phase Two. Both Trinity Close residents and members of TCSG expressed frustration that energy monitoring did not effectively occur. Failure to provide feedback on the domestic energy performance of individual properties led to resentment from the tenants towards the TCSG,

> *"[The monitor has] been broken for months and no-one's knocking on the door saying "Oh we're meant to be monitoring, what's happening?" So they don't care! … We want to be living as cheaply as we can… they're meant to be eco-homes and I thought they wanted to know how we lived... But no, they're not even bothered!"* (H2C).

But as a housing officer from BDC explained, the TCSG remained committed to the prospect of using (partially collected) numeric energy performance data to shape future planning decisions in Broadland,

> *"We will use [Phase One] to help inform future [initiatives] with RPs [Registered Providers of social housing]… Thinking around technologies and green homes has moved along a great deal, but it would [still] be useful to know whether the scheme is carbon-neutral…"* (PR6, BDC).

Unable to draw on energy performance results, Trinity Close Phase Two was shaped by DJH and WHAs' practical experiences of constructing the first twelve properties and was combined with anecdotal feedback from Phase One occupants obtained during maintenance visits. This knowledge became linked to, and was **reinforced** by, a swell of negative opinion towards CSH from the UK housing industry in light of increasingly onerous regulatory requirements being phased-in at a time of recession.

To address the *"burden of regulation"* on the housing industry, in March 2012 the Government published the New Planning Policy Framework (NPPF) - a series of reforms intended to 'make the planning system less complex and more accessible' (P44). These reforms were heralded as a way to cut red tape[8] and increase housing supply. However, they were based on statutory building requirements alone (i.e. CSH level three), and did not demand environmentally stringent design. As such, a BDC planning team explained how such changes undermined Broadland's low-carbon agenda,

> *"With the NPPF… the main thrust of sustainability [now] is economic sustainability… It's straightforward, approve things, build things and that'll get the country moving… But that isn't how I'd see sustainability… Developers are throwing back the NPPF at us all the time [discussing] sustainable development and saying, "This [decision] isn't in accordance with [the new policy]!""* (PR1, BDC).

Soon after introduction of the NPPF, DCLG introduced the New Homes Bonus scheme, for which they set aside £1 billion for 2011-2015 to provide 140,000 new homes over a ten-year period (P54). As explained by a senior figure in BDC, the 'New Homes Bonus' diminished national requirements for low-energy housing,

> *"Labour Administration was a top-down target-driven culture, Tory[9] Administration are… an incentivised culture where for every house that gets built, you get a significant*

[8] Cut red-tape: remove unnecessary bureaucracy.
[9] Tory: of, or relating to, the British Conservative Party or its supporters.

sum of money… whether it's Code six, Code five, you still get the <u>*same*</u> *sum of money… If I'm refusing something that hasn't got sufficient standards of design or sustainability, the question isn't asked, "Why did you refuse it?" … [Instead I hear] "We're losing an income stream here!"* (PR8, BDC).

Together these two policies generated practice relations that were **destructive** to (or counteracted) the sustainability aspirations that originally configured the Trinity Close Phase One assemblage.

During the design stage of Trinity Close Phase Two, BDC and WHA were subjected to a series of public funding cuts, with **cascading** effects that underlined the need for economical solutions to housing development in Broadland (P55). In particular, the Affordable Homes Programme, which promised to 'build affordable homes at the fastest rate for twenty years' (P53), significantly reduced flows of financial resources to WHA and the TCSG. A senior manager at WHA described how these cuts ruled-out the further pursuit of carbon-neutral house-building in Broadland,

"It's a financial reality. The first phase of the scheme received a substantial grant... We're now getting under the new Affordable Homes Programme … a fraction of that grant - I think its £17k per unit… With that grant we cannot build to Code six. For [housing associations the requirement] is still Code three, that's going to be Code four. The council is giving us some grant to get from Code three to four [for Trinity Close Phase Two], which is useful" (PR7, WHA).

In February 2013, DJH submitted planning application for Trinity Close Phase Two, comprising fourteen CSH level four units. This scaling back of low-energy housing ambitions, and contrasting (or **competitive**) house-building approach, was met with confusion from existing residents,

"I just think it's pointless because in the long term they have to find other ways of dealing with cost of living, try to make us manage energy, and to reduce [energy use]... If they're not going to persevere with something they've started, then I just think it's a bit of a waste of time" (H4C).

Furthermore without the honed knowledge and competences to live in a Code level six home, some tenants contemplated de-enrolling from the pursuit of low-energy domestic practices and relocating to the Phase Two homes that would have fewer low-carbon technologies,

> *"Are they going to leave us having the problems we're having when they know [these houses] are not benefiting us - not lifestyle wise anyway, money wise maybe yes, but not day to day? … If [the TCSG are] not going to [help] and they're building new houses that are just normal, nice houses that don't have any problems, I want an exchange!"* (H1C).

March 2013 placed a further question mark over the low-energy housing agenda, when the Government opened a consultation regarding the implementation of 'allowable solutions' (P42), and launched a Housing Standards Review (P49). The Allowable Solutions consultation sought to identify viable ways to flexibly meet the zero-carbon target. It resulted in four agreed routes (see Section 3.2.1). DCLG stated,

> *"… while we intend to set a more stretching on-site energy performance standard for new homes from 2016, we will also put in place a cost effective and flexible mechanism to allow house-builders to meet the remainder of the zero-carbon target by supporting off-site carbon abatement measures termed 'allowable solutions'"* (P45: 4)

For many in the housing industry offsetting carbon emissions and removing 'plug-in' appliances from the CSH's scope diluted (or was **destructive** to) the standard's requirements. DJH adopted this position, as explained,

> *"The original Code six was difficult… there's larger projects with larger units that couldn't receive that Code status and tried. [The Government] reduced the Code under pressure from… large house builders...We were working off the old Code, not the new Code, which is almost a Code five kind of project"* (PR9, DJH).

The DCLG Housing Standards Review was underpinned by a rationale that sought to streamline the house-building process. It stated that, *"The house building process is difficult… but it is not assisted by the large and complex range of local and national standards, rules, and Codes that any developer has to wade through before they can start building"* (P49: 7).

This rationale was contested by the Environmental Audit Committee[10] (P50), who suggested that Government would be ill-advised to abandon the CSH for a new national baseline standard. Their report stated,

"The CSH is a flexible means of delivering sustainability in line with local circumstances and local choice. As new technologies come to market, sustainable development evolves and local circumstances change, the CSH can continue to set a mark for Building Regulations... The single-track approach of simply setting standards in Building Regulations is undesirable, because it would not include a higher standard to drive incremental improvements and to measure progress, a role which is currently fulfilled by the CSH" (P50: Paragraph 26).

Despite this, in July 2014 the Government announced a single **standardised** on-site energy performance requirement for all new homes from 2016, equivalent to CSH level four (P51). The Minister for Communities (Stephen Williams) commended the move to introduce new national baseline standards for Building Regulations[11] and to 'scrap' the CSH as a pragmatic way forward,

"This represents an improvement on current Building Regulation requirements… a challenging standard for new homes without forcing excessive cost and unrealistic levels of ambition onto house builders" (P51: 5).

The governing practices that helped configure Phase One Trinity Close consequently began to loosen connections with the initiative. Immersed within these shifting practice relations, in July 2014, Trinity Close Phase Two officially opened. Adopting a fabric-first only design approach, supplemented with ASHPs and a simple energy monitoring system – the second phase of the development saw a scaling-back of TCSG's low-energy housing ambitions.

[10] The Environmental Audit Committee received written evidence from a wide range of housing industry representatives, consultants and non-governmental organisations.
[11] Changes to Part L (Conservation of fuel and power) in the 2014 Building Regulations changes saw a modest 6% performance improvement requirement over 2010 prescriptions, far less than anticipated by the mainstream housing industry or hoped for by pro-environmental groups.

Section 6.2 has revealed how a wide variety of practice relations and dynamics led to the emergence of five different configurations of the Rackheath housing system of practice, which each coalesced around particular housing problematisations. Section 6.3 continues to detail the systems of practice conceptual framework, and to explain the significance of networked practice connections and dynamics for directly, and indirectly, affecting the governance of low-energy housing in Rackheath. In addition, it is argued that this framework has significance understanding broader sustainability challenges.

6.3. Mapping and characterising the Rackheath system of housing-related practice

This chapter started by discussing how all of social life comprises networked practices, linked together in an extensive matrix. Understanding how practices change, or remain stable, is only made possible by analysing the relationships and interconnections that occur as part of systems of practice (Shove and Walker 2007, 2010; Pantzar and Shove, 2010; Shove *et al.*, 2012; Watson, 2012; Spurling *et al.*, 2013; Macrorie *et al.*, 2014a&b; Spurling and McMeekin, 2014). In this chapter, I have analysed the connections and dynamics of housing-related practices in Rackheath, and by association traced evolution of the CSH, by applying a systems of practice theoretical framework.

Extending the systems of practice concept, I have used two concepts from arrangement theories and the sociology of translation (Callon, 1986) – problematisations and enrolment/ de-enrolment in networks of practice – to analyse the make-up, dynamics and effects of applying this framework. Analysis has underlined the importance of understanding how practices 'bundle one with another, [helping] to identify intervention points [with] potential to initiate or add momentum to positive feedback processes… [and affect] practices throughout the socio-technical system' (Watson, 2012: 495). Developing these understandings is crucial for encouraging a low-energy housing sector and for attempts to govern broader sustainability transformations.

In the following three sections I further detail this conceptual framework by considering practices as connected and configured as part of a system (Section 6.3.1), enrolment and de-enrolment to and from a system of practice (Section 6.3.2) and different relations and dynamics that act within, and sustain, the practice system (Section 6.3.3).

6.3.1. Systematising systems of practice

Low-energy housing is usually understood in one-dimensional terms, either focusing on economic rationality or technological innovation. Whilst SPT broadens this narrow understanding, it has only recently begun to conceptualise more systemic ways of thinking about socio-technical change. By analysing the organisation of housing-related practices and their relations as they coalesced in Rackheath over a ten-year period, the multi-dimensional nature of networked practices has been described (see Figure 6.1). Whilst this model does not directly represent the Rackheath system of housing practice, the concepts behind the model were gained inductively from analysis of this site (see Section 6.2).

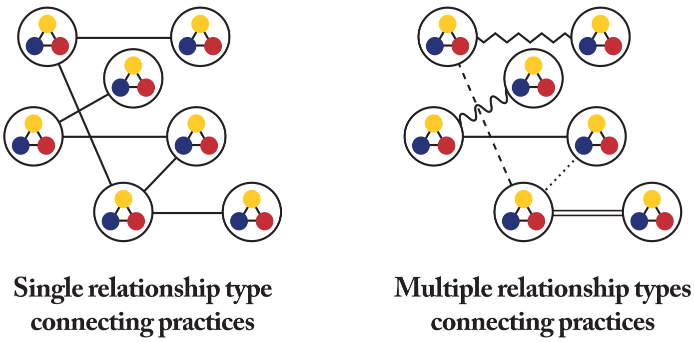
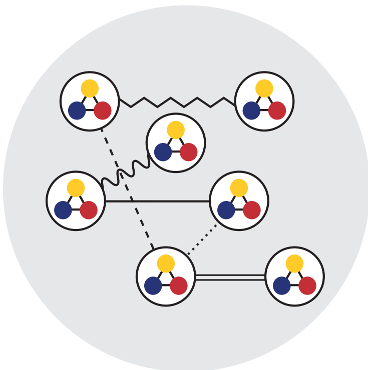


Figure 6.1 – A multi-dimensional model of networked practices

Analysing the housing-related system of practice at the Rackheath site has shown that rather than focus on a single practice type, to inform sustainability transformations in housing it is necessary to understand how governing practices, building design and construction, and household doings are enmeshed within a wide array of networked practices. These practices clustered together in variously complex groupings (i.e. variable numbers of linked practices, connected by more (and less) numerous/ forceful/ dense/ long and intricate ties and relations). Practices also combined in different ways at different times, and their arrangements sometimes remained stable.

Importantly Trinity Close, Rackheath has demonstrated how the qualities and effects of different types of practice relations are important as they generate particular problematisations that recruit practices to the system. For this reason, there is a need to typologise practice relations and to understand how different problematisations come into existence and are dismantled (see Section 6.3.3). The Rackheath housing-related system of practice was held together in a particular configuration according to five distinctive problematisations, which emerged from the practice relations (see Figure 6.2). Additionally, although some practices appeared unrelated in the practice system, linkages between them, and with other often seemingly distant practices, held particular ways of 'doing housing' in place. The forming, sustaining and breaking of these connections, due to events both within and external to the system of practice, allowed established housing practices to change and enabled new low-energy housing practices to form. I argue that understanding these continuously dynamic relations is therefore critical for governance interventions in any system of practice.

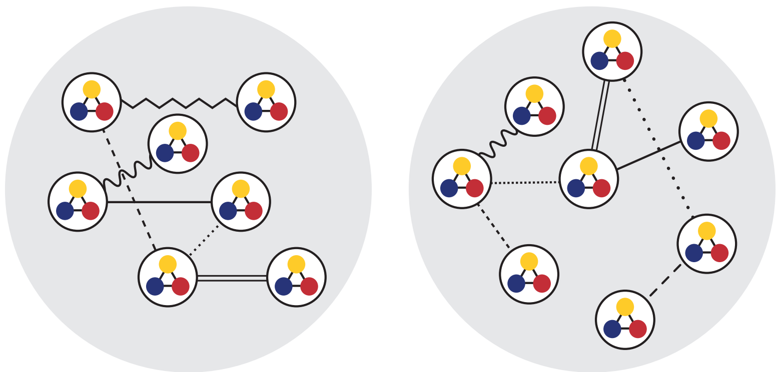


Inter-connecting practices form a system of practice

Figure 6.2 – A system of practice

As seen for the Rackheath example, connections between networked practices and their elements mean that whilst interventions in practice may be attempted – including replacing practice elements, shifting relations between practices, and altering practitioner recruitment/defection levels – they can however go awry, or operate in unexpected ways. This is because no single actor is in charge (Macrorie *et al.,* 2014a). The corollary is that deliberate attempts not to intervene in practice (such as, using technologies to 'design out' householders) are unrealistic. This throws into question traditional top-down interventions in housing practice by 'would-be governors' (see Chapter 7).

As opposed to linear accounts of change purported by techno-rational and MLP perspectives, the evolving Rackheath system of low-energy housing-related practice, has demonstrated that whilst 'social life is not in constant flux' it is dynamic over time and space (Schatzki, 2011: 20). Over a ten-year period, housing-related practices came together in five different configurations in the village. Relational pushes and pulls affected the bundling of practices, shaping the configurations adopted by the practice system (see Figure 6.3), and determining the extent of the stability and dynamism of particular practices at the site. Some relational forces were incremental and cumulative, for instance, the re-skilling of house-building professionals or development of the UK low-carbon technology industry. Other relations were imbalanced or acted unpredictably. For instance, reductions to Feed-in Tariffs and incomplete electricity monitoring data which reduced potential learning from Trinity Close Phase One. Coupled with lobbying from the housing industry against increasingly stringent environmental regulation, these practice relations contributed to the TCSG's decision to build Phase Two to CSH level four, rather than pursue carbon-neutral housing goals.



A system of practice can adopt different configurations, dependent upon the relations between practices

Figure 6.3 – Different configurations of a system of practice

The Rackheath housing-related system of practice has demonstrated how 'novelty and innovation can burst forth anytime' within a practice system (Schatzki, 2011: 19). Change can arise from anywhere in the practice system, and as such, 'largeness and patterness' do not have to imply stability or closure (Shove and Walker, 2010). A catalyst for change can just as easily comprise a faulty piece of equipment or residents' concerns about operating a low-energy house, as national regulatory changes or repercussions of an economic crisis. Here, comparison can be made with Donella Meadow's twelve leverage points to intervene in a system, as a small shift in one aspect of a practice system can produce big changes in everything (and *vice versa*) (Meadows, 1997). Rather than conceptualising one-off leverage points however, a systems of practice framework advocates many points of change that act concurrently through networked practice relations. As such, all social life is understood as a 'complex developing mosaic of continuity and change' (Schatzki, 2011: 20).

The Rackheath example has however demonstrated that some system of practice relations can form a kind of order. For example, a cascade effect type relation indicates that some practices come before/above others, at least for a certain period of time within a given system. This systems of practice framework does not imply the same 'levels' and mechanisms of change described by the MLP. Instead a relational understanding of practice change contrasts distinctly with linear and hierarchical understandings of societal governance and socio-technical change discussed in Chapter 2. The challenge for practice theorists therefore is to understand the patterns and contours produced by networked practices and their relations. This will provide insight as to how practice systems can encourage novelty and change in social life, or reinforce particular patterns of resource use. It will also help to understand the likely implications of interventions in systems of practice.

This complex picture raises the question as to how boundaries can be formed around a practice system to enable analysis and intervention attempts. In Section 2.4.3, I introduced the concept of enrolment and de-enrolment, which originate from arrangement theories. I now explain how this concept provides a means to analyse the evolving nature of the Rackheath system of [low-energy housing] practice.

6.3.2. Enrolment to/ de-enrolment from systems of practice

Applying the concept of enrolment to understand the different configurations adopted by the Rackheath system of housing practice, has demonstrated how different problematisations of low-energy housing variously enlisted elements, practices and practitioners. Similarly, components of the Rackheath system of housing practice detached from the assemblage through the process of de-enrolment. As such, enrolment and de-enrolment provide a way to make sense of evolving, networked housing-related practices that became connected to, and dissociated from, one another at the Rackheath site. Figure 6.4 describes how a system of practice can be reconfigured at any point and in multiple ways through practice and practice relation changes. In this way, just as isolated practices might then be considered in terms of 'proto-practices, practices and ex-practices' (Figure 2.11, Pantzar and Shove, 2010), and connections between practices can emerge, be sustained, and die-out (termed 'pre-formation, formation and de-formation' by Shove *et al.*, 2012: 83), systems of practice can also demonstrate lifecycle dynamics.

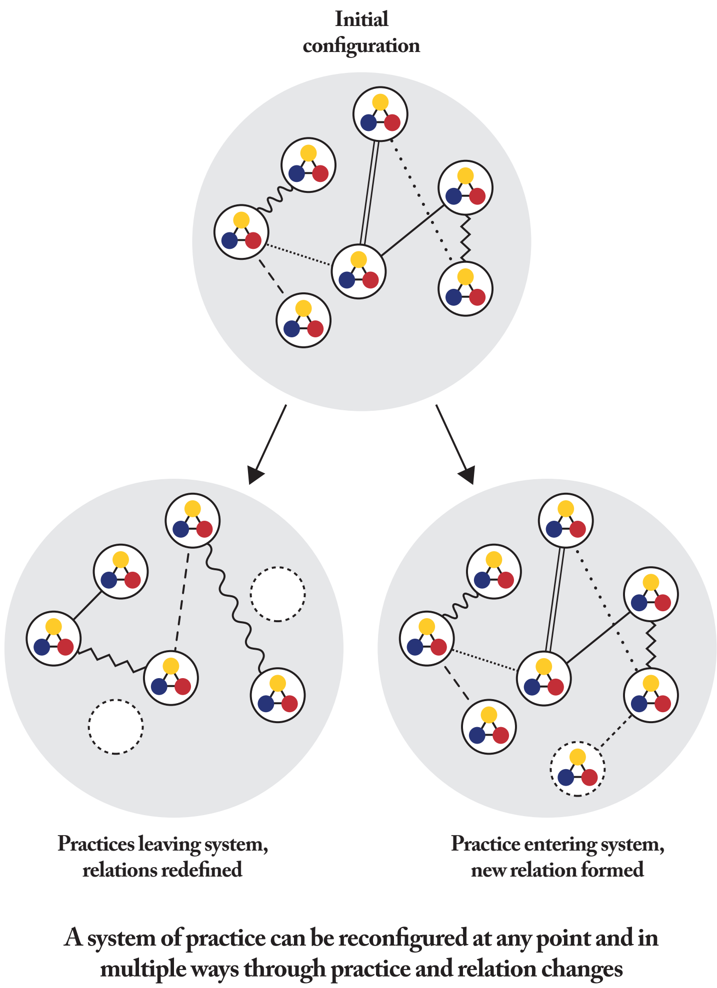


Figure 6.4 – The systems of practice lifecycle

When considering practice recruitment to a system as experienced at Rackheath, pursuit of the 2016 target for all new-build housing to be carbon-neutral led to DCLG's promoting the CSH standard to the conventional house-building industry. Acting as a focal actor (Callon, 1986), BDC enlisted formal institutions to the TCSG, harnessed funding streams, approved design plans, and procured building materials and technologies for the Trinity Close housing initiative. As the project progressed, more practice elements, practices and practitioners were captured by the goal of building a carbon-neutral housing development and became enmeshed by the Trinity Close assemblage.

A particular configuration of practices is sustained when there is full enrolment across the practice system and when practices can be honed through repeated performance. At Trinity Close neither of these opportunities were available for two reasons (see Chapter 5). First, to sustain carbon-neutral housing-related practices at Trinity Close, all elements, practices and practitioners needed to have been completely committed to the ambition of meeting the CSH level six standard and demonstrating energy-efficiency post tenant handover. All components of the system of housing practice - from the bricks and technologies of the housing development, to the residents, the National Grid, the construction workers, and Government policies - needed to remain enrolled by this environmentally sustainable mode of housing.

Second, Trinity Close demonstrates the importance of not only enrolling practitioners to new energy-efficient practices-as-entities, but also holding onto them, by allowing their faithful and regular performance within a supportive system of practice (Macrorie *et al.*, 2014a) (see Chapter 5). With Trinity Close Phase Two being built to a lower carbon standard than the first twelve homes, the repeated performance of carbon-neutral housing design, construction and dwelling practices was not possible. As practitioners involved with the CSH level six housing development were prevented from repeating their newly acquired practices, Trinity Close Phase One must be understood as a 'one-off' experimental project (Lovell 2007b). Similarly, despite exemplar schemes, a codified low-energy housing system of practice has failed to gain a stronghold in the UK. As discussed in Section 6.2.5, the CSH has effectively been 'scrapped', and attention has, for now, shifted towards economic development and away from innovations in low-energy housing infrastructure.

The Rackheath low-energy housing system of practice disbanded from one particular problematisation, and adopted another, as the problem framing for how best to tackle the challenge of low-energy housing changed. As everyday household routines were disrupted at Trinity, and low-energy housing maintenance, materials supply and cost issues were experienced, the arrangement of the carbon-neutral housing initiative became unstable, resulting in Phase Two being downgraded from Code level six to CSH level four. In Section 6.2, I showed how this also resulted as Trinity Close was entangled with broader networked practices - particularly, economic, commercial and policy practices - which contributed to the dissolution of the housing initiative and to the limited longevity of the CSH standard.

'Jostling in a field of force' carbon-neutral housing (codified by CSH) juts up alongside, and overlaps with, alternative assemblages of housing practice (Lovell and Smith 2010, drawing on Bourdieu 2005) (see Figure 6.5). For instance: conventional less energy-efficient housing production methods; energy-efficient designs such as Passivhaus (Passivhaus, 2014); co-housing[12]; or retrofitting existing homes. The shared and interconnected nature of some of these practices, and their elements and relations, highlights the difficulties of effecting change in the residential sector, where one mode of construction has a position of dominance due to its entanglements with the wider world. The five configurations of the Trinity Close housing initiative, have shown how the relations and entities making up systems of housing practice, can change either incrementally through a process of ongoing 'jostling', or more radically as completely different modes of 'doing (low-energy) housing' are forced together. Overlapping systems of practice may also be indirectly connected to housing and yet may substantially shape the configuration of the practice system. Any changes to these indirectly linked systems of practice (comprising for example, mobility, food, or work practices) may consequently have significant ramifications for the target practice system, or may prove a useful intervention point.

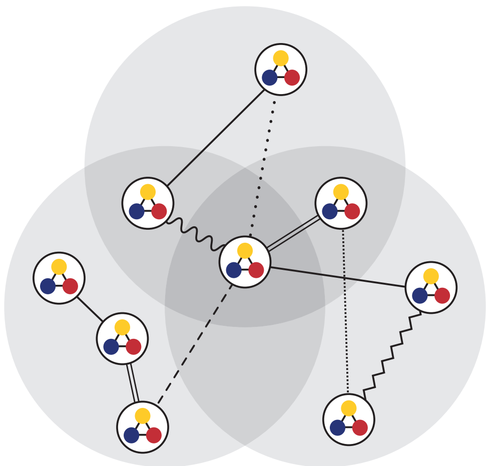


Figure 6.5 – Overlapping systems of practice

[12] Co-housing communities are intentional communities. They are created and run by their residents. Each household has a self-contained, personal and private home but residents can come together to manage their community, share activities, and eat together.

6.3.3. Systems of practice relations and feedback dynamics

When analysing hybrid arrangements, some assemblage theorists advocate 'radical relationality' whereby 'elements have no significance except in relation to their neighbours, or the structure of the system as a whole' (Law, 2000: 4). This position suggests that relations are at least, if not more, important than components of a network. Whilst analysis of the Rackheath housing system has revealed the relations between networked practices (variously termed connections, links, and ties), it has not given precedence to relations over constituent practices. Analysis has however shown practice relations to be crucial in: producing distinct configurations of practice, creating maintaining and collapsing systems of practice, and determining the emergence and translation of novelty.

Analysing evolution of the Rackheath system of housing practice has produced a typology of practice relations (see Table 6.1). This typology, whilst not attempting to be comprehensive, has been generated from empirical results, and conceptually extends contributions in the academic field (described in Section 6.1). Each of the thirteen practice relations listed, have been identified as instrumental in shaping the networked configuration, environmental sustainability and longevity of the Trinity Close system of housing practice. Practice relations vary in: nature (they can be flows of knowledge, skills, building materials, capital etc.), direction (they can be uni-, bi-, or multi-directional), force, density of connections, duration, and/or distance of reach. Despite these gradations, as seen with the effect of the recession on the housing industry, withdrawal of the eco-towns proposal, and the revocation of the CSH, stronger relations/greater numbers of connections do not lead to permanence and immovability, just as weaker/fewer connections do not lead to change. I am not then claiming that these practice relations are absolute, they are not mutually exclusive and they are not all required for a practice system to operate. Importantly, different types of relations can however reveal intervention points with potential to initiate or add momentum to positive feedback processes, and to affect practices throughout the socio-technical system (Watson, 2012).

Practice relation	Mode of operation. Practice relations act so that…	Example from Rackheath system housing of practice
Cascading	A succession of outcomes is induced through practice linkage, each of which triggers or initiates the next stage in the process	As part of governmental policy, the setting of UK housing development targets triggered a cascade of housing-related processes & practices to deliver the required growth.
Chaotic	A set of practices connect/relate in an unplanned way, producing unanticipated effects	Technical malfunctions led to residents becoming resentful of the TCSG and the Code itself. These concerns prompted some tenants to request relocation to new Code level four homes built as part of Trinity Close Phase Two.
Constitutive	One or more practices make-up a bundle/complex or system of practice	Throughout the system of practice
Contingent	One or more practices rely on the performance of another practice	Realisation of the Rackheath eco-town proposal was dependent on funding, suitable materials, practitioner knowledge, a buoyant housing market and local consultation outcomes.
Competitive	Contest between different practices occurs in pursuit of greater time, space, resources, and/or practitioners	Competing eco-town proposals developed by housing practitioners from rival sites.
Cooperative	Practices work jointly to capture greater time, space, resources, and/or practitioners	Previous low-energy housing demonstration projects embarked on by the TCSG supported the experiences at Trinity Close, informing the design and tenant management approach.
Creative/ Enabling	Links between practices purposely created/ encouraged to commence/ speed-up production of a particular outcome	The ZCH's remit was to enable environmentally sustainable house-building practices to become established by mobilising knowledge about the CSH.
Demonstrating	Previously formed configurations of practice are purposely reformed to recruit new carriers and to disseminate particular modes of doing.	The Trinity Close Phase One exemplar was intended by DCLG and HCA to act as a demonstration site for carbon-neutral affordable housing design and construction.
Destructive/ Prohibitive	Links between practices are purposely broken/ limited to cease/slow down production of an outcome	The SNUB protest group campaigned to prohibit development of the Rackheath eco-town and associated infrastructure.
Emergent	As practices are linked into bundles, complexes and systems, new "characteristics" result "which cannot be reduced to the individual practices of which they are composed" (Shove *et al.*, 2012: 87)	UK housing targets prompted new planning objectives to be defined, reallocation of capital, and formation of a new institution (GNDP).
Experimental	Previously unmade connections are purposely formed between practices in an exact way, which is studied to determine the outcome of producing these new relations	When CSH was first introduced, housing associations were required to trial the standard to level three across all new builds. These housing construction practices were appraised in order to disseminate best practice.
Standardising	The faithful reproduction of practices occurs according to a specific set of interconnections	The CSH was an attempt to standardise the way in which new homes were designed, built and lived in, in order to be more environmentally sustainable.
Reinforcing	The stability of the configuration of practices is enhanced	Conventional house-building practices had established stable associations with other practices, which acted to hold them in place (e.g. infrastructural/ supply chain / planning).

Table 6.1 – A typology of system of practice relations determining the evolution of Trinity Close housing development

Feedback dynamics were also evident in the Rackheath practice system. Negative feedback effects regulated Trinity Close housing-related practices. For instance, the CSH level six standard ensured housing construction adhered to particular technical requirements, whilst social conventions around heat comfort, and the institutional interpretation of these, regulated the performance of heat comfort practices in the Close. Positive feedback effects led to the amplification of patterns of housing practice. For instance, experiences of large housing construction companies attempting to build carbon-neutral developments to the initial definition of CSH, led to the introduction of Allowable Solutions. This redefinition of carbon-neutral prompted diminishing confidence in the CSH standard. Spin-off dynamics were also evident. For instance, unanticipated technical malfunctions led to residents becoming resentful of the TCSG and the Code itself. In addition to contributing to the decision to build Phase Two to CSH level four, these concerns prompted some tenants to request relocation to new homes perceived as easier to manage and more comfortable.

I have shown how practice relations and dynamics both encouraged and sustained change in the Rackheath system of housing practice. At the same time, analysis of the five problematisations has revealed how some relations reinforced the *status quo* and restricted change in the practice system. Calling for greater understanding of these networked practice relations presents a very different approach to low-energy housing initiatives advocated by techno-rational disciplines as it does not privilege top-down governing relations or 'techno-fixes'. It also offers a contrasting perspective to much social research supporting the governance of environmental challenges using tools and methods of public policy.

In contrast to conventional governance studies, analysis in Section 6.2 has also shown how power can be considered not just as a force that stands outside of and acts on housing-related practices through the top-down enforcement of codified carbon-neutral construction requirements. Power was not simply wielded by DCLG by phasing in increasingly stringent carbon reduction targets in the residential sector, or by the TCSG in demanding local implementation of CSH standard at Trinity Close. Instead power was dynamically employed *throughout* the practice network (Foucault 1980; Rouse, 2005). Networked practice relations can all be understood as different expressions of power.

At the Rackheath site, power was present in many forms, and was dynamic and dispersed. Power was also not held by particular actors. 'Power is not something that is acquired, seized, or shared, something that one holds on to or allows to slip away' (Foucault, 1978: 94). For instance, power was evident in established supply chains that restricted DJH identifying low-carbon technologies, and in expectations around heat comfort that determined the design and use of the domestic heating systems. Disruptive power relations were demonstrated when the modified functioning of tenants' homes affected their daily routines and led to disenchantment with the housing scheme. Powerful relations were exhibited by the housing industry's lobbying forces, which ultimately led to the retraction of the CSH. They were also inherent in the economic downturn, which limited available capital for low-energy housing development and curbed confidence in the housing market. These examples reveal how power was distributed throughout complex networks, and demonstrate the heterogeneity of power relations within a practice system.

By holding certain housing-related practices in place and encouraging others to change, these relations also contributed to the broader patternings of power demonstrable in the housing practice system and society at large. For instance, by pursuing a CSH level four scheme for Trinity Close Phase Two, and advocating a fabric-first only approach to construction in Broadland, legitimacy was added to the Government's decision to delay and scale back carbon-neutral housing ambitions.

There is not scope to discuss the full implications of this relational conceptualisation of power within the confines of this thesis. But here I have highlighted the importance of attending to the multiplicity and diversity of practice relations, and their implications, when attempting to intervene in any system of practice.

6.4. Summary

This chapter began by setting out how analysing relational systems of housing practice provides a more contextualised, nuanced and productive means to deliver sustainability transformations in the residential sector than attempts to shift individual practices, or to reconfigure practice elements. Recognising the complexity associated with systems of practice analyses, two concepts from arrangement theories – problematisation and enrolment/ de-enrolment from networks – were drawn upon.

Examining the Rackheath practice system over a ten-year period identified five problematisations or housing challenges that shaped the networked arrangement adopted by the housing initiatives. These problematisations included: responding to a need for greater UK housing supply (Section 6.2.1), attempts to ensure green growth through an eco-town bid (Section 6.2.2), delivering Trinity Close Phase One low-energy housing trial to CSH level six (Section 6.2.3), using learnings from Phase One to inform the second phase of the initiative (Section 6.2.4), and subsequent development of a housing strategy for Broadland District (Section 6.2.5). These distinct problematisations emerged from relations between linked practices (housing and associated practices). At the same time, these relations held the problematisations in place, and could prompt reconfiguration of the system of housing-related practice.

The chapter proceeded to provide a multi-dimensional model of systems of housing practice, and distinguished between viewing social change in this way rather than in a linear, uni-dimensional way, as put forward by techno-rational perspectives. Analysis of networked housing-related practices in Rackheath further suggested that whilst interventions in practice may be attempted, they can go awry because no single actor is in charge. The corollary of this is that deliberate attempts to keep practices the same (such as using technologies to 'design out' householders) were unrealistic.

Using a systems of practice approach, many points of change were seen to exist, and to act concurrently through networked practice relations. Studying the system of housing practice in Rackheath demonstrated how change can arise from anywhere within a practice system, and how largeness and patterness do not have to imply stability or closure (Shove and Walker, 2010). As such, all social life can be understood as a 'complex developing mosaic of continuity and change' (Schatzki, 2011: 20). This provides a very different understanding of governance interventions than put forward by the MLP.

Just as seen for individual practices, systems of practice have been shown to demonstrate lifecycle dynamics. Particular networked configurations are reinforced and sustained first, by full enrolment across the practice system, and second, when there are opportunities for repeated practice performance. Without such reinforcement, at Trinity Close codified carbon-neutral housing practice relations became unstable as components of the network detached and de-enrolled. This led to Phase Two Trinity

Close being downgraded to CSH level four. More broadly, these changing relations were related to revocation of the CSH standard, changing political agendas, and the economic recession.

Recognising the importance of relations in sustaining, and bringing about change in systems of practice, analysing evolution of networked housing-related practices in Rackheath (Section 6.2) led to the development of a typology of practice relations. The different types of relations varied in: nature, direction, force, density of connections, duration, and/or distance of reach. Despite these gradations, stronger relations/greater numbers of connections were shown not to lead to permanence and immovability, just as weaker/fewer connections did not lead to change. Feedback dynamics – negative, positive and spin-offs – were also shown to operate within the system of housing practice. These forces of change regulated, gave momentum to, and led to unintended effects as part of the housing intervention.

Finally, as opposed to conventional understandings of power over actors' actions, it was suggested that networked practice relations all constituted different expressions of power. As such, I drew on a Foucauldian conceptualisation of power, as distributed, dynamic, and acting through networked practice relations.

What then are the applied consequences of adopting a systems of practice framework? This chapter has suggested that greater attention should be focused on understanding the multiplicity and diversity of practice relations, and the dynamics occurring within and between networked configurations of practice, to better understand and attempt to deliver sustainable transformations in the residential sector. Chapter 7 explores implications of this theoretical position for research and practice.

Chapter 7. Conclusion: Doing low-energy housing differently

I began this thesis by highlighting growing calls for changes to how society lives, in order to respond to the threats of climate change, natural resource depletion and endangered national energy security. The ways we design, construct and live in our homes have been identified as major contributors to UK energy consumption and carbon emissions generation. The refurbishment of energy-inefficient existing properties would arguably help to address ambitious government targets for carbon emission reductions. However, whilst recent years have seen a downturn in housing construction, the drive to build more homes in the UK (particularly affordable properties) and the recent rise in single occupancy dwelling underscores the need for less energy-intensive new-build houses and associated domestic life. As such, it was recognised that there is an urgent requirement to ensure the increased sustainability of new-build housing both in the UK and further afield. This challenge is made all the more pertinent as how we build homes today shapes how we live in years to come, contributing to future energy use and carbon emissions.

I set out by suggesting that developments made to the technical specification of new homes (particularly improving the thermal envelope) have gone a long way to reducing residential energy demand. Despite this, conventional ways of thinking about designing, building and living in low-energy housing were argued to be insufficient and deleterious for meeting the scale of this task. I suggested that policy, industry and research approaches remain distinctly shaped by the techno-rational paradigm, which privileges technological solutions to energy reduction, and where desired savings rest upon optimising design, technological diffusion and ensuring 'correct' operation by end-users. Where homes are considered post resident handover and householders enter the frame, it is typically assumed that wasteful energy-related behaviours and bad resource-consuming habits will be ameliorated by the provision of education, incentives and appealing to householders' green values. These dominant and mutually reinforcing approaches present a largely rational view of change that assumes guaranteed reductions in energy consumption and quantifiable decreases in carbon emissions. However, such conventional approaches frequently fail to meet planned energy and carbon savings and often produce unintended consequences. Hence, I argued that an alternative approach for addressing the low-energy housing challenge, and broader environment-behaviour interventions, is desperately required.

To avoid the reductive shortcomings of conventional low-energy housing approaches, this thesis is underpinned by four principles. First, by adopting a social practice theory (SPT) approach, a focus on the social and collective organisation and doing of housing practices was advocated, as opposed to providing techno-fixes or seeking to influence individuals' attitudes, values and behavioural choices. Second, this research focused on appraising the implementation of a particular building performance standard – the Code for Sustainable Homes (CSH) – as a policy approach that sought to embed a particular way of thinking about change in the housing sector. The research assessed the implementation and post-handover implications of building domestic properties to CSH level six (i.e. carbon neutral housing) at an exemplar site. Whilst political momentum on sustainable housing has since fallen, and the CSH standard was dropped by the coalition government in 2014, at the time of completion, Trinity Close, Rackheath was an innovative initiative, forming twelve of only thirty-nine UK properties accredited to CSH level six between April and December 2011 (DCLG, 2011).

Third, whilst practices have predominantly been analysed in isolation, have focused on mundane aspects of domestic everyday life, and have neglected to focus on interactions between practices, their dynamics or effects, this research has applied and developed the recently proposed concept of systems of practice (Shove and Walker 2007, 2010; Pantzar and Shove, 2010; Shove *et al.*, 2012; Watson, 2012; Spurling *et al.,* 2013; Macrorie *et al.*, 2014a&b (see Appendices O&P); Spurling and McMeekin, 2014)). Emphasising the need to consider the role of specific contexts in shaping and structuring housing practices, I have examined how different practices from across the housing sector (and beyond) overlap and relate, and examined what these interconnections mean for reconfiguring housing practices in less energy-intensive directions.

Fourth, these three positions pointed to the need for a particular methodological approach suitable for observing the situated performance, interrelations and dynamics occurring between practices. As such, this research provides one of the first ethnographic, multi-method investigations of carbon-neutral housing practices. From these starting points, I set myself the following overarching research question and three sub-questions:

How can social practice theory inform the governance of low-energy housing?

1. Can the Code for Sustainable Homes (CSH) be conceptualised as an intervention in practice? If so, how?
2. What effects does CSH have as an intervention in practice?
3. What is the potential for applying 'systems of practice' to the governance of low-energy housing?

As a result, the preceding chapters provided an account of low-energy housing that differs theoretically, empirically and methodologically from most contemporary research, policy and practice in this area. In this concluding chapter, I will review the major findings of this study and relate them to my research questions. I will then consider the conceptual implications of this thesis and set out the basis for a new research agenda on low-energy housing that rests on understanding housing as a relational and dynamic system of practice.

7.1 Summary of findings: Answering the research questions

Each of the three preceding empirical chapters distinctly differs from the conventional technical, behavioural and linear socio-technical models discussed in Chapter 2. Furthermore, Chapter 6 takes forward the concept of systems of practice by presenting an alternative to understanding isolated and de-contextualised singular practices, which to date have focused on the mundane operations within the home. Commencing with the three sub-questions, this section answers the research questions set out at the start of the thesis.

7.1.1 How can the Code for Sustainable Homes (CSH) be conceptualised as an intervention in practice?

In Chapter 4, I introduced the principle stakeholders involved in the Trinity Close CSH level six housing initiative. A detailed account of these actors' housing-related practices prior to embarking on the initiative was provided, and the institutional context in which the Trinity Close Steering Group (TCSG) was established and the initiative emerged, was outlined. The aims, objectives and approach advocated by these principle stakeholders – which crucially included the Trinity Close householders –

were analysed using Shove and Pantzar's (2005) conception of practices as assemblages of meanings, materials and skills. I argued that instead of examining design decisions informing the selection of particular energy-efficient building materials and renewable technologies, or interrogating the values and choices underpinning the actions of members of the TCSG, it would be more productive to understand technologies and 'behaviours' as intertwined and embedded in social practice.

Some social practice (SPT) theorists set up dominant techno-rational approaches for social change as a straw man, proceeding to knock down this paradigm because of the 'blind spots it creates, and the forms of governance [that] it sustains' (Shove, 2010: 1273). In so doing, techno-rational assumptions, models, tools and techniques risk being grouped together as one homogenous singular and limited approach to achieving social change. In contrast, I suggested that whilst the TCSG professional practitioners' vision of change broadly coalesced around a techno-rational paradigm, each of the six emblematic sets of Trinity Close actors profiled put forward subtly different aims and objectives for how the initiative would achieve social change. Furthermore, whilst the CSH standard advocated models and assessments that did not take into account the properties post-occupancy, the interviewed actors varied in the extent, and ways, that they envisioned residents would be involved in changing their 'energy-consuming behaviours'.

I demonstrated that far from there being consensus as to how the Trinity Close initiative would be implemented, it was a contested project from its outset. Rather than techno-rational approaches being neutral or context independent, as is often claimed by dominant research paradigms, at Trinity Close, the aims, objectives and assumptions of the initiative were conditioned by the dominant practices in which the Trinity Close principal stakeholders engaged. As practices underpinning design and implementation of the Trinity Close initiative were not abstract, but were informed by real life contexts, it was necessary to use a SPT-based methodology to understand how meanings, materials and competences bundled together, and generated a distinct strategy for change at the housing development. This outcome highlighted the need to question what TCSG and the Trinity Close householders' contextualised understandings and established 'ways of doing' would mean for steering housing practices in less energy-intensive directions.

I thus began to try to understand how implementation of the CSH standard at Trinity Close could be conceptualised as an intervention in practice. From the outset, SPT provided an evaluation that was wider-reaching than the longstanding and broadly accepted assumption that ensuring low-energy housing and associated domestic life relied solely on ensuring technical build performance. However, in practice terms, the TCSG perpetuated this paradigm by aiming to enhance the environmental sustainability of social housing infrastructure by inserting energy-efficient building materials and low-energy technologies into the everyday practices of housing design and construction professionals. Furthermore, by adhering to the codified requirements of the CSH level six standard, these housing design and construction practices could be modelled, measured and monitored. In these respects, the initiative conformed to conventional technical approaches for achieving environmental change in the residential sector.

Consequently, the TCSG professional practitioners researched, installed, operated and maintained energy-efficient building materials, renewable technologies, and energy-monitoring devices at the housing site that were intended to reliably deliver codified carbon-neutral homes. In order to work to the CSH level six standard, the professional practitioners at Trinity Close also required new competences - developed on training courses or learnt on the job - and had to embrace new meanings – for instance, meeting carbon neutral targets as opposed to ensuring maximum economic profitability.

Whilst the CSH and Trinity Close initiative sought to intervene in the professional practice of housing construction, simultaneously the initiative sought to keep household practices largely intact (i.e. non-intervention in household practice) (Macrorie *et al.*, 2014a). It was assumed by the TCSG that domestic routines and ways of life could be unaffected by the insertion of new materials and technologies into the building fabric. In addition, Trinity Close was designed to look as 'normal' as possible so as not to challenge cultural expectations around domestic living and energy. Further, I showed that the design of Trinity Close was based on the assumption that only particularly motivated householders would reflect on the energy implications of their daily domestic routines, and that these individuals would respond rationally to energy-saving information and the inducement of potential financial savings on their electricity utility bill.

A SPT reading of social change puts forward a more nuanced understanding of what is involved in bringing about low-energy housing. It considers householders as actively engaged actors and understands both professional practices and domestic routines as involving complex relations between meanings, materials and competences that are crucially embedded within broader social practices. In this way, SPT provided an interpretation of low-energy housing capable of offering more possible purchase points for change than either individuals' thoughts, attitudes and values, or reliance on technical fixes that frequently perform below predictions. A SPT framework also revealed that whilst addressing some (mainly material) aspects of practices, the techno-rational strategic approach adopted at Trinity Close was narrow as it failed to attend to how housing-related practices are mediated through societal culture, formal institutions, politics, and economic structures.

Furthermore, it was suggested that codified standards, such as CSH, serve to reinforce expectations and perpetuate assumed needs around how energy is used in everyday life. By applying a SPT framework, I therefore recast the Trinity Close initiative as radical in some parts (for example, in enlisting innovative low-energy technologies and materials) but not in others (where conventional ideas about consumer engagement, behavioural change and the role of energy in everyday life were reinforced). This led me to raise the question of whether one could intervene in certain elements of practice (i.e. physical materials), without disrupting entire practices and prompting wider repercussions.

Whilst the majority of SPT-based research to date has focused on everyday resource consuming practices occurring within household practitioners' homes, I demonstrated that the practices of the TCSG were pivotal to determining the design, implementation, and outcomes of the Trinity Close initiative. This shifts SPT's focus from everyday household practices and their influence on resource demand, to policy, public sector and commercial housing practices. As highlighted by Watson (2012), this can be just as crucial, if not more important, than understanding how energy is embroiled in domestic routines. I went on to suggest that household practices cannot be fully understood without an appreciation of the broader system of diverse practices within which they are entwined.

Finally, I revealed how the TCSG considered that the CSH standard, and their governing decisions and actions, were positioned outside of, and could act upon, both professional and domestic housing practices (even if attempting to maintain the *status quo*). By implementing codified housing design to CSH level six at Trinity Close, it was the TCSG's belief that a carbon-neutral development would result, complete with abiding (albeit potentially unaware or passively engaged) carbon-neutral residents.

In essence, the Trinity Close exemplar initiative was planned as a neatly bounded 'urban laboratory' experiment (e.g. Evans and Karvonen, 2014), which whilst seeking to reduce energy demand and carbon emissions, was designed to further solidify the TSCGs' governing practices and roles. In contrast, according to the SPT-framework, I argued that actors and their practices can never be isolated, and that practitioners cannot be separated from the context within which they operate (as context emerges from practice). This raised the question of whether (as is often assumed in policy and academic work) it would be possible for TCSG to govern practices from an external position, without invariably becoming implicated in those practices. It also prompted the question of how the Trinity Close initiative would be received when it was released 'into the wild', and how the world would respond (Callon and Rabeharisoa, 2003: 193).

7.1.2 What effect does CSH have as an intervention in practice?

In Chapter 5, I analysed what effect(s) the CSH had as an intervention in practice. I considered first how the new codified design and materiality of the Trinity Close housing development performed, and whether the code six accredited technical specification of the home met the expectations of the TCSG in terms of energy reduction and carbon-neutrality. I also appraised how the professional housing practitioners designed and built in accordance with the CSH sustainability performance standard, acquired new understandings, and developed competences to master low-energy technologies and energy-efficient building materials. I proceeded to analyse what happened when the newly built properties were handed-over to the WHA tenants, and they became a site in which everyday domestic life was performed.

Whilst the Trinity Close development succeeded in achieving certification as a CSH level six scheme, and was one of the very first social housing schemes in the country to gain this sustainability standard, closer inspection revealed the limitations of this accolade. The housing development excelled in terms of thermal efficiency, resulting in significantly lower energy consumption compared with national and regional housing averages. It also surpassed the TCSG's expectations in terms of levels of photovoltaic electricity generation, producing enough electricity to offset 25 tCO_{2e} of the 34 tCO_{2e} emitted during the first year. Despite this, the Trinity Close homes failed to achieve carbon-neutrality (as originally defined by the CSH standard, and as originally intended in the scheme's design) resulting in net carbon emissions of 8.7 tCO_{2e}.

Despite the Chairman of the Environmental Excellence Committee at Broadland District Council (BDC) commending the Trinity Close scheme for its innovative nature and environmental and energy credentials (meeting of the board held 21st January 2015 – see Table 3.7), it was only when the new zero-carbon definition was adopted, which only included regulated emissions (from heating, cooling, ventilation and lighting), that the development could be considered carbon-zero. In addition, the CSH standard - whilst regulating building design, materials procurement, working practices and housing construction - failed to take into account the energy-related practices of the WHA tenants. Although the housing development was accredited to CSH level six, this was a significant oversight because building energy performance crucially depends on how a home is used (e.g. Branco *et al.*, 2004; Juodis *et al.*, 2009). I thus highlighted how it was necessary to analyse the Trinity Close properties as lived-in homes, rather than as a technical accomplishment, as advocated by the CSH standard.

Installation of energy monitoring equipment to appraise technical performance at Trinity Close, required by the project's funders, further entrenched this techno-rational paradigm. In addition, to the extent that post-occupancy was considered, providing tenants with electricity monitoring feedback in an attempt to curb or shift energy demand, perpetuated rational understandings of behavioural change and treated energy as a topic in its own right. In distinct contrast and with significant governance implications, a SPT approach understands both energy demand and supply as necessary embedded in, and reproduced through, social practice (e.g. Warde, 2005; Shove and Walker, 2014).

Despite TCSG intentions to use the electricity monitoring data to inform future architectural and planning decisions, and to encourage individuals to consciously modify their energy-consuming routines and actions, the installed monitoring systems did not reliably collect data. Consequently, not only were planning decisions for Phase Two of the development not informed by quantitative analysis of Phase One, but the WHA residents were only provided with reports advising them about their first year's energy consumption patterns after three years of residency, by which time tenant interest in the sustainability project had seemingly waned[1].

[1] Whilst BDC offered follow-up appointments for households to discuss their individually produced energy monitoring reports (see Appendix L), they did not receive any requests to discuss the results and implications.

The TCSG's analysis of these limited quantitative energy performance data alone provided an opaque picture of how the Trinity Close householders' domestic practices led to particular energy consequences. Energy monitoring results demonstrated that far from the technical specification of the properties leading to a uniform decrease in electricity usage across the Trinity Close properties, during the first year of tenancy, huge variation in all categories of household energy demand, particularly heating, resulted across the twelve households, with implications for associated carbon emission reductions. This underscores the importance of understanding exactly how domestic energy demand is produced, and reinforces the need for qualitative data collection and analysis in order to understand how and why variation in household energy demand results. Further, the building energy performance assessment revealed that even when evaluated according to the TCSG's own techno-rational objectives, the governance approach adopted at Trinity Close initiative was found to be deficient. I therefore emphasised the need to explore energy-consuming domestic practices in more detail.

I suggested that unpacking the composition, performance and dynamics of interconnected domestic energy-related practices using qualitative ethnographic research could provide potential leverage points for potentially shifting or transforming household energy demand in less energy-intensive directions. By demonstrating that heating and hot water usage (bathing/washing) constituted the largest household electricity use at Trinity Close, TCSG's analysis of the quantitative energy monitoring results provided a target household practice on which this research could focus. Accordingly, I sought to understand variety in household energy demand by interrogating the composition and performance of household heat comfort practices, and by understanding their relations and dynamics with associated practice bundles and complexes. I stressed that as homes are designed to be increasingly thermally-efficient, household energy demand - particularly socket-related consumption but also heating related energy use - will be of greater importance for determining overall building energy performance.

In Section 5.2, I appraised Trinity Close heat comfort practices, and associated bundles and complexes, as an explicit non-intervention in practice – where implementation of the CSH at the site sought not to disrupt the everyday lives of the tenants, nor to challenge accepted cultural norms around energy use in the home. To explore how, if at all, ways that householders maintained their domestic heat comfort at Trinity Close differed from practice performances in residents' previous properties, analysis 'zoomed in' (Nicolini, 2009) on the elements of domestic heat comfort. I also recognised the crucial importance of understanding how domestic heat comfort practice elements became linked and connected, how these ties were reaffirmed or were broken, and the consequences that these relations had for household electricity demand.

I showed how TCSG assumed that the installed energy-efficient materials and renewable technologies at Trinity Close would reduce domestic energy demand with indiscernible wider effects, viewing them as 'bounded entities' (Shove *et al.*, 2014: 113) that could be easily inserted into tenants' daily lives. This proved not to be the case. Even when the homes worked in accordance with the architects' intentions, their modified material qualities substantially reconfigured the composition and performance of householders' heat comfort practices, with wider repercussions for the organisation and undertaking of everyday domestic doings. For some households, the unfamiliar technologies and building materials made it difficult to manage heat comfort, and produced uncomfortable thermal conditions that disrupted home life. Other householders objected to and contested inserted technological systems that were different to those previously experienced (for example, the air source heat pump and the mechanical ventilation system), or which had been set-up according to assumptions that did not mesh with tenants' practices. Even when the modified material layout of the new homes was accepted, far from the TCSG's assumptions that the tenants would passively interact with the installed devices, they were actively and continuously incorporated into everyday household practices and could not be considered as socially neutral.

The energy-efficient features and renewable technologies installed at Trinity Close were designed and installed so that they appeared discrete. However, where tenants were required to use their property in a specific way, the TCSG believed that optimal energy-efficiency could be encouraged through information provision and education. I noted five different responses to this: (i) the information did not mesh with householders' everyday lives (ii) householders' refrained from using technologies due to confusion (iii) householders experimented with operating the devices by drawing on tacit understandings (iv) residents made the technologies work for them by learning from and adjusting their practice performance and (v) householders operated the installed technologies and managed their heat comfort practices collectively. This range of competences led to the inserted materials and technologies being used differently by the householders (institutional compliance/ passive operation/ not being used/ experimentation /subversion) and to heat comfort being managed variously, with clear implications for domestic energy demand and carbon emissions.

Whilst the TCSG thought that 'normal' domestic life would continue unchanged at Trinity Close, residents held strong beliefs and understandings about their heat comfort practices and the installed technologies, that were vital to shaping their everyday domestic practices. Far from the TCSG's assumptions that individual residents would make rational, profit-maximising decisions about their energy consumption, energy use associated with maintaining heat comfort was bound up with prevailing meanings and conventions that sustained 'normal' household life. Energy-related heat comfort practices were also structured by past experiences and future visions. Together this meant that, even in homes designed to be carbon-neutral, electricity demand and heating use were highly variable and for fifty percent of households did not decrease. Understandings related to heat comfort practices were developed and adjusted in constant negotiation with members of the household, neighbours, friends and family, rather than being a product of individual cognition or thermal sensation alone. Importantly, householders also held strong opinions about the TCSG, their organisation of the initiative, and the planned second phase of the development. I showed how issues of transparency, trust, communication and inclusion had both partially configured domestic life, and shaped delivery of the TCSG's objectives.

Analysing the changing elemental composition of householders' heat comfort practices, and associated bundles and complexes at Trinity Close, demonstrated how the TCSG's ambition of non-intervention in household practice was an unrealistic goal. In fact, 'introducing new practice elements necessarily ha[d] knock-on effects on other elements, which often play[ed] out in unexpected ways' (Macrorie *et al.*, 2014a: 103). My findings in Section 5.2 shifted attention from a narrow technical or behavioural focus for inducing change in housing practices. Such approaches were shown to have limited, short-term results and to lead to a wide range of unexpected, and sometimes negative, understandings of the technology, the initiative and its organisers. Instead opportunities for intervention in other practice elements – such as meanings and competences – were opened up. Importantly I highlighted the importance of understanding the relations between elements of household practices, and of recognising the potential implications of modifying these connections and linkages. As such, I argue that 're-crafting' the elements of individual practices is unlikely to succeed unless consideration is also given to interrelations occurring between practices.

In Section 5.3, I took forward research from the traditional SPT domain, which has been preoccupied with everyday practices within the home, to consider how domestic practices are related to practices occurring in policy decision-making and commercial settings. I analysed Trinity Close as an explicit intervention in housing design and construction whereby implementation of CSH level six deliberately sought to shift professional housing practices in less energy-intensive directions. This appraisal was framed by a mode of practice intervention termed 'substituting practices' (Spurling *et al.*, 2013), which seeks to replac[e] less sustainable practices with more sustainable alternatives by encouraging defection from unsustainable practices and recruitment to more sustainable alternatives and/or by encouraging more sustainable versions of existing practices (Spurling and McMeekin, 2014). I appraised how low-energy housing design and construction practices were initiated at Trinity Close, how professional practitioners were recruited to this standardised way of building homes, and whether performance of this alternative practice could be sustained. I argued that governing the sustainability of low-energy house-building practices crucially requires not only intervention in practices-as-entity, but also needs opportunities to reproduce sustainable practices by more or less faithful performances over the long term (Macrorie *et al.*, 2014a).

The TCSG assumed that simply replacing conventional house building materials with the latest renewable and thermally efficient technologies and standardising construction practices in accordance with CSH level six, would automatically deliver carbon-neutral housing at Trinity Close. In distinct contrast, this research took the position that attempts to steer housing construction in less energy-intensive directions would require the bringing together, and integration, of low-energy house-building materials, modified meanings and competences. I demonstrated that generating low-energy housing construction practices at the site needed not just the introduction of new materials, but also demanded modified ways of thinking about, planning and responding to building processes, alongside new skills and abilities for interacting with the materials and tenants post-occupancy. These non-material requirements were frequently overlooked. Some technologies were harder to source, understand and operate than anticipate, and it proved difficult for the professional practitioners to move away from skills and approaches accumulated through their exposure to 'leaky' and lower Code builds. As a result, those at the front-line of the initiative increasingly questioned the technically prescriptive and points-led approach put forward by the CSH standard.

Attempting to deliberately standardise and shift unsustainable housing design and construction practices in less energy-intensive directions, proved more difficult than the policy-makers responsible for producing the CSH, or the TCSG, had envisioned. This was because the planned transformation required the insertion of a whole set of interconnected low-energy practices into the housing system, and was not limited to revising house-building practices alone (Macrorie *et al.*, 2014a: 104). Working to the CSH accreditation process at Trinity Close sought to generate connections between housing-related practices and practitioners, sufficient to encourage the professionals away from conventional build approaches and simultaneously construct a new system of low-energy housing practices. For example, TCSG accessed a funding stream provided by DCLG to cover the increased cost of building carbon-neutral properties, training materials in relation to the standard's requirements could be accessed, the CSH was underpinned by the familiar Standard Assessment Procedure (SAP) used in UK Building regulations, and energy consultants provided advice on suitable low-energy materials and how to nurture a low-energy Rackheath community. However, house-building approaches were intricately connected to a whole raft of practices, relations with which had been established through extensive past performance. This made it exceptionally difficult to single out, and attempt to transform, entrenched housing construction practices at the Trinity Close site.

I explained how it had not been fully possible to deliberately target and alter housing construction practices to be more environmentally sustainable at Trinity Close (see Section 5.3). First, the initiative produced variety in housing construction practices rather than a standardised outcome, with some housing practitioners struggling to utilise, install, maintain and/or introduce to tenants the low-energy features of the Trinity Close properties, and some inserted materials generating resistance across the practice system. Second, attempting to shift housing construction practices in accordance with the CSH standard was shown to represent a modal shift in practice as opposed to a complete transformation in practice, as it failed to challenge social conventions and institutionalised assumptions associated with 'normal' energy needs in domestic life. For instance, the Trinity Close homes offset domestic energy demand with substantial amounts of electricity generating photovoltaic panels. They were also designed in accordance with traditional western understandings of a home, and to meet or exceed all energy-related service and comfort requirements provided by a standard new-build property. Third, targeting housing construction practices in Rackheath produced unintended knock-on effects – for instance, levels of tenant trust in the housing provider fell, and tensions grew between the TCSG and the local Parish council over the Trinity Close development.

Whilst involvement in Trinity Close Phase One enabled the TCSG and professional practitioners to learn from their experiences, they were constrained in their ability to apply these understandings in subsequent housing development projects. They quickly recognised a failure of the techno-rational paradigm to take into account householders' practices, resulting in highly variable building energy performance. For some this failure only served to reinforce their commitment to improved technical performance and provision of education and incentives to ensure that residents used the installed technologies optimally and ceased 'wasting' energy. Others considered broader sociological reasons for the unexpected results, such as ingrained cultural conventions. Whilst a range of strategies were voiced as to how to ensure low-energy housing going forward, the majority of professional practitioners were captured by the option of designing-out occupant involvement and adopting a more fabric first approach to housing construction. This translated into pursuit of a highly thermally efficient building fabric, abandoning 'add-on' technologies, and continuing emphasis on minimal impact on householders' everyday lives.

The original ambitious aims at Trinity Close – to achieve the highest CSH level six – were abandoned for Phase Two of the development in favour of building fourteen units to CSH level four, only one step above statutory building requirements. Regardless of what the TCSG had learnt from the first phase of the development, the new housing design and construction practices that they had acquired, and the new systems of practice that they helped to construct, I showed how they were unable to replicate CSH level six practices in Broadland district. With limited opportunities to build carbon-neutral housing in the near future, the TCSG risked losing out on the progress made in Phase One in reshaping elements, and reconfiguring housing practices and their linkages.

As such, I demonstrated that neither re-crafting housing-related practice elements (by inserting new energy-efficient materials into housing construction practices without disrupting everyday domestic life), nor attempting to shift whole practices (by standardising CSH level six housing construction practices) proved sufficient to bring about and sustain low-energy housing at Trinity Close. Further, I asked whether it was even possible to intervene in a single practice. Within the home, it was shown that heat comfort practices were intricately connected to a whole raft of other household practices (and practices that extended outside of the home) and changing the elements of this practice, had distinct ripple-effects on the make-up and performance of everyday domestic life. Regardless of what the professional practitioners had learned during Phase One of the initiative, shifts in the systems of practice, of which they were but a small component, prevented further reproduction of low-energy housing practice.

7.1.3 What is the potential for applying 'systems of practice' to the governance of low-energy housing?

In Chapter 6, I considered the outcomes of Trinity Close by analysing implementation of the CSH at the site as an intervention in a multi-dimensional system of practices, with the aim of exploring whether, and how, a systems of practice framework could progress the low-energy housing agenda. This chapter extended conceptual contributions made by Shove and Walker, 2007, 2010; Pantzar and Shove, 2010; Schatzki, 2011; Shove *et al.*, 2012; Watson, 2012; Spurling *et al.*, 2013; Spurling and McMeekin, 2014; and Macrorie *et al.*, 2014a&b (see Appendices O and P).

I developed a definition for a system of practice - a relatively stable configuration of linked practices and relations that together sustain a particular socio-technical mode of doing and can vary in size and complexity from a modest complex or bundle of practices, to an intricate, multi-dimensional configuration of practices. According to this view, 'specific practices are connected to, shape and are shaped by, practices that they precede or follow in time, those they co-exist with in space, as well as those they are connected to more distantly' (Macrorie *et al.*, 2014a: 98). Adopting this systems of practice approach demanded that attention was paid to whole practice systems as opposed to single practices, their elements, or the practitioners that carry them. Second it called for a greater focus on the ways in which practices interrelate. Third this approach broadened the temporal and spatial focus conventionally adopted in practice studies.

Whilst acknowledging the limitations of arrangement theories, in order to find a 'way in' to analysing the Trinity Close initiative as a system of practice intervention, I used two concepts derived from a fundamental component of Actor Network Theory (ANT) – the sociology of translation (see Section 2.2.2) – problematisations and enrolment/de-enrolment. In describing how practices became configured by different housing challenges, I argued that problematisations (Callon, 1986) emerge from networked practice relations and provide a way to negotiate and study systems of practice. I used this concept to understand how particular challenges led housing-related practices in Rackheath, their elements and the practitioners carrying them, to interlock in particular ways. At the same time, I noted that problematisations, to some degree, artificially divided the network of practice bundles and complexes studied in Rackheath, because change is ongoing.

I also used the notions of enrolment and de-enrolment (*ibid.*) to analyse fluidity in the Rackheath system of housing-related practice, and to account for how elements, practices, and practitioners were able to disband from a network as easily as they were enrolled. These concepts were utilised, instead of, for instance, Pred's (1981) dominant projects, because they provide a relational understanding as to why particular practices, or elements/practitioners become influential (and not others). Coupled with the concept of problematisations, enrolment and de-enrolment arguably provide an understanding of change that is more organic, broader and dynamic than that of institutional projects (*ibid.*). Understanding the evolving nature of low-energy housing initiatives in Rackheath, and implementation of the CSH, in this way, enabled appraisal of the entangled practice relations and dynamics that continuously shaped this system of housing practice.

My analysis revealed that the Trinity Close initiative sequentially adopted five systems of practice configurations over a period of ten years, in accordance with different housing problematisations. Whilst these problematisations to some degree artificially divided the network of practice bundles and complexes performed at Trinity Close, they included: responding to a need for greater UK housing supply, attempts to ensure green growth through an eco-town bid, delivering Trinity Close Phase One low-energy housing trial to CSH level six, using learnings from Phase One to inform the second phase of the initiative, and subsequent development of a housing strategy for Broadland District. These distinct problematisations emerged from relations between linked practices. At the same time, these relations held the problematisations in place, and prompted reconfiguration of the system of housing practice.

Using the notions of enrolment and de-enrolment to understand the evolution of these different networked configurations of practice, I demonstrated how the five different problematisations of low-energy housing at Trinity Close variously enlisted practices. Similarly, components of the system of housing practice detached from the assemblage through processes of de-enrolment. First, I showed that a particular configuration of practices could only be sustained when there was full enrolment of components across the practice system (from the bricks and technologies of the development to the residents, the National Grid, construction workers, and government policies). Second, I demonstrated that it was not only important to enrol practitioners to new energy-efficient practices-as-entities, but that these practitioners also needed to be retained, and their faithful and regular performance nurtured within a supportive system of practice (Macrorie *et al.*, 2014a). As explained for Trinity Close, neither of these opportunities were available. Without such reinforcement, codified low-energy housing practice relations became unstable as networked practice components detached and de-enrolled. This led to Phase Two Trinity Close being downgraded to CSH level four. More broadly, these changing relations were intricately linked to changing housing policy and financing practices.

Analysis showed networked practice relations and intersections to be crucial in; producing distinct configurations of practice at Trinity Close, creating, maintaining and collapsing systems of practice, and determining the emergence and translation of novelty. Analysing the evolution of the Trinity Close system of housing practice produced a typology of thirteen practice relations, which included, but were not limited to, relations that were: cascading, chaotic, constitutive, contingent, competitive, cooperative, creative/enabling, demonstrating, destructive/prohibitive, emergent, experimental, standardising, and reinforcing. The different types of relations varied in: nature, direction, force, density of connections, duration, and/or distance of reach. Despite these gradations, stronger relations/greater numbers of connections were shown not to necessarily lead to permanence and immovability, just as weaker/fewer connections did not inevitably lead to change. Extending the work of Schatzki (2011) and Shove *et al.*, (2012) feedback dynamics – negative, positive and spin-offs – were also shown to operate at Trinity Close. These forces of change regulated, gave momentum to, and led to unintended effects, within the housing system of practice.

Using a systems of practice analytical lens to study Trinity Close, I demonstrated that to understand and attempt sustainability transformations in housing, it is essential to recognise that governing, construction and household practices are all enmeshed within a broad relational and dynamic assemblage of networked practices. Implementation of the CSH level six at Trinity Close produced a particular (predominantly techno-rational) configuration of the housing-related practice system. However, the way that the housing-related system of practice was structured in Rackheath was jointly configured by diverse practices including: international economic practices, European environmental policy-making, national electricity micro-generation practices, local planning procedures, low-energy technology manufacturing and cultural conventions around domestic living. Whilst such practices initially appeared unrelated, I found that linkages between them, held ways of 'doing housing' in place. At the same time, I demonstrated that networked practice relations and dynamics also allow established practices to change, providing a distinct governance opportunity.

This research has shown that whilst interventions in practice may be attempted – including replacing practice elements, shifting relations between practices, and altering carrier recruitment/defection levels – they can go awry, operate in unexpected ways, or fail to be sustained. Adopting this systems of practice approach I have shown that every action can be conceived as a potential intervention in practice, change can arise from anywhere in the practice system, and that attempting non-interventions in practice (such as by using technologies to 'design out' householders) is unrealistic. Furthermore, no single actor can be seen as 'in charge' given that practices and their carriers inter-relate, feed back and can spin off as part of more extensive systems of practice (Macrorie *et al.*, 2014a). Understanding housing and sustainability interventions according to a systems of practice perspective therefore has definite applied implications.

7.1.4 How can social practice theory inform the governance of low-energy housing? Recommendations for Policy and Practice.

The contributions made by this research have clear implications for policy and practice in terms of governing and implementing low-energy housing and for sustainability transformations more broadly. At a fundamental level, this research challenges the assumptions embedded in the dominant techno-rational paradigm that underpinned the former CSH standard and that form the basis of the recently revised UK Building Regulations. By reframing the problem of low-energy housing as a challenge of reorganising networked housing-related practices, widely accepted policy and practice objectives of: technological development and distribution, codifying sustainable housing construction, standardising equipment usage, and delivering end-user energy savings using behavioural change strategies, have been shown to provide only a partial response to this substantial challenge.

It has been recognised that there is an ongoing critical need to build more homes (particularly affordable homes) to meet UK demand (e.g. Wilson, 2010). Coupled with this, how we build our homes today will shape how we live in years to come, thereby contributing to future energy use and associated carbon emissions (Macrorie *et al.*, 2014a). Perpetuating a techno-rational approach and linear governance strategy has however led to lower than expected results and meant that the Labour government's original target of delivering zero carbon homes in England from 2016 seems at present unachievable, particularly given the change in political administration. The ZCH Timeline to Zero Carbon group (comprising representatives from all sectors of industry, related associations and 'green' lobby groups) last suggested in September 2013 that the overall Red-Amber-Green (RAG) status of meeting the 2016 target was Red/Amber: Requires substantial attention (ZCH, 2015).

Continuing pursuit of this techno-rational strategy has also thrown into question the ability to meet the less-stringent carbon-neutral housing goals agreed by the Coalition government (which include exemptions for housing developments smaller than fifty homes and permit allowable solutions). As a consequence, it is vital that research and governing approaches for low-energy housing are reassessed and revised. A single case study cannot hope to fulfil this requirement on its own. However, here I suggest recommendations for policy and practice that form the beginnings of a new policy and applied low-energy housing agenda, and that have broader relevance for achieving sustainability transformations.

Building performance standards, such as CSH, are important in shaping sustainable transformations to low-energy housing. Watering down of the 2016 zero carbon homes target and the policy-decision to drop the CSH have certainly slowed the trajectory of building more sustainable homes in terms of energy and water. However, whilst CSH encouraged more energy-efficient housing construction practices across the UK housing industry - primarily by inserting new materials and technologies into conventional house-building methods - the standard has been shown to have limitations. This research has highlighted how it is important to question whose visions and assumptions are contained within standards, and has revealed how standards created in the context of high consumption of energy and energy services can reinforce assumptions around housing and domestic life. For example, assumptions about levels of energy consumption can be inadvertently inscribed in the products promoted by CSH (e.g. highly insulated buildings may not require a centralised heat source). Similarly, offsetting energy demand via allowable solutions may only serve to legitimise unsustainable levels of domestic energy consumption. As a result, this research recommends that building standards, and changes to building regulations are implemented with caution.

Current policy and practice in this area focuses on enhancing building energy and carbon performance by developing, disseminating and installing highly energy-efficient materials and measures alongside renewable energy technologies. I have framed this approach as one that sought to insert cutting edge technologies, modified materials and tightly controlled construction techniques into the practices of housing design and construction professionals. However ingrained professional practitioner competences and meanings associated with conventional 'thermally leaky' housing often failed to be connected to, newly inserted material elements. This led to unexpected technical breakdowns and less than optimal building energy performance. Whilst improving the structural qualities of buildings clearly forms part of the solution for bringing about low-energy housing, it is essential for policy and practice to place attention on developing appropriate skills and knowledge to enable low-energy housing design, construction and domestic life. Particularly given recent changes to housing policy, I advocate clear institutional advice, tailored information provision and supportive training programmes for housing professionals. This support package should go beyond the Zero Carbon Hub's advice for closing the energy performance gap (ZCH, 2014), which does not include occupation, to consider resident handover and residents' technical concerns where possible.

The development of Trinity Close, Rackheath, as an initiative that emerged from the failed Rackheath eco-town proposal, was hailed as a technical demonstration project that would inform the planning strategy for Broadland district and would encourage housing developers to be more environmentally ambitious by proving the merits of building to CSH level six. However, it was shown in this research that without the opportunity for repetition of low-energy housing design and construction practices, modified practice performance is not sustained and practitioners abandon newly learnt modified ways of doing. As such, rather than one-off trial projects that act as a test-bed for new technologies, longer-term opportunities for nurturing alternative forms of low-energy housing and professional and household practices should be developed. Furthermore, projects that challenge the techno-rational agenda – for instance, eco-villages, co-housing developments and 'alternative' housing projects (e.g. Pickerill and Maxey, 2009) – should be encouraged. These alternative, often marginalised, approaches to low-energy housing can pay greater attention to householder and professionals' practices in their design and operation than dominant commercial approaches. Rather than pitting these different modes of low-energy housing against each other, as Karvonen *et al.* (nd.) suggest is commonplace, opportunities for shared learning should be sought.

Standards, such as the CSH, fail to consider new build properties as 'lived in homes', omitting household interactions from technical assessments and undertaking the accreditation process prior to handover. This research has shown that the building fabric, technical measures and electrical monitoring devices installed in CSH level six properties are never socially neutral because they are only ever used as part of social practices. Furthermore because householders often interact with these measures in unexpected ways and potentially subvert their function, they cannot be expected to deliver energy reductions in a linear manner according to a simple cause-effect relationship. This has significant implications. Planning, designing and assessing the performance of low-energy housing should take into consideration householder practices and the inextricably social nature of technological change. This prompts greater emphasis on practice-oriented design approaches and on incorporating household practitioners' feedback in the design process. It also encourages low-energy housing to be viewed as an ongoing process rather than a product (Ball, 2002), demanding the development of new types of models and appraisal methods.

To the extent that householders were considered at Trinity Close, they were framed as passive actors who would not be affected by their altered domestic environment and whose primary concern was to maintain (or improve) the quality of their contemporary lifestyles. It was hoped that education (provided through electricity feedback data and energy saving tips) and incentives (reduced electricity bills) would encourage motivated individuals to change their wasteful habits. This research argues that householders and their practices are pivotal to the performance of low-energy housing and should be central to strategies for change. Rather than understanding energy consumption as important in its own right, a SPT based approach to policy and practice contends that it can only be understood as a moment in (almost) every practice (Warde, 2005). In addition, SPT offers a radically different conception of change to one that argues that energy-efficient behaviours can be brought about by individual cognitive adjustment. Rather than seeking to change individuals therefore, what is needed is to change the nature of institutional arrangements, provide supportive infrastructure and nurture social interactions and conventions that encourage less energy intensive domestic practices.

This thesis has advocated a systems of practice approach for a low-energy residential sector and society. According to this perspective, it was argued that there is a critical need to attend to how different practice relations intersect, and to the dynamics of change and stability within and across practice systems. The first challenge for policy and practice then, working outwards from the specific practice of interest, is to 'map the system' and delimit the network of practices involved. This conceptual mapping approach would identify the links within a practice system that are most important (strongest/closest) to the target practice or intervention in question, as well as the most closely involved actors or agents (for instance construction training materials or building regulations). It would also advocate looking across whole system of practice and potentially intervening in connected practices that are seemingly indirectly linked to housing practices – for instance, work, shopping, or mobility practices.

A systems of practice perspective also encourages a different understanding of governance for sustainability compared with conventional policy and applied practice. The DCLG and the TCSG held assumptions that carbon-neutral housing would automatically be delivered through implementation of the CSH level six standard. Whilst Trinity Close gained certification to CSH level six, such 'modernist steering' (Rip, 2006) led to highly variable energy performance results between households and produced unexpected results (for instance resistance and resentment from the WHA tenants). A systems of practice understanding contends that such anticipated linear change is rarely possible given the connections and ties that hold practices in a particular configuration. Consequently, dynamics and relational effects within the system often lead to unanticipated initiative outcomes.

According to a systems of practice perspective, every action, whether intentional or unintended, should be conceived as a potential intervention in practice. This calls for more 'modest' approaches to governance which recognise that would-be governors are 'part of evolving [practice] patterns and can at best modulate them' (Shove and Walker, 2010: 475). This perspective also however brings into view a far wider cast of political actors than government institutions or initiative organisers alone. From a systems of practice standpoint, everyone is a carrier of practice and no single actor is in charge. Whilst the 'would-be governors' of Trinity Close had the privileged position of being able to dictate the terms of practice-as-entity (i.e. formulating the requirements of the CSH standard and setting the objectives for the Trinity Close initiative), the Trinity Close initiative failed to connect with similar schemes and drew minimally on findings from previous initiatives. The organisers of the scheme failed to obtain feedback from the Trinity Close householders regarding their experiences. Phase Two of the scheme was also implemented before full appraisal of institutional findings from Phase One had occurred.

Far from inhibiting change however, I argue that a systems of practice approach could more usefully reconfigure the housing sector in less-energy intensive directions than current dominant approaches. Building on ideas of reflexive governance for sustainable development (e.g. Voß *et al.*, 2006) - but focusing on practices, their relations, and dynamics - this research advocates the 'reflexive governance of [systems of] practice' (as first conceptualised by Shove and Walker, 2010). This has four important implications.

First, would-be governors of practice should recognise that their actions and responses in part constitute, and therefore cannot be thought of as outside of, and acting on, target systems of practice. Second, this position advocates multi-actor and multi-pronged interventions. Third, whilst seemingly presenting unlimited complexity, the reflexive governance of practice systems opens up more possible intervention points than current policy and practice (in the form of modifying practice elements and links, affecting carrier recruitment and practice performance, substituting practices, altering practice relations and changing practice system dynamics). Fourth, sustainability interventions for systems of practice may need to look outside of target practices and systems, to change indirectly connected practices and overlapping systems.

According to the reflexive governance of practice systems, continuous and ongoing system change leads to a fifth implication – initiatives, standards, policies and institutions 'must be seen as hypotheses that are to be probed in practical interaction with the world' (Voß and Kemp, 2006: 19). This calls for monitoring, adapting to the results of, and linking-up learnings from a range of different practice system interventions (planned using the previously discussed conceptual mapping strategy). By paying attention to how flows within and between practices change over time (strength/direction/speed of links), and constantly to how interventions generate reactions, interactions and resistances throughout practice systems (Macrorie *et al.*, 2014a: 108) initiatives can be adapted according to experience and learning. Whilst not ruling out radical change, this line of argument supports cumulative and adaptive socio-technical transformations. It also requires new forms of evidence and policy tools that help to understand systems of practice, whilst excluding others e.g. randomised control trials.

7.2 Research contributions: Empirical, theoretical and methodological

The following three sections describe the empirical, theoretical and methodological contributions made by this thesis.

7.2.1 Empirical contributions

By studying one of only thirty-nine carbon-neutral housing properties built in 2011 (April to December), this research was unique in providing one of the first in-depth case studies to appraise the highest level of the CSH building performance standard. In undertaking in-depth research investigating implementation of this standard at the Trinity Close (Rackheath) site over an eighteen-month period, this research has provided unparalleled insight into the implications of designing, building and living-in low-energy housing. Furthermore, by conducting ethnographic and grounded theory research, I have highlighted the complexity, reflexivity and important details associated with realisation of this standard, which commonly fail to be captured by other research approaches and methods.

As opposed to conventional practice research that has focused on the everyday doings that occur in the domestic setting, this investigation addressed the relative lack of attention given to housing professionals' practices and interventions in housing infrastructure. The research analysed a range of Trinity Close stakeholder practices including: central and local policy-making, financing and project management, architectural practices, property construction, technology manufacturing, tenant and community engagement, property maintenance, environmental advisory practices, and building energy performance monitoring and appraisal. This is not to say that householder practices were overlooked. Indeed using heat comfort practices as an entry point – an important target practice given their energy and carbon implications - I gained a detailed understanding of how household practices were shaped by, and shaped, low-energy housing, and how they inter-related with housing professionals' (as well as a wide array of other) practices.

In providing an account of low-energy housing as a system that includes the practices of housing professionals, design and build outcomes, and interrelations with householders' practices, this research is arguably broader reaching and more targeted than research that does not examine the practices of initiative organisers and end-users or *vice versa*. Emphasising the need to consider the role of specific contexts in shaping and structuring low-energy housing, this thesis offers a radically new understanding of low-energy housing by showing how different practices from across the housing sector (and beyond) overlap and relate. Understanding the implementation of carbon-neutral housing as an intervention in a whole system of practices has distinct implications for reconfiguring housing in less energy-intensive directions.

7.2.2 Theoretical contributions

This research has sought to explore questions set out at the start of this thesis using a social practice theory (SPT) based approach. This theoretical framework presents a distinctly different approach to dominant building and energy research which privileges technical assessment, improvement, dissemination and optimal end-user usage as a means to optimise energy reductions. Instead of understanding energy consumption as important in and of itself, using a SPT approach has advocated an understanding that low-energy housing is only created and sustained through the performance of social practices. Analysing the composition, performance, relations and dynamics of practices has offered a sociologically attuned understanding of low-energy hosing, which contrasts with reductive behaviourist accounts of socio-technical change that seek to analyse and influence individuals' attitudes, values and choices. I have also provided a radically different view of socio-technical change to research that seeks to understand and overcome an increasing array of structural barriers to change.

In this thesis, I have framed the CSH and Trinity Close initiative as an intervention in a whole system of practices. Empirical investigation applied the practice-oriented framework for policy interventions developed by Spurling *et al.* (2013) and Spurling and McMeekin (2014) by showing how the practices of housing professionals (and indirectly, householders' domestic practices) became shaped through changes to i) the elements of practice, ii) the recruitment of carriers and iii) relations between practices. Exploring the first mode of intervention considered whether it was possible to intervene in one element of practice alone, and found that it was impossible to do so without disrupting the practice as a whole, and causing repercussions on linked practice complexes and bundles. I found that the CSH standard privileged the insertion of new energy-efficient materials into housing construction practices, and overlooked the possible intervention points of re-crafting of meanings and competences related to low-energy housing. I highlighted the importance of attending to the links between practice elements. Importantly, I suggested that re-crafting the elements of individual practices is unlikely to succeed unless consideration is also given to interrelations occurring between practices.

When empirically analysing the second mode of intervening in practice – practice substitution or the recruitment of carriers – I found that in order to encourage low-energy housing design and construction practices, it is crucial not only to intervene in practice-as-entity (as suggested by Spurling *et al.*, 2013), but also to generate opportunities to reproduce sustainable practices-as-performances over the long term. Furthermore, far more than simply paying attention to how practices connect and interconnect (Spurling *et al.*'s third mode of intervention) I found that the coming together of alternative practice entities and the repeated performance required to sustain new or modified practices necessarily occurs within a relational and dynamic system of practice. As such, I suggested that adopting a systems of practice approach demands that attention is paid to whole practice systems as opposed to single practices, their elements, or the practitioners that carry them. In this research I have applied and extended the systems of practice concept.

In response to pleas for this concept to be made less 'fuzzy' (Shove, 2015), I defined a system of practice as a relatively stable configuration of linked practices and relations that together sustain a particular socio-technical mode of doing and can vary in size and complexity from a modest complex or bundle of practices, to an intricate, multi-dimensional configuration of practices. To analyse implementation of CSH level six at Trinity Close housing development as an intervention in a whole system of practices, this research innovatively provided a means to make sense of complexity by drawing on relational assemblage theories. I proposed use of two notions derived from a fundamental component of Actor Network Theory (ANT) – the sociology of translation (see Section 2.2.2) – problematisations and enrolment/de-enrolment. In describing how practices became configured by different housing challenges, I argued that problematisations provide a way to negotiate and study networked practices within and across systems. Enrolment and de-enrolment of practices (and their elements and carriers) were used to analyse fluidity in systems of practice. These concepts helped to explain how practice bundles and complexes were able to disband from a network as easily as they were enrolled.

I demonstrated how practice relations and intersections are crucial in: producing distinct configurations of practice, creating, maintaining and collapsing systems of practice, and determining the emergence and translation of novelty. Consequently, because performances that actualise a particular practice entity (such as housing construction) are part of multiple practices, single practices may not always be the appropriate unit of analysis (Spurling and Blue, 2014; Welch, 2015). I also showed that just as for individual practices, systems of practice have lifecycles that extend through time and space, and that can be studied. In seeking to understand what constitutes a practice system and how it changes (a question raised by Shove, 2015), this research placed emphasis on the linkages and connections that contribute to shaping configurations of practices. I suggested that links between practices differ in nature, number, length, direction, strength and permanence. I also highlighted how standards, such as CSH, form an interesting way by which practices are linked, reproduced and potentially transformed. Extending work by Schatzki (2011), in Chapter 6 I produced a typology of different practice relations, and described how networked practice dynamics include positive and negative feedback and spin-offs that can produce unintended consequences.

Understanding the Trinity Close site as a networked configuration of linked and overlapping practices offered a vastly different account of socio-technical transformation than either the techno-rational paradigm or the multi-level perspective (MLP). As opposed to hierarchical assumptions that transitions will arise from nurturing technical and social innovations (such as the Trinity Close demonstration project) which then burst through at a regime level, and can take hold when landscape pressures are conducive, this research has argued for a 'flatter' understanding of socio-technical change. Whilst advocating more of an organic structure, it is acknowledged that there will invariably be some 'dynamic ordering' within any practice system (Schatzki, 2015). I contend that any change need not proceed in a 'top-down' or 'bottom-up' direction, but will be dependent on the practice relations holding the practice system in a particular configuration and allowing it to be modified according to different problematisations.

This research supports understandings that all social life is a 'complex developing mosaic of continuity and change' (Schatzki, 2011: 20). Hence, I have shown that change can arise from anywhere in the practice system and that therefore no one actor is in charge. All actions are potential interventions in practice, and networked practice relations and dynamics mean that attempts to govern practices invariably lead to ripple effects throughout the system. Change can arise from anywhere within an interconnected practice system or from linked/overlapping systems of practice. This highlights the limitations of linear techno-rational interventions and explains why governance initiatives often go awry, operate in unexpected ways or fail to be sustained. At the same time, it presents more opportunities for bringing about transformative change for sustainability within the housing sector (as well as further afield).

7.2.3 Methodological contributions

This research is novel in conducting in-depth research into the implementation of the CSH level six at a demonstration site – Trinity Close, Rackheath. To describe how social practices were made-up, performed and related to one another, and to explain the variety in practice identified by quantitative energy performance monitoring at this site, I argued that in-depth, qualitative research was needed. As a result, I combined a range of qualitative data collection techniques – documentary review, semi-structured interviews, household audio tours, research diaries, discursive games, and interpretation of temperature plots. These techniques were used to explain variety identified by quantitative energy performance monitoring data.

Methods of data collection and analysis used in this study provided one way of understanding the Rackheath housing-related system of practice (for other possible approaches see Macrorie *et al.*, 2014b). The selected methodological approach was used in order to examine the way in which practices, elements and practitioners became enrolled and de-enrolled from distinct problematisations at the site. In contrast to conventional practice studies that have focused on the composition and performance of isolated practices (commonly mundane household practices), this research adopted a greater methodological focus on how different practices (performed by different practitioners in contrasting sites) interrelate, form links, and how these connections break apart. The methods that I used also provided understanding of how practice relations and dynamics determined particular configurations of the housing-related system of practice.

The theoretical notions of problematisations and de/enrolment meant that I attended to the dynamics of change and stability within and across the housing practice system. I considered the linking and dissociation of a wide array of practices, some of which were indirectly connected to the practice system and were not immediately relevant. In addition, as opposed to capturing a single snap-shot of the system of practice, the documentary review and in-depth *in situ* investigation provided a means to examine evolution of the practice system over a ten-year period. As opposed to exploring the context of a particular case study at the start of a research investigation, mapping the practice system led to a widening out from seemingly small to larger contextual issues (as context emerges through practice). I argue that this recursive relationship is a vital part of the systems of practice methodological approach. By following practice relations, I have shown how implementing the techno-rational CSH (the initial subject of this research) forms only part of a far broader practice system. I have also demonstrated how the CSH problematisation of low-energy housing overlaps with other system of practice configurations, which may need to be taken into account to better understand the potential for a low-energy housing sector.

This thesis has identified distinct methodological implications associated with the systems of practice concept. I have argued that only by using mixed-method SPT-informed data collection and analysis that takes into account different actors and sites and by studying different parts of the practice system, can an accurate picture of the relations, dynamics and potential for transformative change in less energy-intensive directions be developed. Abstract assessments of the performance of particular materials, large-scale surveys of factors influencing individual decision-making processes, cost-benefit modelling and randomised control trials, can only ever capture a narrow slice of this complexity. At the same time this complexity highlights the importance of targeting, being reflexive about, and potentially revising which practices and relations have research significance.

7.3 Next steps: A new research agenda.

This thesis has demonstrated the merits that social practice theory, and application of the systems of practice concept, has for progressing low-energy housing and enabling broader sustainability transformations. This outcome raises five areas for future research investigation: i) Greater conceptual development and empirical work on systems of practice ii) Developing mixed-method approaches for studying systems of practice iii) Researching links between multiple systems of practice and iv) Studying how governance and power operate through practice and v) Encouraging practice-oriented policy-making and applied interventions.

First, this thesis has shown the potential of the systems of practice concept to make substantial contributions to policy and practice in the field of low-energy housing, and has suggested that it would have value for addressing wider sustainability and societal challenges. Given the lack of research conducted using this concept to date, it is imperative that greater conceptual development and empirical work is conducted on this topic. In terms of conceptual development, further investigation is required to understand how to boundary systems of practice as an object of study, and the nature and effects of different types of networked practice relations and dynamics. This research has applied the notions of problematisation and (de)enrolment to understand how systems of practice are reconfigured and change from one configuration to another more or less sustainable arrangement. Further work is required to understand how reconfiguration and how change occurs at the systemic scale, and the implications for sustainability interventions. In terms of empirical investigation, the challenge for practice theorists is to identify and study the links, flows and relations occurring within systems of practice that have most relevance to particular sustainability interventions and/or target practices (Macrorie *et al.*, 2014a). Paying attention to these relations and dynamics and how they change (or remain stable), future empirical work could trace how practice systems have historically been reconfigured, apply a systems of practice analysis to the appraisal of sustainability initiatives, and experiment by deliberately altering practice links, connections and patterns and monitoring the effects.

Second, in order to study systems of practice, mixed methodological approaches are required. This thesis has described how recent SPT investigations has challenged dominant building and energy research that reduces the low-energy housing problem to a matter of objectively measuring, modelling and comparing technical and physical parameters. Instead SPT research purports that building energy performance and residential energy demand can only be studied as artefacts of the performance of (most) social practices. It has been shown that it is not adequate to predict residential energy demand on the basis of factors such as size of household, socio-economic status and tariff availability, because energy-related practices always vary in their performance. Large-scale questionnaire surveys, used to predict residential energy demand, also not only reinforce the realities that they describe (e.g. Corral-Verdugo, 1997), they also perpetuate methodological individualism by focusing on the attitudes, values and choices of individual consumers (Shove, 2010), as opposed to questioning how practices are produced, sustained, relate and can be transformed with and across systems. Consequently SPT approaches have highlighted how dominant housing, energy and social research is insufficient to meet the scale of the sustainability challenge being faced.

Whilst SPT research provides a valuable alternative to dominant methodological approaches in this field, this thesis has highlighted how the majority of SPT studies have focused on isolated practice entities, and their performance by particular actors (especially within the domestic setting). This thesis recommends that in order to investigate the interactions and dynamics occurring between multiple practices and elements, SPT research needs to move beyond qualitative small-scale studies that focus on the lifecycles of isolated practice entities and their carriers (Pullinger *et al.*, 2013: 8-9). This research has found a combination of in-depth qualitative methodological approaches (participant observation, repeat semi-structured interviews, heat comfort practice diaries, household audio-tours, interpretation of temperature data logs and discursive games on energy-related domestic practices), coupled with documentary analysis and a review of secondary building energy performance data, suitable for this task. However, multi-method approaches to studying systems of practice could adopt various strategies (described in Macrorie *et al.*, 2014b).

By studying practice bundles/complexes and their interconnections, practice researchers might seek to identify a target practice that acts as an entry-point to explore connections, or might focus on a particular locus of intersection. For instance, Hargreaves *et al.* (2013) studied a local food cooperative and analysed the interrelations between cooking, shopping and food-growing practices. Research could be undertaken on the changing dynamics of networked practices, for example by using life-course graphs, time-use data, and oral histories to study how practices grow or decline in popularity over time. Variety in practice composition and performance could be studied through in-depth case-study research. For instance, this thesis broadened its focus from householders' experiences of maintaining their domestic heat comfort to consider how construction practices and housing policy-making practices changed during implementation of the Trinity Close initiative.

Survey-based research (e.g. Pullinger *et al.*, 2013) and analysis of larger data sets (e.g. Anderson, 2011) offer alternative methods by which to reveal variety in practice at varying geographic scales. Geographically dispersed practices could be studied by undertaking international comparisons in the timings and dynamics of practice performance, providing insight into the circuits of reproduction at play in systems of practice (e.g. Southerton *et al.*, 2012; Kuijer, 2014). Finally, detection of trends may be required in order to understand broad scale transformations in systems of practice. This might call for cross-sectoral analysis in order to detect wide-scale shifts in societal practices (Shove *et al.*, 2012: 163).

It will be important to join-up these different methods and distributed sources of evidence from right across the practice system, and potentially from overlapping practice systems. This leads to the third methodological direction for future SPT research. In extending the systems of practice approach, this thesis advocates investigation into the links, overlaps and dynamics between multiple systems of practice. For instance, looking beyond housing practices and directly energy-related practices to consider interactions with health, work, shopping etc. Even if distantly connected to the target practice or intervention, investigating these indirect networked connections might provide a fruitful means of system reconfiguration.

Fourth, a major strength of this thesis is that the operation of power within and through the practice system has been shown to be crucially important for the governance of sustainability interventions. Whilst I have wrestled with this topic and its place within the practice system throughout my doctoral study, this investigation has not provided adequate opportunity to develop my initial observations and thoughts. I have recognised that a systems of practice perspective involves a wider cast of political actors and agents than government institutions alone and suggested that, whilst practice relations differ in strength, length, direction and permanency, change can originate from any part of the practice system. Consequently, I contend that applying the reflexive governance of systems of practice (building on Shove and Walker, 2010) could provide a useful way forward. Whilst some practice theorists have begun to consider how power can be placed in practice (e.g. Watson, 2014) it remains an understudied topic, and one that requires crucial development in order for SPT to contribute to reconfiguring society in more sustainable directions.

Finally, this research has conceptually developed and empirically applied a systems of practice perspective and used it to appraise the CSH building standard as a means to develop low-energy housing. Answering the overall research question set out at the start of this thesis, I have been able to clearly explain the potential for social practice theory to progress this sustainability challenge, and I have highlighted how it presents the opportunity for understanding and potentially intervening in other societal and environmental issues. Whilst SPT is gaining increasing recognition at a policy level it remains a marginal approach that some argue provides a direct challenge to incumbent modes of governing and political ideologies (e.g. Shove, 2010). At the same time, it offers an optimistic outlook on socio-technical transformations, and presents a far broader, and arguably more useful, array of intervention strategies than currently relied upon. Consequently, to begin to address urgent sustainability issues, such as low-energy housing, practice theorists need to further disseminate and promote research on systems of practice and its potential application.

Appendix A

BDC report completed after household pilot interviews

Governing change in household energy-consuming practices:

A qualitative review of occupant experiences of low-carbon housing

A research report completed for Broadland District Council

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2nd October 2012

Report contents

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1. Executive summary

This report provides a summary of initial qualitative research findings resulting from a series of eleven householder interviews and audio-tours conducted with residents of a low-carbon social housing development in Norfolk, UK. The householder interviews were conducted approximately five months after occupant move-in. The research forms part of a three year PhD project, funded by the School of Environmental Sciences, University of East Anglia. In line with the PhD research questions, the interviews and audio-tours were intended to provide an account of: initial perceptions and encounters with the household low-carbon technologies, family dynamics and interactions between neighbours in relation to managing energy-demand, and householder experiences of the 'energy governance organisations' responsible for managing the initiative.

The report proceeds by outlining the research approach and design. The 'move-in' and induction period is discussed and householders' initial encounters with particular low-carbon technologies are reviewed. The report then considers the extent to which the low-carbon technologies and low-carbon household space has, to date, brought about a change in domestic interactions and potentially led to a reduction in electricity use. The way in which individual householders interact both within the home and between houses is shown to influence energy-consuming domestic practices. Finally, the effectiveness of governance processes underlying the initiative is considered. Recommendations for the governance of future low-carbon housing developments are provided throughout the report.

2. Research overview

This report was commissioned by Adapt Commercial, environmental consultants for the Trinity Close (Rackheath) low-carbon housing initiative, on behalf of Broadland District Council (Norfolk), as part of a consultancy project designed to reduce domestic energy-demand in the Norwich area.

The empirical research findings outlined in this report form part of a University of East Anglia (UEA) School of Environmental Sciences three year funded PhD entitled 'Energising Communities: The dynamics and governance of everyday energy practices in low-carbon housing'. The PhD researcher, Miss. Rachel Macrorie, is supervised by Dr. Jane Powell and Dr. Irene Lorenzoni (School of Environmental Sciences, UEA). The research is being undertaken in association with the Tyndall Centre for Climate Change Research and the Science, Society and Sustainability (3S) Research Group at UEA.

The overall research aim of the PhD is:

To analyse how, and the extent to which, low-carbon homes and the way in which they are governed encourage less energy-intensive domestic practices.

This overall research aim is to be addressed through assessing the role(s) of: (i) low-carbon technologies (ii) 'communities of practice' and (iii) energy governance organisations in shaping the composition and dynamics of everyday energy-consuming domestic practices.

Definitions:
Energy-consuming domestic practice: Combining the understandings of Gram Hanssen (2008) and Schatzki (1996), an everyday energy-consuming domestic practice is defined as a 'temporally unfolding and spatially dispersed nexus of doings and sayings existing in four forms; know-how and embodied habits, institutionalised knowledge and explicit rules, engagements and technologies, the performance of which results in energy consumption'. For example, the practice of cooking leads to the artefact of energy consumption. Cooking is made up of informal knowledge about how to combine ingredients as part of a recipe, ways of moving when preparing a dish, emotional connections around food, formal rules about how to maintain and operate the oven, and equipment such as the oven itself as well as the electricity infrastructure system.

Communities of practice: The concept of 'communities of practice' recognises the fundamentally social nature of practice and is concerned with how people organise and learn to jointly negotiate and perform particular practices (Lave and Wenger, 1991, Wenger 1998).

Energy governance organisation: Energy governance organisations are here defined as formal institutions involved in making and reproducing (to a varying extent) the systems and arrangements that shape everyday energy-consuming domestic practices within low-carbon homes. Here energy governance organisations are taken to include: the housing developer (Dove Jeffrey Homes (DJH)), the housing association (Wherry Housing Association (WHA)), the local authority (Broadland District Council (BDC)), and the environmental consultant (Adapt Commercial).

The PhD adopts a mixed methods (qualitative and quantitative) research approach to conduct an in-depth study of a single low-carbon housing development. Trinity Close, Rackheath (Norfolk) comprises a low-carbon social housing development designed as a pilot for the proposed Rackheath eco-town (Barratt Homes Strategic, 2009; Broadland District Council, 2011). The twelve properties, which are located approximately five miles north-west of Norwich (Norfolk), have been designed to be occupationally carbon neutral and to conform to the Code for Sustainable Homes Level 6 building standard (DCLG, 2006). In line with this standard, the houses were constructed to have a high thermal mass and passive thermal and solar properties (including high levels of insulation, triple glazing, and a south-facing orientation). The following low-carbon technologies were also installed in each of the properties: an air source heat pump (ASHP), mechanical ventilation and heat recovery (MVHR), a grey-water recycling system (GWR), and solar photovoltaic panels. In addition, electricity consumption at the properties is continuously monitored at a circuit and appliance (up to five appliances) level. Residents are provided with a Geo-Options Geo-Trio energy monitor and In Home Display (IHD) unit

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through which feedback on energy demand is provided. Temperature, humidity and carbon dioxide levels are not being monitored at the properties. Following completion of construction, householders took up residency in the properties in the week commencing 26th September 2011.

This report provides a summary of initial qualitative research findings resulting from a series of householder interviews and audio-tours conducted with the residents of Trinity Close. The householder interviews were conducted approximately five months post occupant move-in. In line with the PhD research questions, the interviews and audio-tours were intended to provide an account of: initial perceptions and encounters with the household low-carbon technologies, family dynamics and interactions between neighbours in relation to managing energy-demand, and experiences of the energy governance organisations.

3. Research design: Data collection & analysis

The residents of Trinity Close were invited to participate in the research by Adapt Commercial by means of a telephone call. On the basis of this introduction, and as part of the condition to provide feedback as part of the tenancy agreement, eleven interviews and audio-tours (the 12th household was not available), were conducted over a two-week period commencing 1st March 2012. The opinions of the residents can be considered as representative of the UK population, in respect to the properties having been allocated on a local needs basis through applications to the housing register, and given that they had no prior green credentials. As such, the residents can be considered as 'passive adopters' of their low-carbon homes (Monahan and Powell, 2011)

Prior to data collection, Research Ethics and Health and Safety approval was gained from UEA. The informants were provided with a written invitation providing an overview of the PhD project, stating the independence of the research. Fully informed consent was gained from the participants and all interviewees agreed to the discussions, which lasted approximately one hour, being voice recorded (for the purposes of transcription). Respondents were made aware that all data would be fully anonymised and held securely. Interviews were undertaken with individuals and couples (termed respondents where interview held with a single individual and household where more than one interviewee contributed to the discussion per household). As a precursor to the interview, the respondents were asked to complete a brief survey in order to obtain demographic information and provide information about the households' previous domestic arrangements. In addition, respondents were asked to complete a brief survey on travel habits as part of the Rackheath Carbon Footprint study (conducted on behalf of Adapt Commercial).

The in-depth semi-structured interviews were designed to take an open format to be flexible to the informants' responses, however an interview protocol (designed in line with Social Practices Theory, Schatzki, 1996; Shove, 2003; Gram-Hanssen, 2008) was used to prompt and broadly steer discussion. Such qualitative research methods aim to examine the variety of perspectives held by a sample of respondents. They provide contextualised information regarding respondents' perceptions and viewpoints and have 'significant strength over survey techniques in that they avoid presumptions about the preferences and interests of the research participants' (Knamiller and Sharp, 2009: 313). Coupled with the discussions, the respondents were invited to introduce the researcher to their home and the ways in which they interact with the low-carbon technologies, through means of an audio tour. Such participatory and collaborative research techniques are designed to enable researchers to share in and gain a more accurate and empathetic understanding of respondents' experiences (Pink, 2007).

The interviews were transcribed by the researcher and through an iterative data-coding process were grouped into research themes and empirical findings.

4. 'Moving-in' and the induction process

The new occupants of Trinity Close, Rackheath received the keys to their new low-carbon homes from 26th September 2012. Respondents overwhelmingly stated that they were pleasantly surprised by the layout of the properties and that they did not fully envisage the implications of residing in a low-carbon home at the time of move-in, for instance, ''*I just couldn't believe it, I just didn't expect it… the water recycling system, and the heat pump and the trickle vents that bring in cool air. It was just amazing, I was shocked*."(Interview K). In line with previous research (Foulds *et al.*, 2012), these empirical results show that this 'move-in' period is a time when shared excitement about new beginnings and attending to the décor and furnishings of the property take precedence over understanding the technical configuration of the home.

Approximately 64% of interviewed households felt that they were conscious of energy-efficiency prior to the move-in and already had agreed actions to minimise energy demand, primarily as a means to minimise financial outlay, for example, "*We were already pretty good at turning everything off when we weren't using them, and we made sure that all our appliances were fairly new.*" (Interview A). The remaining households had minimal interest or capacity for understanding their energy-outgoings, for instance, they were unfamiliar with their monthly utility outgoings, the white-good electrical appliances (which were not supplied with the property) were "*just what [they] ended up with*" (Interview E), and the demands of life, restricted capacities to alter their interactions in the home *"I haven't got the brain capacity to change my routines at the moment, I've got a new baby to look after. I'd forget, and I wouldn't do it, so there's no point in me even considering it"* (Interview D). As such, rather than the technological arrangements of the new properties being taken-up by the household practitioners in a neutral way and to a similar extent, the established meanings, priorities and cultural practices of each household, which change over time and space, provide a lens through which the low-carbon technologies are encountered and made sense of. It is against this landscape of social pressures, pre-existing household engagements and routines that the Trinity Close low-carbon homes and the associated technologies were first introduced to their new occupants.

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Prior to the 'move-in', Trinity Close residents were encouraged to attend a presentation, delivered by WHA, DJH and Adapt Commercial, which was intended to provide an overview of the low-carbon technologies and continuous energy monitoring arrangements that form part of the conditions of tenancy. The majority of householders stated that it was at this stage of the social-housing application process that the technological set-up and obligations associated with residency became apparent. Although several households found this meeting insightful, for some households, unfamiliarity with the engineering measures led to feelings of intimidation and resultant confusion, for instance, *"You could ask questions but we just sort of sat there and listened and thought 'oh no'. And at the time you're more interested in what the house size is and that, but hearing that information, it was the heating that worried me"* (Interview E). Initially the residents were amenable to the technological set-up, and excited by the continuous energy-monitoring arrangement as a means to ensure the smooth running of their homes and inform the design of future low-energy housing. For instance, *"[Energy monitoring] is being done for a reason, then [the governance organisations] can see and make comparisons between these homes and other homes. I think it's important to have that sort of information to make sure that it's all working and make sure it's worthwhile..."* (Interview F). Prior to moving-in, the feelings and emotions of the householders varied widely from nervousness or impartiality around operating the low-energy features, to excitement associated with the social kudos of living in a green home, for instance, *"I showed my future home to my friends and they said 'Ooh it's the ones with the solar panels'. They're a little bit jealous some of them, but yeah I like that [laughs]"* (Interview F).

At the time of 'move-in' and in the initial weeks that followed, housing officers from WHA and representatives from DJH ensured that an induction to the low-carbon measures was provided. These empirical results suggest that this introduction did little to engender confidence around operation of the technical measures, and in particular led to confusion around how to work the unfamiliar heating and ventilation systems. For example, *"[WHA housing officers] took us through in groups…but they didn't know anything and didn't explain nothing, they just told us that the thermostats are in each room but they didn't tell us how to use anything, so basically when we moved in the instructions were just in a big binder and we had to work it out ourselves"* (Interview L). This confusion largely stemmed from the time of delivery (which coincided with the stressful period of unpacking belongings), and the means of delivery (by several members of the WHA housing department who had limited technical knowledge). In the following weeks, various technicians, for example energy monitoring equipment technicians from Green Energy Options who installed the In Home Display (IHD) units, completed installation of the low-carbon technologies at the property, and used this opportunity to provide the householders with operating instructions and guidance. As a consequence, some of respondents found the induction process *"just totally baffling"* (Interview G). For instance, out of fear of incorrectly operating the controls, several households simply turned off their heating and one respondent was so daunted by the foreignness of the technological set-up that they contemplated moving-out (Interview G).

Recommendations:

- It is recommended that the low-carbon features and potential implications of living in a low-energy home are discussed with future potential residents before move-in. Information should be made accessible by minimising technical language, allowing for hands-on interaction with the low-carbon technologies and/or presenting visuals of the devices, and providing adequate time for discussion.

- It is recommended that the potential benefits of living in the low-carbon homes are conveyed to occupants, in terms of not only offering the potential for reduced household utility outgoings, but also in terms of offering environmental benefits, as a means to inform the future design and development of low-carbon properties and a means to help improve current and future occupant experiences.
- A clear communication process between the governance organisations and future residents is advised, for instance to advise upon timings and requirements associated with the move-in process and/or relating to the low-carbon features of the properties.
- It is recommended that the induction process takes place approximately two to four weeks following occupant 'move-in' in order to allow for residents to settle into their new homes. The induction process should involve, a hands-on introduction to the low-carbon technologies. The induction should be clearly communicated, well organised and delivered by a trusted and well-informed governance organisation.

5. Initial encounters with low-carbon technologies

Initially, without exception, the residents of Trinity Close were excited by the low-carbon technologies that had been installed in their new homes. Although the householders had not specifically sought to live in low-energy properties (being allocated residency through the housing register), every household was attracted by the homes having been marketed as affordable properties and the possibility of reducing their utilities expenditure. For instance, *'We thought it would be cheaper to run, because you've got the solar panels and so the electricity to a certain extent would be free, and anything you would pay for would be what you use in the evening"* (Interview B). As shown by Table 1, by March 2012, the households varied in terms of their perceived financial savings, (approximately 55% of interviewed households were of the opinion that they had saved money on their electricity and or water bills).

At the start of the tenancy, primarily due to the confused induction process, but also a consequence of inappropriate information provision, the residents experienced confusion around the role of the low-carbon technologies and their operation. For instance in relation to the MVHR system - *"they suck in warm air, hang on, they blow out cool air, they suck air from within [mumbles] or something [laughs]. They're just on all the time, we don't actually do anything with them."* (Interview K). This confusion applied in particular to the setting of the thermostatic panels for the heating system (as discussed below) (see Table 1). Residents were provided with a technical manual at the time of 'move-in', but for many households, given that it largely comprised technical specification documents, it proved to be inaccessible. For instance, *"the first time I tried to look at the heating settings, I looked at the manual but it was so bloomin' confusing. I thought I don't understand a word of that. Then my son had a look, but in the end we had to call out the technicians."* (Interview G). This confusion, led some respondents to experience anxiety and self-doubt, whilst others reacted angrily and became resentful, for instance, *"you're afraid to touch them [the thermostatic controls], because you don't want to break it [the heating system]"* (Interview L). In

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contrast, some respondents were happy to draw upon their tacit knowledge and discover the technology through means of trial and error *"I'm not worried by all of this technology, I'm quite happy to fiddle around and I don't think it's going to bite and go bang or anything [laughs]"* (Interview F).

Within the home, residents felt that the low-carbon technologies had been installed to be discrete so as not to interfere with established household routines and ways of life. Residents considered that they were predominantly expected to play a passive role in reducing their domestic energy consumption, whereby they could rely on the operation of the technologies to lead to efficiency savings, for instance, *"Everything does what it has to do on it's own, so there's nothing really that you have to do"* (Interview C). In this way, at the time of 'move-in' the thermostatic controls for the heating system were pre-set, so that the heating operated within a recommended energy-efficient temperature range, and needed little active involvement from the residents. Some respondents were happy with this arrangement although the settings may have challenged their existing thermal comfort expectations, for instance, *"The technician said what the heating settings would be, and I was happy to agree because he said that that was the most energy efficient way… Apparently you're not supposed to interfere with [the thermostatic panels]…but as long the heating works, that's alright with me"* (Interview J). In contrast, some householders were keen to be more actively involved in managing their energy demand through; understanding the role(s) of the technologies and ways in which they functioned, and adjusting technological settings to suit the household's personal preferences and ability to modify their existing energy practices. For instance, *"There's so many things that say 'don't switch off this, don't switch off that'… 'It would be nice to know how things work so that if something does go wrong, you can sort it out yourselves"* (Interview B) and *"16 degrees, I thought that's bloomin' freezing, so then I had to get the manual out to see if I could up it myself"* (Interview G).

In order to maintain existing household routines or personal preferences, as well as in response to technical failures, in some instances, the occupants would attempt to alter or 'subvert' the technological set-up of their homes. As an example, householders would attempt to change the settings of the devices, consider alternative ways in which the technology could be operated, or bring in supplementary equipment in order to maintain their thermal comfort levels. For instance, *"We can't understand why [DJH] haven't set up the air source heat pump to work in reverse and blow out cool air. With the new baby we're going to have to get air conditioning units for here because we're not putting up with that heat."* (Interview B) and *"It's not cost effective for me to stick the heating on, because it will take 2-3 hours to heat up, so therefore we just have a little heater on that I have on in the night if I'm chilly..."* (Interview C).

Far from the householders interacting as individuals with specific low-carbon technology devices, these empirical results demonstrate that groups of householders both within and between households interact with multiple dynamically interacting devices. Indeed, as opposed to relating to particular technologies in isolation, many respondents considered the low-carbon home as a whole as a new domestic space, for instance, *"its a lot more challenging living in an eco-house"* (Interview D). Furthermore, Social Practice Theory (e.g. Shove, 2003) suggests that when considering householders' interactions with low-carbon technologies, we should focus not only upon particular devices within the home, but also the infrastructure and institutional systems that are behind the delivery and operation of such technological devices.

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Appendix A

The following sections describe respondents' initial encounters with specific low-carbon technologies. As Table 1 indicates, the householders experienced some technical faults, which influenced their experiences.

A. Passive thermal & lighting e.g. thermal mass, insulation, triple glazing, orientation.

The respondents were overwhelmingly impressed with the heat retention properties of their homes, which led to a reduced reliance upon the heating system. For instance, *"Because all the windows were always closed and I was always wearing jumpers and that, I sort of realised that it just doesn't get cold as much. If you have the heating off, the house just retains the heat so well" (Interview H).* However, particularly during October (2011) where above average temperatures were experienced, as a consequence of being instructed not to open windows or doors for ventilation, confusion around how to operate the heating system, and possible deficiencies in the MVHR system, 45% of interviewed households complained of the properties overheating. For example, *"The insulation is amazing [laughs] if you wanted to move to the North Pole or something"* (Interview K). Respondents reportedly took time to realise the effect of household activities, such as vacuuming, using a hair dryer, or entertaining guests, upon ambient temperatures within the property. Some households experienced excessive temperatures as a result of these activities and would respond by opening windows and doors to let in cooler air, for instance, *"At Christmas we had quite a lot of people in here and it was really warm in here. I mean on Christmas Day, we had all the windows open didn't we, because it was hot. We turned the heating off, and opened the windows, because it was really hot... it went up to like 24 or 25 didn't it?" "Yeah, on Christmas Day, scary!"* (Interview L). In two instances, excessive room temperatures (reportedly over 30˚C) led to significant detrimental changes to existing routines, for instance, one household gave away their dogs and another respondent modified her evening routines by going to bed early to avoid the heat in the living room.

The passive lighting design of the Trinity Close properties was unanimously well received, with all respondents claiming that passive lighting has led them to reduce the amount of electric lighting used in their property.

B. Photovoltaic panels

All interviewed residents welcomed the opportunity to generate electricity by means of the photovoltaic panels, primarily as a means to reduce their electricity bills, but also for environmental reasons and to subscribe to a self-sufficiency ideology. For instance, *"I think that's another reason why I like the eco-house because you're basically self-sufficient… yeah, 'the good life'. It appeals to me because you know where everything's coming from. You know nothings polluted. You know everything you're getting is yours and what you've done, if you know what I mean."* (Interview B).

Based upon institutional advice around load shifting, at least 36% of the interviewed households claimed to have shifted their appliance use times to take advantage of solar-generated electricity. These residents were also conscious of spreading the load of appliance use in order to maximise gain from the solar-energy. Other householders were keen to put their appliances on during the day, but were restricted by work commitments, for instance, *"It sort of feels like free electricity… but obviously I can't put*

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washing on in the day when I'm at work, because I can't [laughs], but obviously I would like to be able to do everything during the day" (Interview F).

64% of interviewed households were however concerned as to whether the photovoltaic panels were generating electricity, primarily as they were not able to confirm their operation by checking on the energy monitor (which were frequently out of action). Additionally there was some confusion around the type of system that had been installed i.e. solar-photovoltaic panels or solar-thermal panels, and whether the electricity generated could be stored. For instance, *"when they first gave us our little monitor, and I saw how much the solar panels were making, they weren't making as much as I'd hoped. Because I'd thought that you'd get free electricity at night too, and that it would store it. But I was aware then, that you'd only get it during the day when the sun was out, and when it's cloudy you'd hardly make any at all."* (Interview J).

Three of the interviewed households discussed technical faults associated with their photovoltaic panels, for instance, rattling in the wind and short-circuiting resulting in an electrical power-cut for four adjacent homes. One of these households was particular distressed and concerned by the perceived lack of safety of the solar-photovoltaic panels, for instance, *"You're sort of living in fear, when it rains, are the solar panels going to catch light? Because if they were tripping out and all the electrician did was put a bigger fuse board on, well they're still faulty."* (Interview B).

C. Mechanical Ventilation & Heat Recovery (MVHR)

As previously discussed, there was confusion as to the role and mode of operation of the MVHR system. Additionally, the majority of householders were uncertain as to whether the equipment was working due to its quiet operation and the lack of confirmation that it was turned on. For instance, *"I said, 'I don't know whether that's working as I can't hear it', but the engineer said 'you won't hear it, but it is working'… So, we'll never know if it's working or not, but he did say if certain places are damp, then the vents are obviously not working."* (Interview L). One household was also particular worried about potential indoor air quality issues as a consequence of the MVHR system.

The households were provided with institutional advice as to how to heat, cool and ventilate their properties most cost and energy effectively. Despite this, embodied understandings and personal preferences, for example, for fresh air, led many households to 'break' these rules in an attempt to maintain established ways of interacting in the home. For instance,

> *"The idea is that you never have to open a window or a door. If WHA came around and you had your windows open they would be absolutely devastated because that's not the way it's supposed to be... You should have the heating set for 16˚C overnight and a maximum of 20˚C during the day. If you don't open the doors and don't do X, Y, Z, then it will all be fine… But we find that you can't breathe, it's heavy, we get very stuffy… So I'm afraid we don't play by the rules. If we're hot, we open the door. If we're cold, the heating goes up to 25˚C"* (Interview C).

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D. Air source heat pump (ASHP) & under-floor heating

Many of the respondents reacted favourably towards the under-floor heating system, however several households expressed a longing for a central and immediate heat-source, as opposed to under-floor heating and this affected various practices, including maintaining thermal comfort, relaxing with the family and doing the laundry, for example, *"I don't trust [the heating system], I don't like it. I'd much rather have a radiator, or because I'm old fashioned, a coal fire, I love coal fires [laughs]. I just don't like not sitting in front of something that produces heat"* (Interview C) and *"that is one big thing I do miss, having radiators because you can bung some trousers on there for half an hour and they're dry"* (Interview D). One particular household particularly objected to the time taken for the ASHP heating system to heat up and the cost implications of this and as such used a small convector heater to circumvent this.

The confusion experienced in relation to setting and adjusting the thermostatic has previously been discussed *(see start of Section 4 of this report).* This lack of a transfer of knowledge to the householders and the presumed passivity of the residents resulted in a second induction into the thermostatic-controls being undertaken. At this time, the householders were asked to confirm whether they were in agreement with the temperature settings and were provided with an instruction sheet on how to adjust the settings according to their personal needs, for instance, health issues and young children. Following this measure, some respondents considered that they were more equipped to manage their heating system, whilst others still felt unsure, for instance, *"I don't change anything with the heaters, I don't change anything, I don't touch the thermostats at all…I don't understand them, so I don't want to break it and then have to pay for it…yeah I've been shown how to use them, but they're so complicated, everything is so complicated, and they just expect you to know."* (Interview D).

55% of households interviewed experienced (in some cases repeated) technical faults with their ASHP system which included; not having been turned on, refrigerant leaks, and running continuously. Unfortunately, these faults, which reportedly lasted from a couple of days to a few months, often coincided with cold external temperatures. In some cases, these disruptions led to householders changing their existing thermal comfort practices by, for example, putting on additional layers of clothing (Interview H), taking hot showers (Interview L), and closing doors to keep heat in (Interview L). In more extreme instances, some respondents moved into accommodation as a result of cold temperatures, for instance, *"I had no heating for a month… It had got to the point where we couldn't even live here, cos we were living in coats and hats and things like that… Over Christmas I wasn't here, I was at my mum's because of the cold"* (Interview D).

E. Grey water recycling system (GWR)

Householders supported the GWR system and water meter as a means to primarily conserve water from both an environmental perspective and also as a way to reduce their monthly outgoings on water. For instance, *"I didn't realise that it's drinking water that goes down the toilet, I didn't know that and I think it's a really good idea, because that's so much water that you're wasting."* (Interview F) and *"It's quite a good idea for saving money because it takes in less water which means less water going past the meter and that. That does save you quite a bit of water and money at the end of the day."* (Interview H). Although some

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households discussed making savings on their water bills, 27% of interviewed households perceived that their water bills were in fact higher than they were used to and a further 27% considered that their water bills were approximately the same as for their previous property. One respondent discussed how the GWR system encouraged her to take longer showers, "*It's good. If you're having a shower and you're thinking 'oh I've been ages in the shower', at least you know that you've not just wasted water, that it's going to be reused for the toilet'* (Interview K). This 'rebound' behaviour might contribute to understanding the reasons as to why, for some, household expenditure on water reportedly increased.

Although cultural conventions for hygiene and cleanliness largely did not deter householders from using the GWR system, several households complained of issues around not being able to use certain bath products and perceived odours due to stagnant water. For instance, "*I don't mind the idea of recycling water but sometimes when you've just had a bath, the toilet water's a bit hot when you flush. And if you use bubble bath or shampoo sometimes it's a bit frothy and it does stain your toilet so… The toilets always smell stagnant. You've got dirty bathwater sitting in your tank…for possibly days on end.*" (Interview B). During the initial stages of the tenancy, 64% of households interviewed experienced the toilets auto-purging at regular intervals throughout the day and night or not flushing at all. For instance, "*apparently you're supposed to use a bottle of sanitizer once per year and I got through a bottle in a month. Yeah, the toilet was flushing on it's own. They say it's meant to automatically flush once per day anyhow, but mine was flushing every few hours.*" (Interview F). Respondents described how they found the auto-purging frightening, for instance, "*The first time I heard it, well, I wouldn't get out of bed, I didn't know who was in there!*" (Interview L) and the inability to flush the toilet was deemed socially embarrassing. 45% of interviewed households experienced the effects of the GWR system leaking either within their own apartment or from a neighbouring apartment above them.

Energy monitor & In Home Display unit (IHD)

Although energy consumption monitoring data continues to be collected for the Trinity Close properties, all interviewed households stated that their IHDs were non-operational from approximately mid September 2011. Householders reported frustration as they attempted to initially set-up the energy monitor (for example, to reflect their utility rates) and then as they struggled to keep the IHD online. For example, "*It worked the first week maybe two weeks and then I think there was a power cut or something so it wouldn't connect up. So I rang up and got the wireless code, which I put in, but that still weren't giving me all the information*" (Interview L). Some households remained optimistic around the potential benefits of using the energy monitor, for instance, "*I think if we had it on the wall there and it was running all the time, I would check it. And if I could put in my own values, and see how much things were costing then I would use it.*" (Interview J). In contrast, partly due to the installation process and also the equipment failure, others no longer trusted the equipment, "*When the monitor was working, it said we were using 700 Watts in that socket, but there was nothing plugged into it…And when it was a blue sky, sunny, it was saying that there's no kilowatts being produced on the panels… What's the point of having all of this equipment, when you don't even know if it's working because the monitors don't work*" (Interview B).

Due to the induction process, it was a common finding that the residents were unsure as to how to programme the energy monitor. Although the technicians from Adapt Commercial took the residents

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through the set-up process, many respondents remained confused, for instance, "*How to set values, I'm not too sure about. I think you're supposed to, but I haven't because I don't know how to.*" (Interview J). The householders considered that the IHD was user-friendly and several respondents were attracted by the aesthetics, whereas other respondents objected to the energy-use judgements made by the display characters, for instance, "*I call him my angry man because he's orange*" (Interview G), and prior to the equipment having failed, had moved the device out of sight by putting it in the hall or packing it away.

Householders varied in the way that they interacted with the operational IHD. For instance, some claimed that they would check the display on a daily basis, others weekly, some occasionally and others, after the initial novelty had passed, not at all. Competing with the energy monitor to reduce household energy demand was seen by some as a challenge, for instance, "*[Checking the energy monitor] was exciting, thinking will we get to the green man. I felt like it was a challenge for us.*" (Interview K), whereas others claimed that the information served only to increase their awareness and would in fact reinforce their existing practices without leading to change, for instance,

> *The idea is, you look at the monitor, you see 'oh yeah the solar panels are producing so and so, so I can put my washing machine on'. You see, 'oh yeah, I'm doing okay today'. But at the end of the day we've got … children, so sorry but if it's raining or not, we've still got to wash… we've got brand new appliances and things, so there's no more we can do anyway.* (Interview C).

The householders used the IHD for different functions ranging from a tool to encourage other household members to make changes around energy use, to ensuring that they had not accidently left on appliances, to checking whether the low-carbon technologies were working, for instance, "*I did use [the energy monitor] last week, as I was curious to see whether I could find out whether my solar panels were working*" (Interview J). The IHD was also used to verify the performance of particular electrical appliances and justify upgrades to more energy-efficient devices, for instance,

> "*I'm going to get a new fridge freezer because that's really old. So I'll be interested to see how much electricity it uses… I wanted to make sure that I had an A++ freezer because I knew that it would be more energy efficient, and I wanted to see what difference it would make. So [the energy monitor] is really influencing those kind of decisions with the things that I buy.*" (Interview F).

In addition to these functions, the energy monitor was also suggested as a means to provide evidence to other householders within the Close of deficiencies of particular low-carbon technologies, for instance, "*I might then have proof that the ASHP was faulty because at the moment all I've got is my electricity bill… And I would really like to know, so that I then have proof to give to [the neighbours] who don't want to know that there is something wrong*" (Interview B).

Recommendations:

- Offer more active involvement in managing energy demand to residents in order to potentially increase household energy savings and comfort levels. This will also help to empower residents and strengthen relations between energy governance organisations and technology users.

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- Ensure that the manual to the low-carbon technologies is user-friendly and accessible. Include energy-saving advice and objective energy-saving targets. These targets are recommended to take Social Practice Theory assumptions into account (see Chatterton, 2012).
- It would be beneficial to provide a hands-on induction to the energy monitor so that residents are able to programme the device and set household goals. Follow-up feedback and discussions with individual households are recommended.
- Following the initial induction, support should be available for the residents should any technical issues or concerns arise.
- It is recommended that householders' experiences are incorporated into the future design of low-carbon technologies & low-carbon residences.
- The design of low-carbon technologies and low-carbon housing should take account of users' interactions with multiple co-evolving low-carbon technologies and systems, and not consider only individuals' interactions with specific devices.

6. Extent of change(s) in energy-consuming domestic practices

82% of households perceived that life in their new homes had led to only minimal changes in existing routines or not led to significant changes in domestic energy consumption. For instance, *"I would every now and then maybe have the lights on for less or watch television less just to think, maybe I'd save a bit of money. But no, I didn't make any huge changes"* (Interview C). However householders' perceptions of what counted as a significant change in domestic interactions and lifestyle changes varied enormously. For instance, in comparison to previous arrangements, one household considered that setting the thermostatic controls in each room to 23˚C (when advised a maximum of 20˚C during the day) represented a major compromise.

Changes to domestic energy-consuming practices included, making adjustments to existing appliances by either getting rid of energy-inefficient equipment, increased attentiveness to energy-efficient usage (e.g. by turning equipment off stand-by) and making use of the passive and low-carbon features of the domestic space (e.g. using passive lighting rather than electric lighting). Institutional advice around load shifting and tacit knowledge around taking advantage of solar-generated electricity led to some adjustment in the time of use of appliances and ensured that appliances were used at spaced out intervals.

18% of interviewed households considered that they had made significant changes in their previous domestic energy practices as a result of living in Trinity Close. At least two interviewed households felt that they now subscribed to a new energy and environmentally aware ethos, and consequently were doing all that they could to reduce their energy-demand. These households also felt that they had made broader lifestyle changes, for instance, growing vegetables, recycling and reducing reliance upon the family car. Often technical faults and disruptions led to creative responses and demonstrated a

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capacity for existing routines and expectations to be more flexible in times of crisis. These changes in routines varied from, for example, conserving heat by putting on additional layers and shutting doors, to more significant changes driven out of fear of high expenditure on energy bills, for instance:

> *"Before we'd cook tea… two or three times in a night because the boys would be going out at different times and they all wanted dinner at different times, … Now if they're not here when we cook, they go without… we'll put it in the microwave rather than cook a whole load more of dinner, when it would only take a few minutes in the microwave. And the dishwasher… would go on two or three times per day… but now, I've even got to the stage that I won't even put the dish washer on, I'll just do the washing up."* (Interview B).

Recommendations:

- Social Practices Theory (SPT) (see Chatterton (2011) for a useful introduction) would recommend that rather than focussing upon reducing units of energy (e.g. KwH) or emphasising household financial savings as a result of energy conservation, attention should be given to understanding the composition and dynamics of as well as influencing factors that shape energy-consuming practices e.g. cooking/cleaning/running a home. These factors include technologies and infrastructures, but also social and cultural meanings and engagements and formal and informal skills, rules and knowledge.

  Practical implications of SPT might for instance suggest that, as opposed to focussing upon reducing individual electricity demand, low-carbon housing initiatives should aim to bring about new forms of social interaction that support reductions in energy-consuming practices. This might include making opportunities for electrical appliances to be shared between households, providing a forum to enable householders to exchange experiences and tips and advice around undertaking low-energy practices, or ensuring open communication channels between householders and governance organisations managing the low-carbon housing development.

7. 'Communities of Practice': Within & between household interactions

As previously discussed (see page 9) respondents interacted both within the household space and between households in terms of: sharing ideas, conversing with, learning about and operating the low-carbon technologies, and performing and modifying energy-consuming domestic practices.

Within the household, the new low-carbon living arrangements frequently altered existing household dynamics and/or led to family conflicts by challenging routines and practices, for instance, *"a certain somebody, our teenage boy, kept washing his clothes everyday. Yeah, his uniform, he'd want washing everyday. He'd just put that in the wash and that'd be that. You know, but no chance now."* (Interview B). Interactions with the low-carbon technologies also emphasised (often) gendered roles and made apparent conflicting personal preferences, for instance, "*Myself, I find the heating a nightmare, the wife does all that. She goes along and turns all the thermostatic controls up, and I go behind her and turn them all down cos I'm hot [laughs]*" (Interview C).

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Within the household domain, relatives were recruited during the technological familiarisation process, but this guidance also extended between households, for instance, *"I had my sister and her boyfriend around trying to programme the heating and set it up. I also asked, because I do speak to quite a few of the people here, I asked some folks on the road if they knew how to set the controls, and they didn't know either."* (Interview J). Tips and advice were shared both within and between households as occupants experimented with using the low-carbon technologies, for instance in relation to not using products in the GWR system, *"As I say, I didn't know until one of the neighbours told me 'oh you can't use toilet duck'"* (Interview B) and *"To be honest it hadn't even crossed my mind before. It wasn't until… my sister came to stay when we were away, and she dyed her hair and we came back to this bluey-black coloured toilet…They told us not to use things in the bath. But it just doesn't click, you go ahead and do it and don't worry about it."* (Interview C). One resident advised several neighbours to use a bath plug-hole strainer to prevent the GWR system filters from becoming blocked. Other respondents discussed ways in which their domestic experiences had been shared with friends and family members that were further afield. For instance, *"I was speaking to one of my manager's about it, about all the things that the flat has got. We were just talking generally about energy efficiency, and I told him about my flat. And so I brought him [the manual] in and he had a look at it, all about the solar pv and things."* (Interview H).

Neighbours commonly discussed how they were settling into their new homes, made comparisons around any technical difficulties that they encountered, and exchanged advice as to how to improve their low-carbon experiences. For instance, *"Us four families are quite friendly. So we'll go around and ask 'is your heating working, is this working, is that working, are your monitors working now?"* (Interview B) and *"My neighbour said to me the other day 'oh I can't get my washing dry' and I said 'oh I stick mine in the boiler cupboard' so we do talk about stuff"* (Interview K). In some instances, neighbours lent each other items in order to improve their thermal comfort experiences, for instance, loaning convector heaters during the cold snap when several ASHP units failed. Neighbours would also make comparisons between the way that they used the low-carbon technologies, for instance, *"Next-door, sets her heating different to mine. She has her heating on at 26/27˚C and that would kill me..."* (Interview E), which in some cases reinforced existing practices. It was, in part, these conversations and comparisons that brought about the residents request for a second induction to the thermostatic panels.

Recommendations:

- The design of low-carbon technologies and low-carbon housing, as well as energy demand management related advice and support should take account of how individuals interact to undertake domestic energy-consuming practices. These interactions are pivotal in influencing the receipt of new technologies or approaches, sharing knowledge and expertise, highlighting energy management issues and identifying opportunities for practice change, as well as being critical in influencing governance relations.

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8. Governing change towards less energy-consuming domestic practices

This Section focuses upon the means by which energy governance organisations involved in the Trinity Close development have encouraged a reduction in household energy consumption. After briefly summarising the 'move-in' and induction processes (which were discussed in Section 3), the effectiveness of institutional support provided in the later stages of the tenancy is discussed.

At the start of the tenancy, the Trinity Close residents received institutional advice and information, which instructed the householders as to how to interact with the low-carbon technologies and largely framed the householder as passive in managing their energy demand. Some respondents discussed how they found this information inaccessible and confusing. The residents were also provided with key advice around energy load shifting and ways in which they could reduce their domestic energy consumption. It was intended that the energy monitoring feedback system would enable residents to make informed choices, predominantly driven by possible financial savings, regarding their energy use. However all households experienced technical faults with their IHDs meaning that they were unable to access this feedback from mid September (see Table 1).

Several respondents suggested that institutional advice was useful in managing their energy demand, for instance, "*We were told not to have the washing machine, and the dishwasher and the kettle on at the same time, and if we were going to do cooking, to try and get a lot of it done during the daytime to be more energy efficient, which made sense*" (Interview K). Respondents discussed how they would find appropriately timed demonstrations of the technology particularly helpful, for instance, "*It would be great if, once you're settled, they could come around and show us how the heating works and how our little screen [energy monitor] works.*" (Interview L). The residents also suggested that they would benefit from continued support in managing changes in their energy-consuming practices, for instance, "*Yeah, we want people to give us feedback, because they could be really good homes*" (Interview B).

These results demonstrate that some householders were satisfied with the governance process, for instance,

> "*I think that was fairly smooth really. I got the keys and was told there you go, if you need anything call… [then] we got offered for someone to come and show us how to use [the equipment] and we got a couple of little leaflets on how to use [the thermostatic panels] and things like that. So, everything we needed to do, we got told how to use it…[and] I'm confident in the contractors. They all seem to know what they're doing. They all seem fairly competent*" (Interview H).

However, as the householders' tenancy progressed, some residents encountered issues relating to the finishing of the Trinity Close properties, listing faults that they'd experienced as, for instance, "*my heating, broken bins, I can't shut or open my window, my washing bowl's broken, my back gate is broke. When I first moved in the seal on my door hadn't been put on properly, my cupboards were broken. I know they were rushed to be finished, but they were really rushed.*" (Interview D). As some properties began to experience technical faults, the energy governance organisations adopted the role of organising the maintenance and repair of the Trinity Close low-carbon technologies. Some households approved of the way in

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which these technical faults had been addressed, for instance, "*Broadland and Wherry have been really, really good… They've had lots of these eco-things, the technologies going wrong. But they have, with the exception of the heater, been fixed really, really quickly…I mean you're going to get niggles, it's a brand new house*" (Interview C). However in some instances, the technical knowledge and training demonstrated by the energy governance organisations was questioned, for instance, "*The guy that came around to repair my toilet had never seen a toilet like that before or been trained*" (Interview J) and "*The heat pump went wrong, it was on 24/7. It was on all the time and we used an awful lot of electricity. And Wherry couldn't fix it, Dove Jeffrey couldn't fix it, so we had to wait for the actual heating manufacturers to come out. If I hadn't have turned it off at the mains, it would have been running continuously for two weeks*" (Interview C). Respondents also experienced confusion around the roles and responsibilities in relation to maintenance and repair, for instance, "*Jarretts [plumbing technicians] have been out, Dove Jeffrey Homes have been out, other engineers have been out. I'm totally confused as to who's been here and who hasn't.*" (Interview G). These scenarios led, in some cases, to increasing distrust of the energy governance organisations.

The importance of maintaining trust relations, between the organisations responsible for managing the everyday operation of Trinity Close properties and the residents, can be highlighted by some respondent statements. Some respondents had financial concerns and blamed the governance organisations for elevated utility bills experienced as a result of technical faults, "*We've had lots of these eco-things go wrong on us, and costing us the earth*' (Interview C), or questioned the financial equity of the scheme, for instance, "*We've never been told what happens to the electricity that we make and then don't use. We've never been told if that goes to the grid and they make money from it, or if that money goes to Wherry or who, I don't know… I think someone is making some money from this.*" (Interview J). Some households expressed concerns around the transparency of communications from the governance organisations, "*[The process could be improved] by them communicating to be honest. You want someone …who will come and sort out the problem… there's no communication, you know, one person should be in charge of the whole lot.*" (Interview B), and "*I'm fine to share that information. I just wish they'd be a bit more, you know, someone actually lives in these houses, and they do have a life…I just wish they'd be a bit more respectful about things.*" (Interview D). Other respondents sought technical advice from more trusted sources, "*My brother-in-law is an electrician... And I'm asking him 'should this be happening, should this be happening?' I shouldn't have to do that. I was actually going to get him in because I didn't trust the people from Wherry [WHA] or Dove Jeffrey [DJH]*" (Interview B). In light of these governance concerns, householders are considering forming a residents association to bring their concerns to the attention of the housing association and developer.

Recommendations:

- It is important to establish and maintain trust relations between the governance organisations and householders through collaborative decision-making processes and transparent communication.
- Roles and responsibilities of the energy governance organisations involved in the low-carbon housing initiative should be agreed, clearly defined and communicated between parties and to the householders.
- Training of governance organisation representatives and technicians should be ensured to enhance technical knowledge around the programme and ensure fast response times for maintenance and repair issues.

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- On-going support to enable householders to make changes to their energy-consuming practices should be ensured, and this should be coupled with feedback on progress and opportunities for discussion at regular intervals.
- It is recommended that the delivery of energy-saving advice framed around making adjustments to household energy practices and routines be considered. This advice could complement the existing approach of highlighting quantifiable reductions in energy consumption and opportunities for financial savings (see recommendation on page 16).

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Appendix A

Table 1. Trinity Close household demographics

Interview Code	**Electrical white goods acquisition**	**Technical faults experienced** (Approximate date & duration)	**Perceived change(s) in energy-consuming practices**	**Estimated change in utility expenditure** (electricity & water)
A	Rental. Aesthetics important. Associated high energy-efficiency rating as new.	• Energy monitor went offline (mid Oct onwards) • ASHP failure for 4 days (date not provided) • Uncertain if MVHR working • GWR system minor leakages (date not provided) • Uncertain if solar photovoltaic panels working, rattle in wind	• Perceived minimal change(s) in energy practices • Continues to turn appliances off stand-by • Uses electrical appliances, e.g. washing machine, when sunny • Uses MVHR boost	Approximately the same
B	Specifically bought high energy-efficiency rated appliances.	• Energy monitor went offline (mid Sept) • ASHP refrigerant leak (Jan) led to no heating/hot water. Convection heaters provided by WHA. • Experiences high temperatures (particular Oct) • Uncertain as to how to operate thermostatic panels • Uncertain if MVHR working • GWR system smells stagnant • Solar photovoltaic panels blew electrics (Oct/ Nov) • Uncertain if photovoltaic panels working	• Perceived major changes in energy practices (to save money) • Load shifting to benefit from solar panels (e.g. laundry, cooking, vacuuming) & not running appliances at same time • Reduced cooking & appliance use • Broader lifestyle change: recycling, overheating led to giving away their dogs	Electricity & water more expensive
C	Specifically bought high energy-efficiency rated appliances.	• Energy monitor went offline (mid Sept) • ASHP fault led to it permanently being on (Oct), fixed within 2 weeks by manufacturer • Uncertain if MVHR working • Toilet auto-purges throughout day & night • GWR system smells stagnant • Uncertain if photovoltaic panels working	• No perceived changes in energy practices in relation to living in the property • Continues to turn appliances off stand-by	Electricity cheaper, water more expensive
D	Prioritised cost in purchase.	• Energy monitor went offline (mid Oct onwards) • Initially ASHP not turned on. Heating failed twice (Nov/Dec & Feb/March). • Uncertain if MVHR working • Uncertain as to how to operate thermostatic panels • Uncertain if photovoltaic panels working	• No perceived changes in energy practices in relation to living in the property	Electricity & water cheaper
E	No specific selection, Acquired via	• Energy monitor went offline (mid Oct onwards) • ASHP failed for 2 days during cold spell (Jan/Feb 2012). • Uncertain as to how to operate thermostatic panels	• Perceived minimal change(s) in energy practices • Reduced washing machine usage • Initially used energy monitor to check energy	Electricity & water cheaper

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Interview Code	Electrical white goods acquisition	Technical faults experienced (Approximate date & duration)	Perceived change(s) in energy-consuming practices	Estimated change in utility expenditure (electricity & water)
	charities.	• Uncertain if MVHR working • GWR system leak & non-flushing toilet (from Christmas 2011) • Uncertain if photovoltaic panels working	consumption of appliances on daily basis & identify whether technologies operational • Switches off lights, relies more on passive lighting • Showers more	
F	Acquired through friends. In process of upgrading to energy-efficient appliances.	• Energy monitor went offline (mid Oct onwards) • Experiences high temperatures (particular Oct) • Uncertain as to how to operate thermostatic panels • Uncertain if MVHR working • Upstairs GWR system leaked into apartment • Toilet auto-purging and not flushing initially	• Perceived minimal change(s) in energy practices • When operational, checked energy monitor on a daily basis for usage and financial outlay • Aims to reduce leaving appliances on stand-by and turning lights off when not in use	Uncertain, electricity & water cheaper
G	No specific selection, Acquired through friends.	• Energy monitor went offline (mid Oct onwards) • Uncertain if MVHR working • ASHP failed during cold spell (27th Jan – 10th Feb), convection heaters provided by WHA. • Uncertain as to how to operate thermostatic panels • GWR system leak & non-flushing toilet (6 weeks from start Jan) • Uncertain if photovoltaic panels working	• Perceived minimal change(s) in energy practices • Initially used energy monitor to check financial savings on weekly basis & identify whether technologies operational • Uses passive lighting, no need for hall light • Turns electrical appliances to stand-by • Uses MVHR boost function • Showers more	Uncertain, approximately the same
H	No specific selection, Acquired through friends.	• Energy monitor went on & offline (mid Oct onwards) • Uncertain if MVHR working • GWR waste pipe leaked into downstairs' bathroom • Toilet auto-purging and not flushing initially	• Perceived minimal change(s) in energy practices • Initially used energy monitor to check financial savings on weekly basis & identify whether solar panels generating electricity • Recycles more • Does laundry at Mum's house	More expensive than anticipated for both water & electricity.
J	Purchased on the basis of cost and energy-efficiency.	• Energy monitor went on & offline (mid Oct onwards) • Experiences high temperatures (particular Oct) • Uncertain as to how to operate thermostatic panels • Uncertain if MVHR working • Upstairs' GWR system leaked into bathroom • Toilet auto-purging and not flushing initially	• Uses energy monitor occasionally to check whether photovoltaic panels are working • Load shifting to use appliances when sunny & to spread load • Turns off lights & appliances not on stand-by • Cooks & does laundry drying at Mum's house	Electricity cheaper, water same as previous property

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Interview Code	Electrical white goods acquisition	Technical faults experienced (Approximate date & duration)	Perceived change(s) in energy-consuming practices	Estimated change in utility expenditure (electricity & water)
K	Rental. High energy-efficiency rating important.	• Energy monitor went offline (mid Oct onwards) • Experiences high temperatures (particular Oct) • Uncertain as to how to operate thermostatic panels • Solar photovoltaic panels blew electrics (Oct/ Nov)	• Perceived major changes in energy practices • Initially used energy monitor to check energy consumption on daily basis & aim to reduce usage • Load shifting to benefit from solar panels (e.g. laundry, cooking, vacuuming) & not running appliances at same time • Aims not to leave appliances on stand-by • Broader lifestyle changes – recycling, growing vegetables & composts, reduced car usage	Uncertain, approximately the same
L	Purchased for the property on basis of cost, aesthetics, then energy-efficiency.	• Energy monitor went offline (mid Oct onwards) • Experiences high temperatures (particular Oct) • Uncertain as to how to operate thermostatic panels • Uncertain if MVHR working • GWR leak • Toilet auto-purging and not flushing initially	• Perceived minimal change(s) in energy practices • Aims not to leave appliances on stand-by	Electricity and water cheaper
M	TBC	TBC	TBC	TBC

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Appendix B

Letter from the Rt. Hon. Don Foster MP (DCLG)

Appendix B

Department for Communities and Local Government

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Our Ref: MP/DF/025869/13

Miss Rachel Macrorie

By email – R.Macrorie@uea.ac.uk

0 3 OCT 2013

Dear Miss Macrorie,

RESEARCH ON CODE FOR SUSTAINABLE HOMES & USER ENERGY RELATED PRACTICES

Thank you for your letter of 3 September to Mark Prisk MP, regarding your research on the Code for Sustainable Homes and domestic energy usage. I am replying as I have responsibility for sustainable homes policy and I apologise for the delay in replying.

I am not sure if you are aware but the Government has recently undertaken a fundamental review of housing technical standards, and energy and the Code were amongst the huge array of issues considered. A consultation setting out the proposals, which includes winding down the role of the Code, has been published at https://www.gov.uk/government/consultations/housing-standards-review-consultation.

A new set of national planning practice guidance has also recently been published at http://tinyurl.com/nl353wh, to support the National Planning Policy Framework. The guidance is currently in 'Beta' mode and we would welcome your views. Finally, we have also recently announced a consultation on "allowable solutions", to support the delivery of the Government's 2016 zero carbon homes policy objective. The consultation has been published at: https://www.gov.uk/government/consultations/next-steps-to-zero-carbon-homes-allowable-solutions. These two consultations will no doubt be of relevance to your research.

We would very much welcome your views to help inform our decisions on the way forward.

Best wishes,

D. Foster

RT HON DON FOSTER MP

Appendix C

Household practitioner - sample interview topic guide

Appendix C

Repeat household interview protocol

A. Revisit/confirm any outstanding details from previous interview

- Details of previous property & the heating system
- Move in date
- What prompted the move & what expectations did they hold prior about life in Trinity Close? [affordability/generating & saving electricity/saving money etc.]
- Details of layout of property
- Details of tenants & their movements

B. General perceptions of living in a low-carbon home & perception of change

1. How have you found living in this house over the last year (to eighteen months)?
2. Which aspects of the house do you like, why? Which aspects of the house do you find challenging, why?
3. Compared to living in your last property, are you pleased that you moved here, why/why not? Do you think that you live differently in this home in comparison to your previous home, why/why not?
4. [Optional] Prior to moving into your new house, how aware were of you of its design and the low-energy technologies? How did you find out about these aspects of your new home? How could this process be improved? Induction/presentation/manual/trial and error
5. [Optional] Why did you choose the appliances that you have in this house?

C. Audio tour

For each room:

- Activities (heating/ lighting/ washing self and clothes/ computing/ entertainment/ cooking) & different to way did things in previous home?
- Heating preferences, ventilation

- How aware of technologies & how operate
- Any problems associated with technologies

Remember technologies include:

- electricity only supply
- insulation
- solar photo voltaics
- air source heat pump
- mechanical ventilation and heat recovery
- thermostatic controls
- grey water recycling

Energy monitor:

- Do you use it to monitor energy usage? Any other recording of energy use?
- How often look at monitor?
- Any problems?
- Do you think makes any difference to how undertake activities in the house?
- How user friendly & why?

D. Review bills

6. Ask to review electricity bills & note KWh electricity used per quarter & cost] How do your energy bills compare to your previous property? Are your electricity bills in line with your expectations for life in your low-carbon property, if yes - why, if no - why not?

E. Technology interaction & performance (add to audio tour conversation)

7. [Address previous interview responses & revisit previous issues with technologies] To what extent have these been resolved/ how has the situation developed?
8. Have you experienced any other technical difficulties this year? (particular

focus upon technologies linked to thermal comfort) - what happened, why, how did you feel, what did you do, how was the situation resolved, did this lead you to change any aspect of your everyday life?

9. How aware are you of having to use new technologies as part of your everyday life in this house & why?
10. Have any of your neighbours shared any advice about their experiences of living in these homes or have you shared any advice with them? Describe? Have you introduced your friends/family to your low-carbon home - describe?
11. If you could give the designers of these homes any advice that they could use in future low-energy housing developments what would it be and why?

F. Governance of the initiative

12. Do you think the information you received before you moved-in about what life would be like living in a low-energy home has matched your experiences?
13. [Address previous interview responses & householder perceptions and experiences of expert advice and support] What support was provided when you first moved in to help you settle in? How useful was this advice & information/why was it not useful?
14. How effective have you found housing support in terms of being able to organise and carry out maintenance & repairs?
15. If you could give the organisers of this initiative (BDC and WHA) any advice that they could use in future low-energy housing developments what would it be and why?
16. Where do you think responsibility lies for reducing dependency on electricity intensive heating/cooling systems in homes & why? [utility suppliers/ construction companies/government/residents etc]
17. How do you feel in general about living here? Do you feel part of a community? Are you able to access services?

G. Play practices game

Appendix C

H. Maintaining thermal comfort in low-carbon homes

Operating the heating (& cooling) systems:

18. How easy is it to control the temperature of each of your rooms? How quickly can you warm each room, does the house retain the heat?
19. Do you use the thermostat? Do you monitor the amount that you put the heating on/use the timer? Why? Describe - temperature/times. How have these settings changed over the course of the year? How did you learn to interact with the thermostat & timer?
20. Have you noticed any differences in how activities that you do in the house contribute to the overall temperature of the house? How do you take account of this?
21. Do you find that different members of the household prefer different temperatures - can you describe patterns of heating use? How are compromises made?
22. If you feel too hot, how do you cool down in your home?
23. Strategies for ventilation

[Go to the coolest & warmest rooms of the house to discuss strategies for maintaining thermal comfort in each room]. Discuss living room.

Experiences & expectations of thermal comfort:

24. Have you experienced any extremes of temperature during the last year when you were not easily able to control your comfort? Too hot/too cold - can you describe what happened, how you felt, what you did to manage this situation, any assistance received?
25. [Thinking both in & outside the home] Can you describe how being i) overly cool/cold might make you feel [e.g. stress/in pain/unable to concentrate] ii) overly warm/hot might make you feel? [tired/sick/content if sunbathing]
26. Can you describe any particular occasions when you might want to be warmer than usual - why? [feel ill, being cosy at night, being on holiday] & cooler than usual - why? [doing lots of activity at home, it’s warm outside].

27. Do you think your expectations around comfort have changed during your lifetime/how previous generations kept thermally comfortable? Have you carried forward any of these 'traditional' ways of keeping warm/cool?

Managing changes in thermal comfort:

28. Can you think of a couple of examples from today when you noticed your thermal comfort level and describe how you might have made changes so that you felt more comfortable
    - what were you doing? what happened?
    - what did you notice about how warm/cool you felt?
    - what did you do to fix your comfort level & why?

29. We've spoken about the heating system as a way to control your thermal comfort. Can you describe any other ways that you might manage how warm or cool you are at home? [follow-up on any responses]
    - Clothing - layers, materials, which clothes are suitable?
    - Bedding & decor - blankets, warm mattress cover, curtains, shading with blinds, carpets
    - Location - move location within the house, or leave the house
    - Activities - change the way do practices?
    - Layout - change room layout, shutting doors, opening windows & doors, blocking up drafts
    - Other technologies - e.g. insulation/triple glazing
    - Eating & drinking - hot/cool
    - Body warmth - cuddling
30. Would you be interested in making any changes to the ways that you manage your thermal comfort at home so that you could save energy? What alternatives would you consider?

I. Check whether the participants will complete the thermal comfort workbook

Appendix D

Professional practitioner - sample interview topic guide

Appendix D

Professional interview protocol: Dove Jeffrey Homes

Professional background & organisation:

1. What is your role & what are your responsibilities within Dove Jeffrey Homes?
2. What type of building projects are you involved with (general contractor) & what proportion of your builds are social housing properties?
3. As I understand, DJHs was established in 2001 - how do you think the way that you approach new build housing has evolved during this time? How has the recession affected the housing construction industry?

Best practice & built energy performance

4. Your company mission on your website, is 'building a better future', what do you think this encompasses & how does DJH aim to do this?
5. What would you say are the driving principles behind a DJH development or build & why? [Best practice, cost-effectiveness, sustainable development] What do these mean to DJH & how are they worked into their operations, processes & practices?
6. What do you think have been the drivers of enhanced energy performance for new build homes? Eg. [Increasingly stringent Building Regs Part L, Code for Sustainable Homes]
7. What role do you think voluntary codes of practice and statutory regulation play in improving the energy performance of new build homes? [Improving the practices of the mainstream housing construction industry]?
8. To what extent do you think the social housing sector and housing associations have been encouraged to lead the way in terms of ensuring the energy performance of new builds? Applying new technologies? Decent Homes Standard?
9. What do you think of the fabric first principle – improving the energy-efficiency of buildings before adding renewable technologies? What role do you think low-carbon technologies can play in raising the energy performance of new builds?

Appendix D

Trinity Close, Rackheath

10. As I understand, Trinity Close was the first CSHL6 development that DJH were involved with, why did you decide to take on this project? What were your aspirations for the project?
11. How did you equip yourselves with the technical knowledge and skillset for the build?
12. Can you explain to me how the Trinity Close properties were designed to integrated into the local community & why was this important? How was it anticipated that the development would contribute to the wider Rackheath community? Do you think this has been successful with Trinity Close?
13. To what extent was DJH involved in specifying the low-carbon technologies & post-occupancy monitoring equipment & contractors for the Trinity Close properties? Can you talk me through the decision making process?
14. So the properties were designed and built to be 'carbon neutral' – what do you understand by this term?
15. When considering low-carbon housing, how important do you consider taking account of the whole life cycle of the property & why? What was the purpose of the embodied carbon study & how is it anticipated that it will be used?
16. What stage are DJH at in terms of appraising the low-carbon technologies installed at Trinity Close? What would you alter in future designs?
    a. Air Source Heat Pumps, under-floor heating - energy bills higher than expected, refrigerant gas leaks
    b. Mechanical Ventilation & Heat Recovery – operational? understand purpose?
    c. Grey water recycling system - leaks
    d. Photo-voltaic panels – short circuiting, not able to see if producing
    e. Geo-trio Energy monitoring system – kept going offline
    f. Triple glazing & super-insulation – overheating during warmer months

17. Can you describe the 'after-care package' that was provided by DJHs for the Wherry Housing? [i.e. training maintenance technicians, repairing technologies, providing support for householders]
18. To what extent will this appraisal & monitoring results feed into Phase 2 & the future design of housing development in Rackheath?
19. The second phase of the Trinity Close development has been approved at Code for Sustainable Homes level four – why was a lower Code level opted for? How will the construction of these homes differ from the first 12 & why? Do you think this undermines the ethos of the first phase?

Trinity Close & 'behaviour change' around energy practices

20. How can you explain the energy performance gap in low-carbon housing – i.e. when more energy is used by the operation of a building than designers predict [construction/technical skills; lack of education etc.]
21. How was it anticipated that the residents would interact with the low-carbon technologies in the home? Were they designed to be discrete/active user involvement?
22. Was it hoped that the residents would modify their lifestyles to become more energy aware/energy-efficient in Trinity Close?
23. How were the residents introduced to the concept of energy management & how was use of the low-carbon technologies explained? How could this have been improved?
24. How were residents instructed to manage their thermal comfort?
25. What was the main mechanism for behaviour change? [Feedback/education?]
26. What do you think are the merits and limitations of households' energy use being monitored and them receiving feedback on their energy use? Why? How effective do you think the monitoring programme with Geo-Options has been & why? How will this monitoring data be used? [intended feedback to the residents?]
27. Do you think that the Trinity Close scheme will achieve a long-term decrease in residential energy consumption; if yes, why/ if no, why not?
28. What would count as 'success' for Trinity Close in your opinion? To what extent has this been achieved? What could have been done better?

Organisational relations

29. How do you think the stakeholders have worked together on the Trinity Close project & wider Rackheath eco-community development proposal? How could organisational relations have been improved? [clearly defined roles & responsibilities]

Governing a transition to low-carbon society

30. How do you think we can achieve long-term behaviour change to reduce energy use in homes? [education/incentives/tax/community-initiated/market driven - tariffs]
31. How can we transition to a low-carbon housing sector ultimately? [decarbonising energy supply/reskilling construction sector/changing attitudes & values/regulation driven etc.]

Appendix E

Household practitioner - interview information sheet

Researcher: Rachel Macrorie
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Email: r.macrorie@uea.ac.uk
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University of East Anglia PhD research project
The dynamics and governance of everyday energy-consuming practices in low-carbon housing

My name is Rachel Macrorie and I am researching 'Energy use, carbon reduction and 'behavioural change' in low-carbon housing' as part of a three-year PhD funded by University of East Anglia (UEA). The project aims to explore how levels of energy use are affected by living in low-carbon homes. Understanding the viewpoints of low-energy households in Rackheath is central to this project. As a resident of Trinity Close, I would like to invite you to share your experiences with me, however your involvement is voluntary.

You may have spoken to me about living in a low-energy home back in March 2012. Today's conversation provides an opportunity to talk to me about how you've experienced living in Trinity Close over the past year. In particular, I'm interested in your thoughts on whether the low-carbon technologies in your property have helped you to reduce your electricity usage and what your experiences of using this equipment has been. We are going to talk about how you have managed the temperature of your home and discuss what life in 'an affordable low-energy home' has meant for you and your household in terms of energy use. Today's conversation also provides an opportunity for you to share your experiences of the management and maintenance of Trinity Close.

All household members who would like to be involved in the discussion are welcome to take part. Our discussion will last between 60 and 90 minutes and we can arrange this conversation over one or two visits, as is convenient for you. It would be helpful if we could review your energy bills today in order to gain an understanding of your energy use over the past year. Following our discussion, you are invited to keep a diary of how you manage the temperature in your home for one week. It would also be really helpful to monitor the temperature and humidity of your living room for one month following diary completion.

Your feedback will be used to develop understanding on everyday electricity consumption in low-energy homes. It is hoped that this research will promote understanding of how residential energy savings can be encouraged in an equitable, inclusive and sustainable way. I'd be happy to share copies of the reports and publications produced from this work with you.

Many thanks for your time and contributions!
Kind regards,

Rachel Macrorie

My PhD supervisors are Dr. Irene Lorenzoni and Dr. Jane Powell. I am affiliated with 3S and the Tyndall Centre research groups.

Appendix F

Professional practitioner - interview information sheet

Researcher: Rachel Macrorie
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University of East Anglia PhD research project
The dynamics and governance of everyday energy-consuming practices in low-carbon housing

My name is Rachel Macrorie and I am researching 'energy use, carbon reduction and 'behavioural change in low-carbon housing' as part of a three-year PhD funded by University of East Anglia (UEA).

Ambitious government targets set an agenda to reduce domestic energy demand, however the leverage of policies targeting energy reduction in the housing sector is poorly understood. This research focuses upon a new-build social housing development in the east of England, which has been designed to be operationally carbon neutral (Trinity Close, Rackheath). The experiences of the householders in this development over the last 18 months have been collected and are being analysed. Building upon this, understanding the viewpoints of the key stakeholders of this housing development is pivotal to this research. As such, I would like to thank you for offering to participate and for sharing your experiences and insights with me.

This project aims to explore how households' electricity-consuming practices are influenced in a more sustainable direction by living in low-carbon homes. Focussing in particular upon 'heat comfort practices' (i.e. ways in which householders' maintain their thermal comfort), the research asks questions around:

i) the 'make-up' and 'performance' of electricity-consuming practices in low-carbon housing
ii) the flexibility, or otherwise, of domestic electricity-consuming practices &
iii) the role of 'governance actors and arrangements' in steering domestic practices in a less electricity-intensive direction.

Ethnographic qualitative data and quantitative building energy performance data are being collected and analysed together in order to address these research questions.

Our discussion will last between 60 and 90 minutes. An interview consent form should be completed prior to the interview. Following our discussion, you will be offered the opportunity to provide a set of consolidated comments on summarised copies of the interview transcripts to verify correct interpretation of our conversation. Your feedback will be used to develop understanding on everyday electricity consumption in low-energy homes. It is hoped that this research will promote understanding of how residential energy savings can be encouraged in an equitable, inclusive and sustainable way. I'd be happy to share copies of the reports and publications produced from this work with you.

Many thanks for your time and contributions! Kind regards,
Rachel Macrorie

My PhD supervisors are Dr. Irene Lorenzoni and Dr. Jane Powell. I am affiliated with 3S and the Tyndall Centre research groups.

Appendix G

Interview consent and release form

University of East Anglia PhD research project

'The dynamics and governance of
everyday energy-consuming practices in low-carbon housing'

INTERVIEW CONSENT FORM

Interview date:
Interviewee(s):

	Please tick to confirm
I confirm that I have read the information sheet and that I understand the purposes of the research.	
I understand that my participation is voluntary and that I am free to withdraw, without giving any reason. If I decide to withdraw then I understand that the information I provide will not be used in the study if my withdrawal occurs within 30 days of the interview.	
I agree for the interview to be recorded and for notes made from the recording to be used in the research.	
I understand that any information that I provide will be treated confidentially and will only be included in publications in a completely anonymised form, unless I agree otherwise.	
I understand that information may have to be given to a 3rd party in an anonymised form if this research is subject to a Freedom of Information Act request.	

Signature of participant(s) _________________________________ Date___________

_________________________________ Date___________

Signature of researcher _________________________________ Date___________

Appendix H

Household practitioner interview transcript excerpt

Appendix H

Key – **RM:** Researcher, **AA:** Household participant 1, **BB:** Household participant 2

RM: So you said that you were able to arrange [for WHA to visit] if you needed some help or if you needed some advice on anything. So did you ask to be shown anything, did you have some questions?

AA: I think the only reason they came round was to see how the heating worked, other than that, we've been alright. Obviously we've had some other little maintenance issues, but they're only teething problems within the first year.

RM: So [WHA] set it at 16 [degrees] for the heating to come on if it goes below that?

AA: Yeah, [WHA] said not to let it go under 16 [degrees].

RM: And you were happy with that? Are all the rooms set at that temperature?

BB: Well I set them at that. I think they set them at 18 [degrees] or something but I set them at 16 [degrees].

AA: You set them at 16 because otherwise that'd be like you'd open that door and [the underfloor heating] would kick in straight away, and obviously that's too quick because if you're only nipping outside you don't need the whole thing to kick in. So you just dropped [the thermostat setting] to 16 didn't you?

BB: I set them all for 16 [degrees].

RM: Right and [WHA] said that you could just… set them up how you wanted?

AA: Yeah, you could set them up however you want.

BB: [WHA] advised us that you shouldn't really have them set at no less than 14 [degrees] because otherwise they'd be constantly on, so I just set them for a couple of degrees more so they're not going to kick in all the time.

AA: It's only now that we've had the snow that the upstairs gets cold, but then that's when we're then going to bed, but then you don't need to put the heating on when you're going to bed.

BB: No, that's fine.

RM: So are there any aspects of the house that you find challenging?

AA: Umm I don't think so, no.

BB: Not really.

RM: Do you think you live any differently here to how you lived in your last home? Well you mentioned turning off all your sockets and being quite conscious actually of energy usage.

AA: Yeah, I think we are more aware of what we use I think, aren't we?

BB: Yeah.

AA: Other than that I think we're pretty much the same

RM: So do you think because there were some tips in the manual I remember from having a look at somebody else's, did you look through those? And did they make any different to the way you lived?

AA: I think because we did read a lot of it when we first moved in, you sort of get set in your own ways, that's how you do things. But I think because we'd already turned off most things, I think that was the main thing really, to turn off what you're not using and use the stuff during the day and…

RM: So you, sort of, you figured it out really, you didn't really need the manual to help you?

BB: Yeah, we figured out more from the meeting that we went to, than from the manual really, didn't we?

AA: I think that was just the back up for if people didn't go to the meeting really, wasn't it?

BB: If you've got sun throughout the day, use your appliances when needed. If it's dingy and raining and dark outside don't, cos you ain't going to get free electric. Not unless you absolutely definitely need to use it.

AA: A lot of it's done on common sense really isn't it?

RM: So were you able to play around with things, did you use trial and error or were you worried about breaking things, or did that not come into it?

AA: No, no, [WHA] were quite good really. They said just do what you want. You shouldn't be able to break anything, didn't they?

BB: Yeah.

AA: Yeah, we've sort of set things up, how we use them haven't we?

Appendix I

Professional practitioner interview transcript excerpt

Appendix I

Key – **RM:** Researcher, **Dave:** Senior Manager, Wherry Housing Association (WHA)

Dave: Yes, there is school of thought, with Building Regs you have to put in a heat source, central heating or some form of room heating to each room, but maybe there is a debate that some properties are so well insulated that you don't need a traditional heating system...

RM: I was going to ask you about that, as well. Some of the residents have spoken about the properties being quite warm during summer…

Dave: Yeah too warm.

RM: Too warm, pushing 30 degrees, going over 30 degrees. What advice was given to the residents around that?

Dave: Umm [sighs] I'm not sure we did. I suppose when we did the defects inspection it was October so it might have been raised once or twice.

RM: Yeah, but when [the residents] first moved in that was October [2011] and it was really warm then.

Dave: Yeah, it's a bit difficult, I mean obviously turn your central heating off, silly question, but it shouldn't be triggering the thermostat if it's 30 degrees. I think the problem you've got is south facing windows and… huge living room windows. I've seen houses designed with a sun trap to reduce that, but it is obviously triple glazed so it is just a case of relying on your ventilation then, either the MVHR or relying on the night latches. Yeah I mean over heating, I think is increasingly an issue in high code properties and it's sometimes that we need to think about what advice we can give residents. Because the only real advice you can give obviously is make sure your heating is off and keep windows open.

RM: Yeah, that seemed to be one of the things that people were concerned around, particularly families with young children.

Dave: I suppose you can have blinds can't you? But it's very difficult. Maybe if you designed a conservatory on the back, so that takes some of the heat and dissolves it into the rooms, but it's very difficult with the design to resolve it, except put blinds up.

RM: Was there any advice given as to whether they could open and close windows because they're not designed as passive homes, but there's…?

Dave: Again, it's a case of see how it goes for that individual in that property. We've suggested in the past if its too hot, yes open windows. But people have to be careful if you've got children, you don't want them falling out of windows, you don't want people breaking in through windows. You are now nailing down the issues which we will learn from and work out what to do. And something around over heating, I'm not sure how we would deal with that, but it's something that I'm now going to do.

RM: Residents also have concerns around the MVHR and don't know what it does and how it works.

Dave: When people moved in everybody had a nice big sheet explaining how it works and that they need to leave it on 1 for normal or 2 if they were having a shower.

RM: So do you think it comes down to educating the residents then?

Dave: Yes I think it does. I think when people moved in, the last thing they were thinking about was how the MVHR works. But we've been out and did a defects inspection in all properties except one, and if people ask us, we'll tell them. Again we left sheets with people explaining how to use it. But we don't want to interfere in peoples' lives too much and we don't want to be constantly door knocking asking 'is it alright, everything alright?' And plus there's a limit on our time as well. I remember the [units] being quiet, fantastically quiet. I don't remember people having issues with condensation...

RM: Yes, so you spoke about people having abandoned their ASHP in preference of fan heaters and I'm aware of properties where people have blocked their MVHR vents. So what do you think of people over-riding these technologies?

Dave: Well that's the problem with MVHR they can be over-ridden and we tell people not to do anything, but we know people do do that. And we do a yearly check on MVHR so when they let the electrician in, he will chastise them for blocking it up [jokingly]. He won't, he'll probably just unblock it and say 'Oh why did you do that?' And that doesn't stop [residents from] doing it the next minute. And one of the common issues about MVHRs is that they blow out cold air. I'm not convinced that that's a particular issue there, if anything, I imagine that people would be quite appreciative of cold air. Again we don't nanny state all our residents. And you've made me think, that not only do we have to go back and speak to the residents about energy consumption, we've also got to go through again with each resident the workings of the house, and just make sure that they are aware of they've got to do, and what they expect us to do, and they can ask us questions. But the trouble is that people lead such busy lives... You've made me think, I think I might do that ahead of the feedback, I think I'll send out a letter and ask people if they've got any concerns with central heating, MVHR, and over-heating...I think maybe we need to talk to them individually about that and pay them a visit.

RM: ...What would count as success for Trinity Close, and what could have been done better?

Dave: Success will be, if it is a zero carbon scheme, if it meets the energy production as well as the energy consumption over a 3 year period...But really success is if people want to live there and enjoy living there and its a stable community. I think there's only been one person move in that past 12 months, which is a relatively stable community... In terms of what could have been done better, I think we shouldn't have put the GWR system in... Possibly a solar-thermal panel in lieu of the amount of PVs. I think that that would have been of direct benefit to the residents because it would have heated the water. But in order to obtain the Code six you needed to max out the PVs and the solar thermal didn't make much difference... Forgetting about the Code six, if I was doing that scheme again I'd build it exactly as it was, I'd get rid of the PVs, I'd stick a solar thermal panel on the roof and I'd get rid of the GWR system, and I'd see if you could get away with traditional extract fans and trickle vents as opposed to MVHR. But the way I've just said it, that scheme wouldn't have got Code six, it would probably have got Code four, but that scheme would be easier to maintain and probably would have been an easier scheme for residents.

RM: So that's technical improvements, what about improvements in terms of inducting the residents and supporting them? And organisational relations as well on the development, how the stakeholders worked together, do you think there was room for improvement there?

Dave: I think we could have communicated better to residents, I think we can always communicate better to residents. I think we probably should be in more dialogue with the residents really.

Appendix J

Heat comfort practice diary excerpt

Appendix J

DAY 1 H4 **DATE** 19 APRIL '13

TIME	ROOM	WHAT WERE YOU DOING?	HOW DID THE CHANGE IN TEMPERATURE MAKE YOU FEEL?	HOW DID YOU WANT TO FEEL?	WHAT DID YOU DO TO 'FIX' YOUR COMFORT?
9am	Bedroom	Getting dressed & putting make up on.	I felt cold. after being in a warm bed	warmer.	Put a cardigan on, hurried up & made a hot drink
2pm	Hallway & living room	Just got in after being out.	anxious after being in the really cold outside. in my hall wasn't much warmer.	warmer & cosier	quickly shut all the doors, kept my jumper on, till the heating had adjusted.

WHAT MIGHT TODAY'S ENTRIES MEAN FOR HOW WE CAN USE LESS ENERGY TO KEEP AT A COMFORTABLE TEMPERATURE?

maybe if I had a porch. I wouldn't lose so much heat out of the front door.

ACTIVITY

Think about the ways in which you kept warm and cool in your previous home compared to your new home. What sorts of things are the same? How are things done differently? What difference do these changes make? Make notes on, draw or take photos of your ideas:

In my other home I had storage heaters and the bedroom was very cold in the winter I would have a thick duvet and in the summer I had a thinner one. Now with constant temperature in the bedroom all year round, I only have one thin duvet.

Appendix J

DAY 3 (H3) **DATE** Thurs 18th April '13

TIME	ROOM	WHAT WERE YOU DOING?	HOW DID THE CHANGE IN TEMPERATURE MAKE YOU FEEL?	HOW DID YOU WANT TO FEEL?	WHAT DID YOU DO TO 'FIX' YOUR COMFORT?
2025	Kitchen	Cooking Tea	warm	warm	Left the oven open after I turned
					it off to use the heat to warm the room
21.00	Living Room	watching TV	cool	warm	sat under duvet.
23.40	Bed Room	Going to bed	woke up Hot from being under duvet on sofa	cooler.	wore summer PJ's and opened window

WHAT MIGHT TODAY'S ENTRIES MEAN FOR HOW WE CAN USE LESS ENERGY TO KEEP AT A COMFORTABLE TEMPERATURE?

ACTIVITY

Make notes on, draw or take photos of how different types of clothing, their fabrics and the way in which they are worn affects how warm and cool we are. You might also want to think about how eating & drinking can affect how warm and cool we are at home:

We find eating a hot meal definitely makes us feel warmer, sometimes too hot on a warm day, so often have the front door open whilst eating. especially if oven has been on a while.

PJ's tend to be thinner materials as being under a duvet at night can make us very hot. Dressing gowns are often thick and warm to put on when we get up as the temp change of a warm duvet & bed to outside the bedroom can be quite a cold shock!

Appendix K

List of analysed policy documents

Appendix K

Ref. (PX)	Title	Author(s)	Publisher	Date	Type
1	Code for Sustainable Homes: A step-change in sustainable home building practice	DCLG	Department for Communities and Local Government	2006	Government publication
2	Building a greener future: policy statement	DCLG	Department for Communities and Local Government	2007	Government publication
3	2016 Taskforce Meeting	ZCH	Zero Carbon Hub. Available at: http://www.zerocarbonhub.org/resources/reports/zero-carbon-hub-progress-report-21st-october-2008 [Accessed 9th October 2012]	2008	Government advisory body publication
4	Definition of zero carbon homes and non-domestic buildings: Consultation.	DCLG	Department for Communities and Local Government	2009	Government publication
5	Sustainable New Homes - The Road to Zero Carbon: Consultation on the Code for Sustainable Homes and the Energy Efficiency standard for Zero Carbon Homes	DCLG	Department for Communities and Local Government	2009	Government publication
6	Code for Sustainable Homes to be made more consumer friendly	Building4Change	Building4Change. Available at: http://www.building4change.com/article.jsp?id=204#.VJNZzkAAFB [Accessed 8th October 2012]	2009	Housing industry publication
7	New common sense code to build greener homes	DCLG	Department for Communities and Local Government. Available at: https://www.gov.uk/government/news/new-common-sense-code-to-build-greener-homes [Accessed 7th October 2012]	2010	Policy announcement
8	Government simplifies code for sustainable homes	Hardman, I.	Inside Housing. Available at: http://www.insidehousing.co.uk/government-simplifes-code-for-sustainable-homes/6512446.article [Accessed 18th December 2014]	2014	Housing industry publication
9	Grant Shapps sets out practical solution to cut emissions from new homes	DCLG	Department for Communities and Local Government. Available at: https://www.gov.uk/government/news/grant-shapps-sets-out-practical-solution-to-cut-emissions-from-new-homes [Accessed 10th October 2012]	2014	Policy announcement
10	Trinity Close, Rackheath, Norwich	DJH	Dove Jeffery Homes	2011	Trinity Close, Rackheath housing development plan
11	Buildings and the Environment	DCLG	Department for Communities and Local Government. Available at: https://www.gov.uk/government/speeches/buildings-and-the-environment [Accessed 11th February, 2012]	2011	Ministerial speech
12	Zero Carbon Strategies: For tomorrow's new homes.	ZCH & NHBC	Zero Carbon Hub and National House Builders Council. Available at: http://www.zerocarbonhub.org/sites/default/files/resources/reports/Zero_Carbon_Strategies_for_Tomorrows_New_Homes.pdf [Accessed 14th March, 2013]	2013	Government advisory body publication
13	Rackheath Community Trust - Progress Report	BDC	Broadland District Council, Norwich	2012	Local authority report
14	Policy making in the real world	Institute for Government	Institute for Government. Available at: http://www.instituteforgovernment.org.uk/sites/default/files/publications/Policy%20making%20in%20the%20real%20world.pdf [Accessed 8th July, 2012]	2011	Government advisory body publication

15	Making Policy Better: Improving Whitehall's core business	Institute for Government	Institute for Government. Available at: http://www.instituteforgovernment.org.uk/sites/default/files/publications/Making%20Policy%20Better.pdf [Accessed 10th January 2012]	2011	Government advisory body publication
16	Better policy making	Bullock, H., Mountford, J. and Stanley, R.	Cabinet Office: Centre for Management and Policy Studies	2001	Former civil service advisory body publication
17	Broadland District Council	BDC	Broadland District Council: http://www.broadland.gov.uk/ [Accessed 19 Dec. 2011].	2011	Local authority website
18	Broadland Business Plan 2010-2015	BDC	Broadland District Council http://www.broadland.gov.uk/PDF/Business_Plan101112red_web.pdf [Accessed 2 Feb. 2012].	2010	Local authority report
19	Circle Housing	Circle Housing	Circle Housing: http://www.circle.org.uk/ [Accessed 19 Dec. 2011].	2011	Housing association website
20	Annual Review 2011/12	Circle Housing	Circle Housing: http://www.circle.org.uk [Accessed 30 Apr. 2012].	2012	Housing association report
21	Dove Jeffery Homes	DJH	Dove Jeffery Homes http://www.dovejefferyhomes.co.uk/ [Accessed 18 Dec. 2011].	2011	Housing construction company website
22	What We Do | LCIC - Low Carbon Innovation Centre	LCIC	Low Carbon Innovation Centre http://www.lcic.com/about-what-we-do [Accessed 19 Dec. 2011].	2011	Former environmental consultancy (now Adapt) website
23	Adapt - Services	Adapt Commercial	Adapt Low Carbon Group Available at: https://www.adaptcommercial.co.uk [Accessed 6 Sep. 2013].	2013	Environmental consultancy website
24	Design and Access Statement: Trinity Close, Rackheath – 14 Dwellings.	Chaplin Farrant	Broadland District Council. Available at: http://www.broadland.gov.uk/MVM.DMS/Planning%20Application/648000/648779/20130217%20Design%20&%20Access%20Statement.pdf [Accessed 12 February 2015].	2012	Planning document
25	Development of Site Trinity Close, Rackheath: Report produced on behalf of Dove Jeffery Homes.	Fusion 13	Broadland District Council. Available at: http://bit.ly/1HqPXGR [Accessed 12th February 2015]	2013	Planning document
26	Planning Decision 20130217	BDC	Broadland District Council. Available at: http://www.broadland.gov.uk/MVM.DMS/Planning%20Application/648000/648779/20130217%20Decision.pdf [Accessed 12 February 2015].	2013	Planning document
27	Review of housing supply. Delivering stability: securing our future housing needs.	Barker, K.	HM Treasury	2004	Government publication
28	East of England Plan. The revision to the Regional Spatial Strategy for the East of England	Government Office for the East of England	The Stationary Office	2008	Government publication
29	Welcome to the Greater Norwich Growth Board (GNGB)	Greater Norwich Growth Board	Greater Norwich Growth Board. Available at: http://www.greaternorwichgrowth.org.uk/ [Accessed 13 Jan. 2012].	2012	Website
30	HBF Response - Code for Sustainable Homes.	Home Builders Federation	Home Builders Federation. Available at: http://www.hbf.co.uk/policy-activities/news/view/hbf-response-code-for sustainable-homes/ [Accessed 10 Dec. 2012].	2006	Consultation response from housing industry

31	Welcome to the Zero Carbon Hub website!	ZCH	Zero Carbon Hub. Available at: http://www.zerocarbonhub.org [Accessed 5 Jan. 2012].	2012	Website
32	Improving the energy efficiency of buildings and using planning to protect the environment.	DCLG	Department for Communities and Local Government.	2012	Government publication
33	Online Standard Results	BDC	Broadland District Council Available at: http://bit.ly/1PvLSec [Accessed 9 Mar. 2012].	2010	Planning document
34	Building a greener future: policy statement.	DCLG	Department for Communities and Local Government	2007	Government publication
35	Planning Policy Statement: Eco-towns: A Supplement to Planning Policy Statement 1.	DCLG	Department for Communities and Local Government	2009	Government publication
36	Concept statement in respect of Rackheath eco-community, Norwich.	Building Partnerships	Building Partnerships on behalf of Barratt Strategic and Manor Farm Rackheath Ltd.	2009	Planning document
37	Eco Towns. Standard Note: SN/SC/4406.	Barclay, C.	House of Commons Library, Science and Environment Section.	2011	Government Publication
38	Feed-in Tariffs: Government's Response to the Summer 2009 Consultation	DECC	Department for Energy and Climate Change	2010	Government Publication
39	Locally-led Garden Cities	DCLG	Department for Communities and Local Government	2014	Government Publication
40	Eco-town funding halved by CLG	Milne, R.	Government Planning Portal. Available at: http://www.planningportal.gov.uk/general/news/stories/2010/july2010/2010_07_week_3/150710_4 [Accessed 17 November, 2012]	2010	Government News and blog
41	National Planning Policy Framework	DCLG	Department for Communities and Local Government	2012	Government Publication
42	Next steps to zero carbon homes - Allowable Solutions. Consultation.	DCLG	Department for Communities and Local Government.	2013	Government Publication
43	Pioneering the volume production of homes to Code for Sustainable Homes level four	AIMC4	The Application of Innovative Materials, Products and Processes to meet the Code for Sustainable Homes Level 4 Energy Performance. Available at: http://www.aimc4.com/ [Accessed 4th January 2015]	2015	Website
44	HBF Annual Industry Lunch 2011 Speech	Baseley, S.	Home Builders Federation. Available at: http://www.hbf.co.uk/media-centre/news/view/hbf-annual-industry-lunch-2011-speech-by-stewart-baseley-1/ [Accessed 12th October, 2014]	2011	Housing industry speech
45	Next steps to zero carbon homes - Allowable Solutions. Responses	DCLG	Department for Communities and Local Government.	2014	Government Publication
46	Response: Comprehensive Review Phase 1: Consultation on Feed-in Tariffs for Solar PV	Burke, A.	National Housing Federation. Available at: http://s3-eu-west-1.amazonaws.com/pub.housing.org.uk/FiTs%20Comprehensive%20Review%20Phase%201%20NHF%20Response%20Dec%202011.pdf [Accessed 24th July, 2013]	2011	Housing industry response to Government consultation
47	The Broadland Carbon Management Programme: An Embodied Carbon Study of the Trinity Close Housing Development at Rackheath Norfolk.	Adapt and BDC	Adapt Low Carbon Group, based at the University of East Anglia, on behalf of Broadland District Council.	2012	Environmental consultancy report.

48	Delivering a low-energy building: Making quality commonplace	Tolfield, B.	Adapt Low Carbon Group, University of East Anglia, Norwich.	2012	Environmental consultancy report.
49	Housing Standards Review: Consultation	DCLG	Department for Communities and Local Government.	2013	Government Publication
50	Code for Sustainable Homes and the Housing Standards Review: Eighth Report of Session 2013-4.	Environmental Audit Committee	Environmental Audit Committee. Available at: http://www.publications.parliament.uk/pa/cm201314/cmselect/cmenvaud/192/19202.htm. [Accessed: 10th February 2014]	2013	Government Advisory Body Report
51	Next steps to zero carbon homes – Allowable Solutions. Government response and summary of responses to the consultation.	DCLG	Department for Communities and Local Government.	2014	Government Publication
52	Consultation Response. HBF response to HCA Core Standards Consultation. 15th June 2010.	HBF	Home Builders Federation	2010	Housing industry response to Government consultation
53	Housing Minister Rt. Hon. Mark Prisk MP keynote speech at Chartered Institute of Housing conference in Manchester	DCLG	Department for Communities and Local Government. Available at: https://www.gov.uk/government/speeches/housing-speech-by-mark-prisk [Accessed: 11th August 2013]	2013	Ministerial speech
54	2010 to 2015 government policy: house building	DCLG	Department for Communities and Local Government. Appendix 8. Available at: https://www.gov.uk/government/publications/2010-to-2015-government-policy-house-building/2010-to-2015-government-policy-house-building [Accessed March 10th 2015]	2015	Government publication
55	Eric Pickles outlines funding cuts for England councils	BBC	British Broadcasting Corporation (BBC). Available at: http://www.bbc.co.uk/news/uk-politics-20784599 [Accessed 13th March, 2013]	2012 - 19th December	Online newspaper article

Appendix L

Sample Trinity Close building energy performance feedback report

Produced by Dr. J. Monahan on behalf of Broadland District Council &
Wherry Housing Association, September 2014

Trinity Close Monitoring Project Individual Report

Dear ' *name here'* household 'of No X Trinity Close

Trinity Close phase one was monitored from September 2011 to September 2012. The data collected has been analysed and this report provides you with your results from the year of monitoring. These results are specific to you. We have tried to make the results as anonymous as possible by showing the average, maximum and minimum results unique to you and from your 11 neighbours. You may want to share your results with your neighbours to see how you compare.

Monitoring project highlights:

- The average annual metered grid electricity consumption for Trinity Close was 5767kWh per year, ranging from 3468 kWh per year to 8042 kWh per year.
- The homes at Trinity Close all had very low consumption compared with the national and regional average. The average household annual energy consumption in the UK is 16,100 kWh[1,2]. In East Anglia, this is slightly lower (15, 500 kWh a year).
- As a whole the $61kW_p$ PV system at Trinity Close generated 51,610 kWh of electricity, 10% more than estimated.

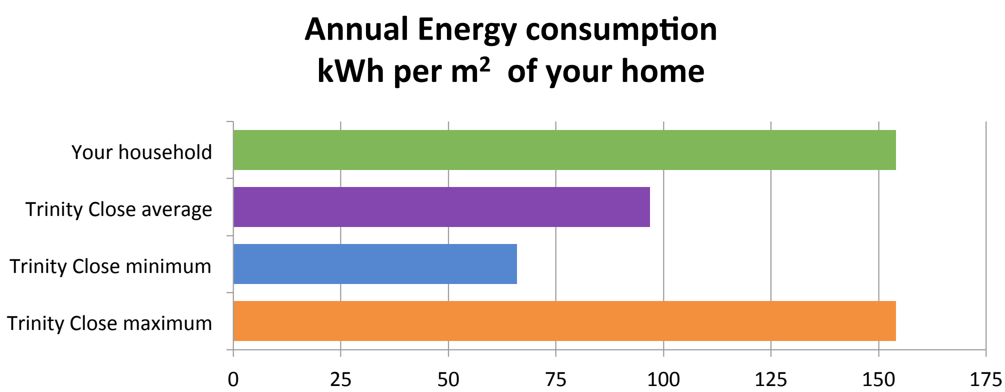
About your household

Annual metered electricity consumption

Your household used 8042 kWh of electricity from the national grid, approximately 22 kWh a day.

How did your household compare with your neighbours on Trinity Close?

To show how your household energy consumption compares with the other households on Trinity close the amount of electricity metered over the year was divided by the size of the house to make the comparison fairer:



Your photovoltaic system

Your PV system generated 3898 kWh of electricity over the year, an average of 10 kWh a day

Some of this your household would have used directly and some would have been exported to the national grid. However, due to the problems encountered during the monitoring period we cannot say how much of this clean green electricity your household actually used. But we estimate that your household may have used a large proportion of the PV generated electricity, reducing your power bills over the year.

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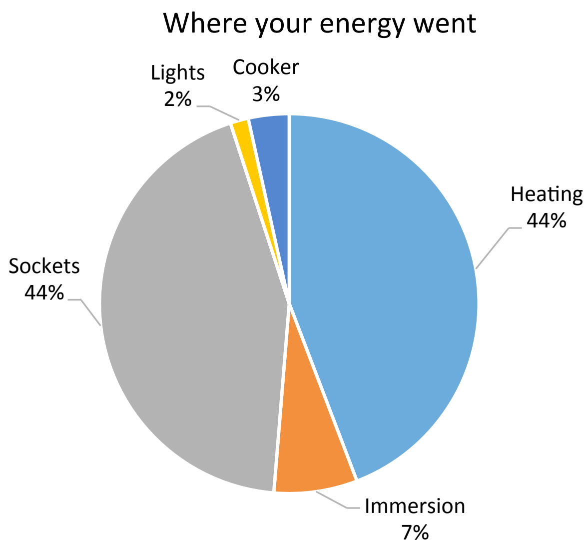
[1] A kWh is a unit of electricity. You can find out how much this cost by multiplying your electricity tariff pence per unit.
[2] ONS 2013: Household Energy Consumption in England and Wales, 2005–11. The Office for National Statistics. HMSO, London.

Where did this energy go?

The GEO energy monitoring system did provide a complete year's data. The pie chart below shows our estimate of where your household used energy:



Heating and hot water used about 51% of your total household energy.

Summary Tips and recommendations

Your household had the highest energy demand of the 12 homes monitored at Trinity close. This was due to a relatively high energy demand for space heating and hot water and also sockets related energy.

Top tips for lowering your energy use:

Switch appliances off when you aren't using them.

Unplug chargers when you are not using them.

A recent Energy Savings Trust report found that 9 – 16% of total household energy was lost in this way as energy used not doing anything useful[3].Computers, TV's, gaming consoles, lights, heaters, chargers all use energy even though you might not be using them.

Make use of the PV panels while the sun is shining.

Use timer plugs.

If you are at home make use of the PV power when the sun is shining (washing machines, dishwashers, ironing, hovering, DIY, mowing the lawn, baking and cooking etc). If you can't be at home during the day use timer plugs for for washing machines, dishwashers, ovens, slow cookers etc to make use of the PV power during the daytime (time things to come on in series not all at once). The PV panels may not provide all the power needed but it will provide some. Every little bit helps.

You can find more helpful advice on cutting your energy bills from the Energy Savings Trust:

www.energysavingtrust.org.uk/Take-action/Energy-saving-top-tips

[3] EST 2012: Powering the Nation Report. TheEnergy Savings Trust, London.

Appendix M

Mismatch between issued tenant advice and realised performance of household heat comfort practices at Trinity Close

Appendix M. Mismatch between issued tenant advice & realised performance of household heat comfort practices at Trinity Close.

Formal advice from WHA, DJH and Adapt	Realised performance of heat comfort practices	Illustrative householder quotation
Passive involvement with energy-efficient materials and renewable technologies.	More active involvement demanded	*"I looked in - there's a big old folder about everything to do with the flat - so I looked in that and it said, 'Take the panel off and press this button'. But it wouldn't actually do what it said on the instructions so I couldn't do it… then the plumber came and said 'Don't get involved with it, don't touch it'"* (H3A).
Maintain a super-sealed environment in the property. Open windows and doors sparingly to retain heat.	Opened windows & doors for ventilation	*"[The summer] was just ridiculously hot. You'd have all the doors and windows open, and the temperature just wouldn't drop. Every time the sun comes up, it is shining through those windows until it goes down at night… We have to be facing that way because of the solar panels… they're built to maximise the heat.... It's so well insulated, but [the architects] didn't think in the summer time, with all the windows and that, how do you cool [the house] down"?* (H12A).
Maintain passive interaction with the MVHR system. Use boost switch when required.	Used MVHR as would a conventional ventilation fan or blocked air vents	*"Come wintertime I had to shut these [vents] up because it was that cold up here and in those two back bedrooms, I had to shut them all up to keep the heat in… You know because some mornings you'd wake up and there'd be condensation all around them… I had to. It was just too cold in here and you could feel the cold air coming through them"* (H2C).
Adhere to recommended temperature range (16-18 at night, max. 21 during day) for heating efficiency.	Reset thermostatic controls according to household expectations, which exceeded recommended temperature range	*"[WHA and DJH] set [the heating] at 16 degrees… so I thought 'that's bloomin' freezing!'. So… I got the [manual] out and tried to do it myself… [WHA] kept saying to me 'that unit outside is not designed to have heating set at 25 degrees'. and I said to them 'well that's rubbish, because the heating has been on for the last couple of weeks at 25 degrees'. He said '21 degrees is quite normal for a bungalow'. But I said 'for people who haven't got health issues, yeah probably it is, but I need it warmer'. So I've set them all for 23 and it's been fine since then"* (H10A).
Programme heating system using timer according to patterns of household activity.	Switched heating on/off as and when required.	*Interviewee: "It's just normally windows open heating off, and windows closed heating on. That's how I use it. I don't really have a good way of doing it. I suppose that's just the easy way." Interviewer: "Yeah, do you think about using the timer at all…?" Interviewee: "No… if there's a jumper to hand, I'll grab one. But normally I'd just knock [the heating] up a few degrees"* (H8B).
Keep ASHP continuously running to provide hot water and heating	Turned off the ASHP to keep cool or to save money on heating bills	*"During the summer I just had that temperature reduced down to zero...but I don't think that necessarily cools [the house] down. I think I just turned [the ASHP] off in the end"* (H9B)
Rely on thermal efficiency of the house and installed heating system.	Brought in supplementary heating technologies to circumvent using 'inefficient' ASHP	"*When [my husband] goes to bed, it's not cost effective for me to stick the heating on, because it will take two to three hours to heat up, so… we just have a little heater… that I have on in the night if I'm chilly, because you can't come in, like in a normal house, and stick the radiators on, because it takes so long to heat up"* (H5A)

Appendix N

Themes emerging from pilot and repeat household interviews, audio tours and heat comfort practice diaries

Themes emerging from pilot and repeat household interviews, audio tours and heat comfort practice diaries	Anonymised Trinity Close households												
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	TOTAL (PERCENT)
Retained advice													75
Refrained from touching technologies as intimidated or confused													33
Manual was not helpful													66
Turned off heating													17
Avoided changing thermostat													50
Trial and error /subvert technologies													58
Drew on tacit understandings													12
Became aware of insulation and passive design													11
Had strong opinions on economising/self-sufficiency/green-living													42
Enjoyed monitoring electricity consumption/generation													50
Prioritised convenience													33
Frustrated by lack of instant heat													42
Prioritise need for heat comfort													42
Perceived that made changes to heat comfort management													58
Faults with ASHP (potentially high electricity bills)													50
Regularly experience thermal discomfort (either too hold/cold)													66
Seek to save money on electricity bills													58
Increased expectation of heat comfort													25
Resentful towards initiative organisers													50
Feel like they have been used in a technology trial													42
Believe that reduced electricity bills do not outweigh challenges													50
Doubt the technical expertise of initiative organisers													42
Frustrated by lack of feedback from initiative organisers													66
Demand more transparent and responsive communications													50
Household electricity demand (bills) decreased at TC													50
Helped neighbours with heat comfort management													75
Aware of TC Phase Two													88
Strong reaction against TC Phase Two													63
Residents' views not incorporated into TC Phase Two													75
Worried that attention of TCSG would shift to TC Phase Two													34
Believe that TC Phase Two (CSH level 4) undermines TC Phase One													75
Concerned by increased cost of building to CSH level six													25
Want a house exchange													38

KEY:

Shaded area = Not able to discuss topic

H10 & H5 = pilot interview data only

Mutual exchange property = primarily data from from tenancy. Second tenancy considered in relation to discussion of Trinity Close Phase Two.

Appendix N. Themes emerging from pilot and repeat household interviews, audio tours and heat comfort practice diaries

Appendix O

Macrorie, R., Foulds, C. and Hargreaves, T. (2014a). Governing and governed by practices: Exploring interventions in low-carbon housing policy and practice

In: Y. Strengers and C. Maller, ed., *Social Practices, Intervention and Sustainability: Beyond behaviour change*, 1st ed. Abingdon, Oxon: Routledge, Chapter 6, pp.95-111.

6 Governing and governed by practices

Exploring interventions in low-carbon housing policy and practice

Rachel Macrorie, Chris Foulds and Tom Hargreaves

Introduction

Throughout the affluent West, domestic energy use is a major contributor to total end-use energy consumption and carbon dioxide emissions. In this context, attempts to reduce and decarbonise domestic energy use are a key focus of energy policies. In the UK, home energy consumption makes up roughly a third of all UK energy use (DECC 2013a) and 15 per cent of total UK carbon emissions (DECC 2013b). As a governance response, construction of new, low-carbon buildings – such as those installed with 'smart' technologies and electricity generation capabilities, and/or designed with high energy efficiency – has formed a central plank of policy approaches to date (Reid and Houston 2013). The importance of these low-carbon buildings is lent added significance given that they will shape how we live in years to come, thereby contributing to future energy use and associated carbon emissions. This importance is widely recognised by policy and, in the UK alone, recent years have seen increasing stringency of statutory standards (for example, Building Regulations), growth in voluntary standards (for example, Code for Sustainable Homes, Passivhaus, BREEAM) and associated professional accreditation courses, new financial incentives (for example, Feed-in-Tariffs, Renewable Heat Incentive, Green Deal), and new institutions (such as Zero Carbon Hub and Passivhaus Institute). Together, these developments have been made manifest in a burgeoning number of pilot projects around low-carbon housing (see Brown and Vergragt 2008; Lovell 2004, 2007a, 2007b). Nevertheless, there remains much work to be done before low-carbon homes constitute the norm for housing practice.

Research, policy and industry activity on low-carbon housing remains underpinned by a mode of problem framing labelled by Guy and Shove (2000) as the 'techno-rational paradigm'. This approach assumes that technological interventions alone will guarantee energy and carbon savings. According to this view, once technological design has been optimised, focus shifts to technology transfer and ensuring the rapid diffusion and 'correct' use of technologies by individual consumers. Persistent 'energy performance gaps' – where realised savings fall short of predicted savings (Shove 1998) – have, however, meant that increasing attention is paid to the activities of householders. In the majority of cases, focus has remained fixed on removing 'barriers' to technology diffusion and educating users to encourage 'correct' technical operation (see Leaman *et al.* 2010; Whitmarsh *et al.* 2011; DECC 2013c).

Recently, social practice theorists have begun to develop a distinct approach to this issue that, far from treating technologies and behaviours as separate, sees them instead as intertwined and embedded within social practices (for example, Gram-Hanssen 2010). Instead of optimising and diffusing new technologies, or educating or exhorting users to change their behaviour, focus turns to practices, which might include everyday routines such as cooking and showering, or home renovation (Wilson *et al.* 2013). Researchers in this domain seek to interrogate how these practices are made up of interrelated elements, and how they evolve and change over time. While this research has generated important insights into everyday routines and associated demand for energy services, it has also highlighted the fact that practices themselves are never isolated. Instead, they should be understood as always interconnected and constituting 'systems of practice' (Shove *et al.* 2012). Understanding change in practices, therefore, demands attention not only to specific and located practices, but also to those to which they are connected across both space and time (Watson 2012). Consequently, the micro-scale focus on how low-carbon technologies do or do not influence domestic activity seen to date (see, for example, Hargreaves *et al.* 2010, 2013; Foulds *et al.* 2013; Gram-Hanssen *et al.* 2012) seems peculiarly narrow. Concomitantly, the relative lack of attention given to how housing professionals' practices and interventions in housing infrastructure appears as a glaring omission (although see Shaw and Ozaki 2013). What is needed is an understanding of low-carbon housing as an intervention in a whole system of practice, a system that includes the working practices of housing professionals, outcomes of the design and build process, and interrelations with householders' dwelling practices. This contrasts with conceptualisations of low-carbon housing as merely an attempt to introduce new technologies to households.

In this chapter we begin to address this challenge by turning our attention to the, to date, largely overlooked practices of housing professionals involved in the delivery of new low-carbon homes, including designers and architects, construction teams, social housing landlords and project managers. The working practices of these professionals include: implementing low-carbon building standards; managing the build process; researching and procuring low-carbon building materials, heating technologies and 'smart' energy technologies; arranging connection to infrastructure systems; and building homes equipped with an insulated fabric and low-carbon technologies that may enable (but may not necessarily seek) accreditation to low-carbon construction standards. Specifically, we explore the experiences of these professionals as they are first exposed to the low-carbon (social) housing context. As such, we also consider low-carbon housing practices as including tenant management and the maintenance of housing stock. We combine this analysis with consideration of the implications of low-carbon housing for everyday dwelling practices. Our analysis draws upon two empirical case studies of low-carbon housing developments in the UK.

Building on Spurling *et al.*'s (2013) practice-oriented framework for policy interventions, as well as their contribution to this edited collection (Spurling and McMeekin, this volume), we conduct empirical investigation of how the practices of housing professionals (and, indirectly, householders' dwelling practices) become shaped through changes to i) the elements of practice, ii) the relations between practices, and iii) the recruitment of carriers. We argue that in order to govern the sustainability of housing design and construction practices, it is crucial not only to intervene in practice-as-entity but also to generate opportunities to reproduce sustainable practices through more or less faithful performances over the long term. Such coming together of alternative practice entities and the repeated performance required to sustain new, or modified, practices necessarily occurs within a dynamic 'system of practice' (Watson 2012).

We begin this chapter by reviewing the systems of practice concept, particularly in relation to the governance of interventions in practice. We then present our two case studies, focusing respectively on the Code for Sustainable Homes and Passivhaus. Analysis focuses on how efforts to make housing practices 'low carbon' were experienced by these professionals (although again, attention could equally be paid to householders' dwelling practices). Specifically, we pay attention to the three intervention framings proposed by Spurling *et al.* (2013) described below. We finish by reflecting on the implications for low-carbon housing, social practice theory, and interventions in practice.

Intervening in systems of practice

Social practice theory (SPT) positions practices themselves, what they consist of and how they evolve and change, at the centre of analyses of social life. In so doing, and in contrast to the techno-rational paradigm outlined above, SPT simultaneously decentres both technologies and individuals, seeing both as secondary to, while still comprising important components of, practices. Specifically, SPT positions individuals as 'carriers' of practice (Reckwitz 2002), who more or less faithfully reproduce and perform them across time and space and are thus crucial to their survival, while technologies (materials, tools, artefacts, infrastructure) are positioned as but one important element of practice. While different theorists emphasise slightly different lists of elements (see Gram-Hanssen 2011), within work on sustainability, Shove and Pantzar's (2005) formulation of practices as composed of materials (stuff, artifacts), meanings (images, social expectations) and competences (skills, practical know-how), has arguably been most influential.

Much early work within SPT focused on analysing the make-up and evolution of specific, individual practices – for instance, cycling (Watson 2013; McHardy 2013) or showering (Hand *et al.* 2005). More recent work has responded to the critique that SPT is suitable only for micro-scale analyses of the 'everyday' (for example, Geels 2010) by emphasising that individual practices are always and inseparably bound up in wider systems of practice that extend across space and time. In this view, specific practices are connected to, shape and are shaped by, practices that they precede or follow in time, those they co-exist with in space, as well as those they are connected to more distantly. This might include practices they are dependent on (for instance, to produce or distribute practice elements) or practices that seek to govern or regulate them (see Watson 2012; Shove and Walker 2010; Shove *et al.* 2012).

This understanding of practices, as embedded within spatially and temporally dispersed systems of practice, has been particularly important in generating insights for interventions in practice aimed at delivering change towards sustainability. Spurling *et al.* (2013), for example, set out three key ways in which interventions in practice might proceed. First, 'recrafting' practices, which involves changing the elements of a practice in order to reduce its overall resource intensity. With respect to low-carbon housing, this might entail replacing inefficient 'leaky' building materials with super-insulated fabric, or changing the meaning of a warm and comfortable home such that it no longer demands mechanical heating or cooling. Second is 'substituting' practices, which involves replacing unsustainable practice entities with more sustainable alternatives. This might involve designing communities that encourage defection from unsustainable practices and recruitment to more sustainable alternatives. For example, installing bicycle racks rather than providing car parking spaces in new housing developments might encourage a shift from driving to cycling practices. Alternatively, more sustainable versions of existing practices might be encouraged, for instance by designing homes without facilities for tumble-drying but with in-built air-drying amenities (Spurling *et al.* 2013). Third, and finally, Spurling *et al.* highlight the potential to 'change how practices interlock' by intervening in how practices are sequenced or synchronised. This could mean seeking to reduce evening energy demand peaks by encouraging flexible working hours. Crucially, acknowledging that specific practices are connected into more extensive systems of practice leads to the recognition that any intervention in any single practice – whether intentional or not – will have ripple effects throughout the whole system of practices of which it is a part. As Watson observes (2012, p. 491) (emphasis in original):

> Processes of change, whether to the elements of a practice or to the patterns of recruitment and defection of practitioners to it, are rarely endogenous to the practice concerned. Rather they arise because of the shifting relative location of a practice within broader *systems of practice*.

Recognising the importance of systems of practice is thus an important first step in understanding how practices evolve and therefore how one might intervene in them. As well as bringing many more practices (and their elements) into view than just the initial 'target' practice, this understanding also introduces a wider range of potential points for, and agents of, intervention. Critically, in relation to low-carbon housing, it reveals the shortcomings of studies that focus solely on houses themselves and the practices performed within them. Rather, research should attend to how homes form one potential intervention site among many and how householders are merely one set of carriers among many others in systems of practice. A systems of practice framing encourages practice-based research that moves beyond the prevalent focus on the doings and sayings of everyday life. Instead, this approach enables increased attention to be paid to those practitioners seeking to govern the systems of practice of which they are a part.

Here, it is important to emphasise the distinction in the SPT literature between practice-as-entity and practice-as-performance (Schatzki 1996, 2002). Spurling *et al.* suggest that practices-as-performances 'are the observable actions of individuals often referred to as "behaviours"' (2013, p. 21). In contrast, practices-as-entities exist beyond and between their instantiation in specific performances; they have a history and trajectory of their own and involve socially shared meanings, materials and competences. Crucially, Spurling *et al.* argue that interventions in practice should move beyond attempts to reshape practice-as-performance, what they see as 'just the tip of the iceberg', and should focus on trying to change practices-as-entities as a more appropriate 'target for sustainability policy' (2013, p. 21). This view implies that attention should be directed away from those who incrementally change practices-as-performances through their more or less faithful reproduction in everyday life, and towards those who arguably are able to intervene at the level of practices-as-entities. Such intervention attempts might include producing and circulating new elements, introducing new or more sustainable variants of existing practices, or acting to change the relations between practices on a societal scale. At the same time, it is recognised that policy makers face considerable challenges, as individual practices are likely to cut across different areas of policy making, the extent or scale of a practice is unlikely to be confined, interventions can only affect processes that are already underway and the scale of transformational change required may lie beyond that which is politically feasible (Spurling *et al.* 2013).

As Watson notes (2012, p. 496), 'practices recruit carriers in board rooms, the physical spaces of futures trading and government offices as much as they do on streets and in homes'. To date, however, despite the growing interest in how to intervene in practices, the practices of these would-be governors – potentially capable of intervening at the level of practice-as-entities – have received scant attention. In this chapter we seek to address this gap by focusing on the practices of housing professionals. Specifically we examine housing professionals involved in two low-carbon housing developments, where the delivery of homes centres around the ambition to reduce levels of carbon emissions generated by the everyday practices of residents.

Housing professionals and low-carbon developments: two case studies

Our discussion draws on two case studies of low-carbon social housing developments in the UK. The first example was built to be 'zero carbon' (also termed 'Code level 6') under the UK Code for Sustainable Homes (CSH). The second example was built to the German Passivhaus energy efficiency building standard. Research, including a longitudinal series of qualitative in-depth householder interviews, audio-tours and research diaries, and real-time building energy performance data, has already been conducted on how these developments influenced the everyday lives of the householders themselves (see Foulds *et al.* 2013; Macrorie 2012). Here, we place greater emphasis on how the housing professionals involved – including designers and architects, construction teams, social housing landlords and project managers – sought to deliver the low-carbon developments. The working practices of these professionals span planning, design, construction, technological installation, infrastructure services, tenant management and maintenance and repair. Specifically, the CSH case draws on 12 interviews with housing professionals, while the Passivhaus case draws on participant observation (from construction site visits, training events, visitor days), documentary evidence and interviews with the lead architect and construction auditor.

Analysing low-carbon interventions in housing practice

As Boxes 1 and 2 show, both developments were successfully constructed and accredited to their respective standards. Post-occupancy, however, neither scheme was entirely successful in meeting its anticipated energy or carbon savings. Rather than focus on technical performance targets, we focus instead on broader conceptual issues relating to systems of practice that transcend these specific developments and that have implications for the future delivery of low-carbon housing. In particular, we discuss how the practices of housing professionals were shaped through changes to i) the elements of practice, ii) the relations between practices, and iii) the recruitment of carriers.

Recrafting practices: changing the elements

In practice terms, the aim of both low-carbon housing construction standards (i.e. the interventions) was to enhance the environmental sustainability of social housing infrastructure by inserting new low-carbon technologies and energy-efficient building materials into the everyday working practices of the housing professionals. The professional practitioners researched, procured, installed, and learnt to operate and maintain a wide range of new technical equipment and devices. The housing professionals also required new 'competences' – delivered through training courses or learnt 'on the job'. They were also required to embrace new 'meanings' around housing. Such new understandings included recognition that the respective developments were built to achieve carbon neutrality, rather than solely economic profitability.

While the two building standards provided quite explicit roadmaps for the implementation of low-carbon housing design and construction, it proved difficult for the professionals themselves to modify their ingrained 'ways of doing', as low-carbon housing skills and meanings lagged behind the newly acquired

Box 6.1 Code for Sustainable Homes (CSH) development: Norwich, Norfolk

This development sought to develop 12 social housing dwellings to Code Level 6 (i.e. negative net CO_2 emissions and zero carbon rating (DCLG 2006; Zero Carbon Hub, 2011)). It aimed to demonstrate the viability of low-carbon housing to the mainstream construction industry and local residents, in order to generate support for development of a proposed 'eco-town' in the area.

The development used a traditional build aesthetic aiming to keep residents' existing lifestyles intact. Involvement of householders was limited to the provision of home-user guides and electricity metering display units, intended to promote low-carbon behaviours. In accordance with CSH methodology, a technologically focused approach was used including air-source heat pumps, mechanical ventilation with heat recovery systems (MVHR), and roof-mounted solar photovoltaic panels. Use of these technologies required the design and construction team to utilise new materials, learn innovative skills and revise their ways of thinking about house building.

The development was successfully accredited to Code Level 6 and received national commendation. However, post-occupancy electricity demand levels were highly variable, preventing carbon-neutrality. Changes to the UK political administration led to withdrawal of support for the eco-town proposal, while the economic downturn led to a shift in focus away from low-carbon and toward cheaper approaches (encouraged by the introduction of the New Homes Bonus and National Planning Policy Framework). Consequently, Phase 2 of the development saw a scaling-back of sustainability aspirations. While planning permission has been obtained for 14 further properties, this development will be constructed to Code Level 4 (one level above current statutory requirements), rather than the more ambitious Code Level 6.

technical devices and materials. For example, while the Passivhaus development gained accreditation, the project was delayed due to disagreements between the housing construction practitioners as they attempted to determine the exact requirements of the standard (in particular in relation to airtightness levels). Prior skills and experience – learnt through engagement with 'leaky' conventional builds – could also no longer be relied upon. For instance, while traditional bricklaying requires only the external face to be flush (for aesthetic purposes), Passivhaus builds demand flush surfaces both externally and internally for airtightness purposes. In addition, the new materials themselves struggled to align with the requirements of the Passivhaus standard. Mould growth occurred as a consequence of the housing construction practitioners' lack of familiarity

Box 6.2 Passivhaus standard ('Passivhaus') development, East Anglia

This small-sized (fewer than 25) UK social housing development was designed and constructed to the Passivhaus standard (see The Passive House Institute (PHI) website). This approach assumes that energy savings will be achieved without the need for households to change what they do at home. Specifically a fabric first approach was employed, focusing on airtightness, super insulation, and solar thermal and MVHR. Further, the project sought to demonstrate the energy saving potential of Passivhaus to the UK design, construction and social housing industries.

While the development achieved the Passivhaus standard, challenges were encountered regarding how the technologies were delivered by industry. For instance, mould growth occurred within the properties due to inadequate ventilation and 'correct' use of the technologies by householders proved challenging (for example, confusion ensued over heating/ventilation controls). Furthermore, anticipated energy savings were not achieved; there was no reduction in electricity consumption (compared to previous homes) and gas savings were less than predicted.

These problems were blamed on a lack of experience and relevant skills among professionals working on the project rather than on any problems with the technologies themselves. The professionals rapidly learnt new skills 'on the job' during the build process while reliance on technologies (and belief in the Passivhaus standard) continued after the project. Yet beyond this specific development, few opportunities exist for the professionals to apply their new skills. As such, their newly accrued experience risks going to waste.

with assisted ventilation in super-insulated properties. Similarly, as well as struggling to use new materials and to employ new technical skills, interviewees from the CSH project described how it took time for the project team to switch from an economics-driven logic to a sustainability-driven housing construction rationale.

As these examples show, by focusing intently on the promise of technical solutions, both initiatives gave considerable attention to sourcing, correctly installing, and operating low and zero carbon (LZC) materials and technologies. As a consequence, associated practice meanings and competences were largely overlooked. Our examples clearly demonstrate that in order for new low-carbon housing practice entities to be formed and sustained, prerequisite practice elements need to come together and be combined. A focus on only one element in isolation is insufficient, leading to a failure to realise and sustain the modified practice. As Spurling and McMeekin (this volume) discuss, it follows that policy makers can seek to make these elements the targets of sustainable (low-carbon housing) interventions. Rather than relying on building standards, which predominantly address the material element, attention should be placed on developing design and construction skills through training, and challenging established rationales informing house building. Similarly, innovation in housing may not always stem from new technical solutions, and opportunities for social innovation in housing infrastructure should also be pursued. For instance, co-housing schemes are designed intentionally around the concept of community and incorporate facilities for communal living.

Although not conceptualised as such in the developments themselves, and ultimately proving far from straightforward to enact, it is clear how, in principle, these low-carbon exemplars represent distinct interventions in the practice-as-entities of housing professionals. At the same time, the design and delivery of the two developments sought to keep the dwelling practices of householders largely intact (i.e. 'non-interventions in householders' practice'). It was assumed that householders would reflect on the energy implications of their daily domestic routines only minimally, if at all, and that their everyday practices would proceed as normal around the newly installed technologies. Both developments were designed to look as 'normal' as possible so as not to challenge cultural expectations around domestic living and energy use. As one interviewee from the CSH case described, 'there was a clear steer from [Council] members that they wanted what they would describe as a traditional build', while another interviewee stated, 'we don't want to interfere in people's lives too much'.

Despite aiming for 'non-intervention' in householders' practices, post-occupancy observations reveal that many householders failed to use the LZC technologies as anticipated (for instance, opening and closing windows and doors to control their thermal comfort as opposed to using the MVHR). Similarly, fearful of negative repercussions, some householders avoided using the LZC equipment (for example, turning off the installed thermostatic control panel and bringing in electric fan heaters). The technologies also led some households to change their practices in ways not envisaged. Unable to control the heating system, some restricted their practices to particular rooms or shifted them to communal spaces outside their home. These examples suggest that non-intervention in practice is an unrealistic goal. Introducing new practice elements necessarily has knock-on effects on other elements, which play out in often unexpected ways. Adopting a narrow focus on only technology or behaviour – as associated with the techno-rational paradigm – seems destined, therefore, to run into difficulties by failing to account for effects on other practice elements, or from connected practices. Building on Spurling *et al.* (2013), these observations shift attention from a focus on the material, and open up opportunities for intervention in other practice elements. They also suggest that 're-crafting', or replacing the elements of individual practices, may be unlikely to succeed unless wider systems of practice are taken into account. We develop this observation further in the next section.

Changing how practices interlock: modifying practice relations

In addition to changing the elements of specific practices, both initiatives can be seen as attempts to insert a set of interconnected low-carbon practices into the housing system, creating a wholly new housing system. As Boxes 1 and 2 show, like many others (Brown and Vergragt 2008; Lovell 2004, 2007a, 2007b), both developments were designed to demonstrate how low-carbon housing could be achieved in an effort to make it more mainstream. For the project teams, the chance to be involved in such exemplar developments, and potentially gain competitive advantage, was a major reason for their involvement. The Passivhaus project team, for example, recognised the initiative as a unique opportunity to develop new skills for what they, and others (such as Feist in McCabe (2012) and Boardman (2012)), considered the future housing industry standard. As one interviewee stated, 'give it 10 to 15 years and every building [in the UK] will be Passivhaus or equivalent'.

The effort to construct new systems of practice was also enshrined in the standards themselves, which often contained stringent specifications for exactly how the low-carbon builds could or should be achieved. Several interviewees from the CSH project team described how the build specification for the properties was 'dictated by the Code' and how they felt 'bound by' the requirements of the standard. Similarly in the Passivhaus case: whenever new technologies were sourced, professionals checked their compliance with the Passivhaus standard by running them through the Passive House Planning Package (PHPP) Excel-based building model. The PHPP not only provided professionals with the competence required to ensure that they could meet the Passivhaus standard; it also determined compatibility with the new system of practice. The standards therefore sought to generate connections between housing-related practices and practitioners that would encourage the professionals away from conventional build approaches, and simultaneously construct a new system of low-carbon housing practices.

Despite these intentions, instituting new systems of practice is hardly straightforward and as noted, unsurprisingly, both developments encountered problems. Sourcing appropriate technologies was one key challenge. Without the necessary (low-carbon) competences, the professionals struggled to source, and receive advice on, specified building materials, a challenge exacerbated by the nascent UK low-carbon housing supply chain. Many Passivhaus technologies (for example, airtight loft hatch; triple-glazed windows; solar gain blinds; *brise soleil*) had to be sourced from Germany or Austria, where the standard held a more dominant position in housing practices. Similarly, one interviewee from the CSH case raised concerns about how the standard connected with recent planning policy making practices. He commented:

> With the NPPF [National Planning Policy Framework] being produced last year by this Government … the main thrust of sustainability is economic sustainability … approve [new housing developments], build things [and that'll get the country moving] …

As such, dependencies and interconnections with policy making and market-related practices had distinct implications for the low-carbon housing system.

Nonetheless, despite these initial challenges, as the initiatives proceeded new systems of practice began to emerge. As one interviewee in the Passivhaus case commented:

> [at the start of the project] there were fundamentally two windows that we felt we could use that would give us the performance … Two years on, [following market developments], and I've probably got fifty windows that I can choose between in the UK.

Alongside the development of new low-carbon supply chains, interviewees commented on the accompanying growth in LZC product development, numbers of accredited properties, and practitioner familiarity with the requirements of the respective building standards. In short, in order for the housing professionals to adopt and successfully perform their new low-carbon practices-as-entities, there needed also to be a system of practice in place to support and maintain them.

The housing professionals we spoke to and observed arguably occupied privileged positions – they have the capacity to intervene directly in the practices-as-entities of householders. Such interventions may be achieved through a range of measures that challenge expectations of accepted everyday domestic life through housing design. However, the remit for our two case studies was to keep householders' daily practices very much intact. Low-carbon technologies that would do the work of saving energy and carbon emissions were selected, and it was anticipated that the tenants would only be passively engaged in managing their energy demand. Where explicit instructions were given to the tenants, they revolved around ensuring correct operation of the installed technologies. As such, any connections between the housing professionals' practices, the outcomes of their interventions, and householders' dwelling practices were largely overlooked.

In contrast, our analysis reveals that housing professionals' practices are always embedded within and dependent on broader systems of practice. Any effort at intervention (or even non-intervention) in any single practice is always likely to encounter resistance and to have unintended effects as it ripples across interconnected systems of practice. This reinforces the importance of examining whole systems of practice rather than focusing on single practices in isolation, and emphasises how no single actor is ever in sole charge of a system of practice. The challenge for successful interventions in practice is then one of, first, identifying the mesh of interconnected practices relevant for the intervention in question and, second, homing in on the flows between practices that are of most significance, while also keeping sight of other links and connections that may lead to resistance or unintended consequences. Arguably, this suggests that rather than seeking to change practices-as-entities in and of themselves, the focus of practice-based interventions should instead be more systemic, seeking to modulate the significant relations and 'circuits of (re)production' (Shove *et al.* 2012) between interconnected practices. Rather than making isolated attempts to insert low-carbon materials into housing contractors' house-building practices, interventions in housing practices need to be undertaken with reference to shifting cultural conventions, a developing low-carbon technology supply chain, and supportive infrastructure planning decisions.

Substituting practices: recruiting and keeping carriers

The third core observation from our case studies relates to the importance of not only recruiting carriers to new practices-as-entities, but also holding onto them by allowing their newly adopted practices to be faithfully and regularly performed. As our case studies progressed, low-carbon housing practices-as-entities were nurtured, and supporting systems of practice began to emerge. For our housing professionals, new competences were acquired as they developed experience in working with low-carbon materials. Despite these showcase schemes, however, low-carbon housing practices have failed to gain a stronghold within the UK yet; neither building standard has been mandated and attention has, for now, shifted towards economic development and away from innovations in low-carbon housing infrastructure. Our two initiatives must therefore be understood, essentially, as 'one-off' experimental projects (Lovell 2007b), as both sets of practitioners were prevented from repeating their newly acquired practices.

In the CSH example, the professional practitioners quickly recognised a failure of the techno-rational paradigm to take into account householders' practices. While there was an overall desire among the project team to engage with householders, this option was shut down by wider shifts in the UK political administration, associated changes in the regulatory environment, and the economic downturn. These inter-related shifts served to turn attention away from low-carbon construction and towards more profitable techniques. The results were that householders were 'designed out' of the development, and the original ambitious aims – to achieve the highest Code Level 6 – were abandoned for Phase 2 of the development in favour of building 14 units to Code Level 4, which is only one step above statutory building requirements. This translated into pursuit of a more fabric-first housing design approach, abandoning 'add-on' LZCs, and a continuation of the emphasis on minimal impact on householders' everyday lives. Regardless of what the professional practitioners had learned, shifts in the systems of practice, of which they were but a small component, prevented further reproduction of low-carbon housing practices.

In the Passivhaus example, the story is different but the result is the same. Again the professional practitioners learnt a great deal and gradually began to adopt new housing practices. Unlike the CSH development, belief in the standard never wavered, and the modified housing practices were reinforced by Passivhaus experts as well as the PHPP model, which confirmed that the scheme was on track to achieve accreditation. Despite this, opportunities for the professionals to apply their learning in subsequent developments were constrained. The Housing Association took the decision that each of its local housing providers should have equal opportunities to learn how to build Passivhaus. While certainly a positive move in attempting to spread low-carbon housing practices beyond specialist providers, it also meant that the specific housing professionals involved in this example had to return to work on more conventional 'leaky' dwellings. This action rendered Passivhaus something unusual and difficult. Further still, ongoing limited recognition of Passivhaus in policy circles has meant that adoption of the standard remains voluntary; also, higher build costs make Passivhaus unattractive to developers in the current period of austerity. In short, despite the new practices they acquired and the new systems of practice they helped to construct, the housing professionals involved in this case appear unlikely to be able to replicate these practices any time soon.

While we agree with Spurling *et al.* (2013) that practices-as-entities are a more appropriate target for sustainability interventions than practices-as-performances, our case studies show that practices-as-performances must not be forgotten in the effort to achieve lasting practice change. In order to govern the sustainability of housing design and construction practices, it is crucial not only to intervene in practice-as-entity but also to generate opportunities to reproduce these practices through more or less faithful performances over the long term. Housing industry award schemes or site visits that connect up learning from successful low-carbon developments could provide opportunities to sustain low-carbon housing practices. However, a shift in performance also requires broader systemic change than that practiced as part of isolated initiatives. Our empirical work has demonstrated how opportunities for repeated modified practice performances are clearly linked to broader social practices, policy making practices and practices of the market. As such, changes to government funding schemes and incentive structures to enable experimentation with technical, as well as social, innovations in low-carbon housing are critical. Both these cases have emphasised that while the practice-as-entity may begin to change, a limited scope for professionals to perform their modified practices can threaten their continued longevity.

Conclusion

This chapter has sought to move practice theory beyond its focus with the everyday, and to instead reframe low-carbon housing as an intervention in a whole system of practice that includes the working practices of housing professionals', outcomes of the design and build process, and inter-relations with householders' dwelling practices. In considering the implementation of two exemplar low-carbon (social) housing developments, the practices of housing professionals have been revealed as crucial in leading the transformation to a less energy-intensive residential sector. Empirical observations have also demonstrated how the implementation of two contrasting low-carbon building standards involves similar, yet subtly different, alterations to the composition and performance of professionals' practices. In analysing these cases, we have applied Watson's (2012) conceptualisation of the 'system of practice' to the UK housing domain and built upon Spurling *et al.*'s (2013) three practice intervention framings.

What, how, and the extent to which new meanings and competences are incorporated into housing professionals' practices has critical implications for how future homes are designed, built and lived-in, as well as the overall carbon footprint of the residential sector. More importantly, however, our analysis emphasises that these professionals are situated within broader systems of practice. Therefore, while interventions in practice may be attempted – including replacing practice elements, shifting relations between practices, and altering carrier recruitment/defection levels – they can go awry, or operate in unexpected ways, because no single actor is ever in charge. Rather than shifting attention from household practitioners to would-be governors of practice, we would argue for attention to be paid to how actors and their practices interrelate, feed back and might spin off as part of more extensive systems of practice. Adopting this systemic approach reveals that every action can be conceived as a potential intervention in practice and that attempting non-interventions in practice (such as by using technologies to 'design out' householders) is unrealistic. The challenge for practice theorists therefore is to identify the links, flows and relations within systems of practice that have the most relevance to the particular sustainability intervention in question.

What then are the real-world implications for the governance of low-carbon housing and interventions in practice? The first challenge, working outwards from the specific practice of interest, is to 'map the system' and delimit the network of practitioners. This conceptual mapping approach, which would consider both actors and agents (for instance the low-carbon home itself, construction training materials, or voluntary/mandatory building standards), would seek to enable identification of the links within a practice system that are most important to the target practice or intervention in question, as well as the most closely involved actors or agents. Second, and given that no single actor is in charge, a systems of practice approach seems likely to generate multi-actor and multi-pronged interventions. Such an approach would look beyond the technical and building energy performance prescriptions of CSH or Passivhaus. Instead it would advocate looking across whole systems of practice and joining up distributed sources of evidence from right across the system, including from specific practices that might initially seem only distantly connected. Third, and finally, such an approach demands that attention is paid to how flows within and between practices change over time (strength/direction/speed of links), requiring constant attention to how interventions generate reactions, interactions and resistances throughout practice systems.

While offering an important step forward, we would argue that recently suggested practice-oriented frameworks for policy interventions (such as Spurling *et al.* 2013) could be usefully extended in two ways. First, by acknowledging the importance of providing opportunities to nurture and sustain modified practice-as-entities through more or less faithful performances over the long term. And second, rather than homing in on specific practices, or on certain actors in isolation, we instead advocate that attempts to intervene in practice prioritise understanding of the flows and relations within and between the practices in question. Using practice-oriented policy-making tools demands an appreciation of how their actions and outcomes mesh and fit within systems of practice. Such an appreciation would involve focusing not only on the practice-as-entity, but also on generating and sustaining opportunities for repeated performance of modified practices. In developing this conceptual approach further, research is needed that goes beyond the UK low-carbon housing domain to explore alternative international and cultural contexts, as well as contrasting policies that target other forms of consumption (such as water, food, waste).

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Appendix P

Macrorie, R., Daly, M. and Spurling, N. (2014b). Can 'systems of practice' help to analyse wide-scale socio-technical change?

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TN 5 – Can 'systems of practice' help to analyse wide-scale socio-technical change?

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This Thinking Note explores the emerging concept of 'systems of practice' (SoP) as an approach to help understand wide-scale socio-technical change. Specifically, the Note: (i) discusses how the concept of SoP has merit for analysing processes of change (and stability); (ii) considers the methodological challenges associated with empirical research framed by the concept; and (iii) explores the applied implications of SoP for policy interventions and attempts to encourage broad, lasting socio-technical change for sustainability.

As noted by Watson (2012), the concept of SoP was developed partly in response to critiques levied at theories of social practice (SPT). These included firstly, SPT's empirical focus on single practices being performed in situated locations, whether at home, in the office boardroom, or on a construction site. The adequacy of SPTs to account for, and enable interrogation of, broad socio-technical patterns has therefore been questioned (e.g. Brand, 2010). Secondly, claims have been made that SPT conceptualisations focus on stable socio-material phenomena and overlook change processes (e.g. Geels, 2011). As we discuss, the SoP concept responds to these two criticisms by shifting empirical focus away from isolated practices and giving precedence to practice dynamics.

Additional concerns relating to application of SPT purport that practices are merely abstract theoretical constructs that have limited relevance in the real world, or alternatively hold that, when it comes to interventions in social life, practices offer little that is new. In response, scholars have begun to consider how SPT can help to analyse and attempt to steer societal transformations towards sustainability (e.g. Watson, 2012; Shove *et al.,* 2012; Shove and Walker, 2010; Spaargaren, 2011; Spurling *et al*., 2013). The concept of SoP has consequently been advocated as a way to analyse interconnections and overlaps between practices, and a means to better understand how governing practices are implicated in the reproduction, reinforcement and transformation of social life.

Whilst SoP have much interesting potential, the concept requires refinement. Further, research on SoP currently remains in the realms of theory rather than empirical analysis. This Thinking Note seeks to provide useful responses to these two challenges.

What explanations of change do SoP offer?

Convincing arguments have been made for the adoption of a SoP approach as a means to research socio-technical change and to help better understand how, and the extent to which, transformations to sustainability can be governed. Whilst some research has suggested that there is potential to understand systemic change by examining points of intersection between practice theory and the multi-level perspective (MLP) (Hargreaves *et al*., 2013), we argue that SoP alone competently accounts for and can explain socio-technical systemic change, and that combining these different theories 'muddies the waters', not least because SoP advocates a flat, as opposed to hierarchical, ontology. As such, we adopt Watson's definition of a system of practice (below). This definition contends that SoP hold promise for identifying points of intervention that might create positive momentum in recruitment to desirable, or defection from undesirable, practices respectively (Shove *et al*., 2012, p.63; Watson, 2012, p.493);

'Practices (and therefore what people do) are partly constituted by the socio-technical systems of which they are a part; and those socio-technical systems are constituted and sustained by the continued performance of the practices which comprise them…Changes in socio-technical systems only happen if the practices which embed those systems in the routines and rhythms of life change; and if those practices change, then so will the socio-technical system… [As such] any socio-technical transition has to be a transition in practices' (Watson, 2012, p.488-489).

Methodological considerations associated with SoP

In order to learn about SoP, their dynamics, and their implications for interventions for sustainability, certain kinds 'of data and styles of enquiry are required' (Shove *et al*., 2012). Whilst not attempting to be exhaustive, here we make suggestions as to how SPT research can move beyond a reliance on qualitative, small-scale studies that focus on the ‘lifecycles’ of specific practices (Pullinger *et al.,* 2013, p.8-9) to explore interactions between multiple practices and elements. We draw on examples to demonstrate how such research is already underway. Studying practice links and overlaps, can enable identification of different underlying SoP that can then be explored in more detail (e.g. via comparative cases). Studying the extent, strength, direction and density of connections between practices highlights opportunities to steer practices and SoP in more sustainable directions. Methodological approaches might therefore include studying:

(i) *Practice bundles/complexes and their inter-connections:* Research should seek to understand the systemic relations between practices, and bundles of practices. Research approaches might identify a target practice that can act as an entry-point to explore connections, or might focus on a particular locus of practice intersection. For instance, Hargreaves *et al*. (2013) studied a local food co-operative and analysed the interrelations occurring between cooking, shopping and food-growing practices.

(ii) *Changing dynamics of practice:* Attention to processes occurring within SoP can enable exploration of the emergent properties of complex practice systems, and the role of positive feedback effects in creating path dependency (Walker, 2012). Whilst this is a complex area, life-course graphs, time-use data and oral histories have been employed to study how practices-as-entities grow/decline in popularity over time. Such approaches might be expanded from single practices, to make SoP dynamics the analytic focus.

(iii) *Variety in practice composition and performance*: This aspect of SoP could be studied through in-depth case-study research. For instance, part of Macrorie’s PhD research looks at the diverse ways in which tenants of a low-carbon housing development maintain their domestic heat comfort having moved from traditionally ‘thermally leaky’ houses. Widening the focus from occupants’ experiences, the research also considers how construction practices and housing policy-making practices (that form part of the SoP in question) change over time. Survey-based research (e.g. Pullinger *et al.,* 2013) and analysis of larger data sets (e.g. Anderson, 2011), offer alternative ways to reveal variety in practice at varying geographic scales.

(iv) *Geographically dispersed practices:* International comparisons of the timings and dynamics of practice performance can provide insight on the circuits of reproduction at play in SoP. A number of studies have explored this area. For instance, research has looked at the trajectories of reading practices across multiple countries (Southerton *et al.,* 2012), and how bathing practices and water consumption varied between Japan, India and the Netherlands (Kuijer, 2014).

(v) *Detection of trends:* If practice research aims to better understand systemic socio-technical change capable of influencing many, or all, domains of daily life, then analysis should include attempts to detect signs of large-scale changes or movements, and to identify distinctly shifting practices (e.g. increased dependency on energy-related services). This calls for cross-sectoral analysis (Shove *et al.,* 2012, p.163).

What do SoP mean for attempts to encourage wide-scale and lasting socio-technical change?

There is much to say on this topic. Given limited space we focus on three points, which in our opinion offer promising insights for those concerned with promoting wide-scale and lasting socio-technical change.

(a) SoP highlights how resource intensive patterns of practice are produced and held in place by multiple, and sometimes seemingly unrelated, infrastructures, institutions and policy domains. For example, understanding why the energy demands of commercial office work have increased in recent years, might be concerned less with the practices of influential individuals, and more about understanding the broader dynamics of SoP in which practitioners are caught (e.g. Falconbridge and Connaughton[3]). Such analysis can demonstrate how technologies, infrastructures and organisations (e.g. facilities managers, manufacturers, developers, standards bodies) are implicated in more energy-intensive working trends.

(b) SoP draws attention to complexity, and highlights that practices are related to one another in ways that go beyond common-sense understandings. These connections help to identify previously obscured ways of intervening in practice, and also alert us to the fact that interventions in everyday life will frequently have unanticipated consequences. Given this, there is scope to attend to ways in which interventions generate reactions, interactions and resistances across the practice system. This is methodologically challenging, but the approaches outlined above (particularly i and ii) offer ways forward.

(c) SoP have histories. That is to say that the relationships between practices that exist in the world today were different in the past, and will change again in the future. Some aspects of these pasts have

[3] http://www.demand.ac.uk/research-themes/theme-3-managing-infrastructures-of-supply-and-demand/3-2-negotiating-needs-and-expectations-in-commercial-buildings/

obdurate qualities (Hommels, 2005). Building standards and regulations are one example of this phenomenon (though other examples include infrastructures that are the product of redundant standards or policy legislation that has association to a different time and place). Because of these obdurate qualities interventions can never be considered as 'one-offs', but rather they are part of a dynamic world that is always, in part, shaped by previous initiatives and knowledge. A recent example can be found in the Code for Sustainable Homes (CSH) (DCLG, 2010). There was no discussion about room size (which has energy implications) when the CSH was developed, as this had been set out in building regulations already in existence. We can see then that, what is, and is not, viewed as a plausible site of practice intervention in the present is, in part, framed by previous modes of understanding and 'ways of doing'.

Final thoughts: Does the concept of SoP offer a way forward?

The concept of SoP offers a potential way forward for the future application of SPT in terms of; scaling-up individual practices, analysing practice relations, being open to the unintended consequences of interventions in practice, developing ways to understand wide-scale socio-technical change, and considerations of how practices in one time and place have implications for other times and places. This conceptualisation has implications for methodology, potential sites of intervention, and for governance approaches (i.e. it calls for a more reflexive approach when intervening in practice). Analysing the complex relationships and linkages between practices, their elements, and the ways in which practices bundle together, that shape and can be reinforced by SoP, is undoubtedly a difficult task. However, theorists argue that it is not only possible (Watson, 2012), and able to provide a means of countering critiques of SPT, but also that SoP illuminate new opportunities for analysing and potentially intervening in the *status quo* to encourage environmental and social sustainability.

This Thinking Note has developed the concept of SoP, however many questions and concerns that cannot be answered here remain. For instance, in what ways can SoP be usefully defined (size/ complexity/ interconnections/ duration/ number of carriers)? How are the boundaries of a SoP drawn, at what scale, what is included/omitted and who draws these boundaries? Is it possible for analysis to tackle multiple systems of practice, and if so, how are SoP inter-related within the 'plenum' of practice (Schatzki, 2011)? Are there particular conceptual tools or methods that might foreground SoP or parts of SoP (for instance, complexes/bundles or 'ecologies of practice' (Shove *et al.,* 2012))? Can we ever have a full understanding of the practice system, and does this matter? How can change in a SoP be understood? Finally, can analysis of flows, and 'sinks' or 'stoppages', linking practices and their systems be undertaken and how useful might knowledge of this 'connecting medium' prove?

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Glossary

Adapt	Adapt Commercial Limited
ANT	Actor Network Theory
ASHP	Air Source Heat Pump
BDC	Broadland District Council
BREEAM	Building Research Establishment Environmental Assessment Methodology
CSH	Code for Sustainable Homes
DCLG	Department for Communities and Local Government
DJH	Dove Jeffery Homes
DR	Energy Demand Response
EPC	Energy Performance Certificates
FiTs	Feed-in-Tariffs
GEO	Green Energy Options
GNDP	Greater Norwich Development Partnership
HCA	Homes and Communities Agency
IHD	In-Home-Display unit
$MtCO_{2e}$	Million metric tons of carbon dioxide equivalent
MVHR	Mechanical Ventilation and Heat Recovery system
Passivhaus	A voluntary standard for energy-efficiency in buildings. Passivhaus buildings employ superinsulation to reduce heat transfer through the walls, roof and floor compared to conventional buildings. They also have high levels of airtightness and use passive natural ventilation.
POE	Post occupancy evaluation
PV	Solar photo-voltaic system
RHI	Renewable Heat Incentive
RP	Registered Provider: Private, non-profit making organisations that provide low-cost social housing for people in need of a home.
SPT	Social Practice Theory
TAM	Technology Acceptance Model

Glossary

TC	Trinity Close low-carbon social housing initiative, Rackheath, Norfolk
TPB	Theory of Planned Behaviour
TCSG	Trinity Close Steering Group: Term used to describe the primary stakeholders involved in the organization and delivery of TC, including DCLG, BDC, WHA, DJH and Adapt.
TWh	Major energy production or consumption is often expressed as terawatt-hours (TWh) for a given period that is often a calendar year or financial year.
VBN	Value-Belief-Norm theory
WHA	Wherry Housing Authority (part of Circle Housing)
ZCH	Zero Carbon Hub

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