An ethnography of installation: exploring the role of heating engineers in shaping the energy consumed through domestic central heating systems

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Thesis submitted for the degree of Doctor of Philosophy in Energy and Human Dimensions

Declaration

I, Faye Marie Wade, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Faye Marie Wade

Acknowledgements

Firstly, this research simply would not have been possible without the heating engineers and industry representatives who gave me their time, knowledge, and good humour. Learning from you has been a pleasure, thank you.

For their fantastic supervision, guidance and support I am deeply grateful to Michelle Shipworth and Russell Hitchings. Michelle, thank you for recognising in me the ability to take forward this idea and for helping to foster the countless skills and experiences that I have collected along the way. You were right; the product of this PhD is so much more than what is contained in this document. Russell, thank you so much for taking on this project (and its lost owner!) despite it already being well under way. You brought such clarity to this otherwise murky process; sharing and developing nascent ideas with you has been a pleasure. I'd also like to extend my thanks to David Shipworth and Cliff Elwell, who were both instrumental in the early stages of this project. I'm grateful to the EPSRC for funding this research, along with the LoLo Doctoral Training Centre and UCL Energy Institute, which have provided excellent environments for nurturing my research skills.

To all of the fantastic friends and colleagues who have listened to me, picked me up when I was down, offered encouragement and read draft chapters, thank you all. In particular, Julia, your support and understanding has been phenomenal, thank you. Thanks also to Lucy, Kim, Jenny, Ed, Sam, Dave and Carrie; it has been great fun sharing this process with you all. Thank you to my friends from beyond UCL, who have been incredible, especially: Annie, Katie, Seb, Amy, Alex, Simon, Helen, and Simone.

Mum, I would not have done this were it not for your ambition, steadfast support and unfaltering belief in me, thank you. To my Step Dad, Chris, thank you for supporting me without hesitation, you provided stability and reassurance when I needed it most. Finally, to my Uncle Tom, who set the idea of me doing a PhD in motion and continues to be a constant source of encouragement and inspiration, thank you.

Abstract

This thesis provides an exploratory account of the ways in which the installation of domestic central heating systems can shape the energy they consume. Space heating is the single most significant contributor to domestic energy consumption in the UK. Despite evidence to suggest that the installer and installation process are influential in shaping this, these have been subject to very little enquiry to date. Instead, attempts to reduce the energy consumed through central heating systems have sought to improve the technical efficiency of the system components, or assumed an economic rationale to encourage end users to operate their heating in more efficient ways. Thus far, these approaches have not yielded the energy reductions necessary to meet the UK government's 2050 targets to reduce carbon emissions by 80%, on 1990 levels.

Given the extremely limited research into central heating installation, or with installers, a highly qualitative, flexible and culturally sensitive method is required to explore these. Consequently, this investigation has adopted an ethnographic approach, including interviewing heating engineers, shadowing them in domestic properties, observing manufacturer training sessions, and spending time in plumbers' merchants, to reveal several distinct aspects of installation that can shape the energy subsequently consumed through central heating systems. These include heating engineers' shared identities, learning and membership within a community of practice; their relationships with plumbers' merchants and sales representatives; the materials and technologies involved in the installation process; and engineers' experiences and assumptions of end users.

Evidently, there are multiple ways in which the installer and installation process can have a significant role in shaping the energy consumed through domestic central heating systems. If we are to achieve energy savings in the built environment, it is vital that academics and policy makers more fully consider these intermediary actors and processes.

List of acronyms

ACS	Nationally Accredited Certification Scheme for Individual Gas Fitting Operatives
ANT	Actor-Network Theory
BSi	The British Standards Institution
CCC	Committee on Climate Change
CIBSE	Chartered Institute of Building Services Engineers
CIPHE	Chartered Institute of Plumbing and Heating Engineers
DCLG	Department for Communities and Local Government
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
ECGA	Electronic Combustion Gas Analyser
E&U Skills	Energy and Utilities Skills
EST	Energy Saving Trust
EWI	External Wall Insulation
GSR	Gas Safe Register
HVAC	Heating, Ventilation and Air Conditioning
HHIC	Heating and Hotwater Industry Council
HSE	Health and Safety Executive
IDHEE	Institute of Domestic Heating & Environmental Engineers
IPCC	Intergovernmental Panel on Climate Change
L, N & I List	Legislative, Normative & Informative Document List
LPG	Liquefied Petroleum Gas
MCS	Microgeneration Certification Scheme
NICEIC	National Inspection Council for Electrical Installation Contracting
RSL	Registered Social Landlord
SAP	Standard Assessment Procedure
SEDBUK	Seasonal Efficiency of Domestic Boilers in the UK
SME	Small and Medium-sized Enterprises
STS	Science and Technology Studies
TRV	Thermostatic Radiator Valve

Glossary

Organisations

Gas Safe Register	The body responsible for registration, inspection and complaint investigations concerning those working on gas at its point of utilisation.
Health & Safety Executive	The body responsible for the regulation and enforcement of health and safety in the workplace. The HSE write the Gas Safety (Installation and Use) Regulations 1998, and enforce these along with Gas Safe Register.
Heating and Hotwater Industry Council	The trade association that represents the domestic heating market in the UK. Committed to improving the quality of customer service given by the heating industry, this group oversee the Commissioning Checklist.
Energy & Utility Skills	As the Sector Skills Council (SCC) for the gas industry, E&U Skills are responsible for establishing and maintaining competence standards, and providing routes to registration with Gas Safe Register.
British Standards Institute	The organisation responsible for producing standards to which the installation of central heating systems should adhere.
Department for Communities and Local Government	This Government Department oversee the writing of the Building Regulations, which include a series of requirements for the installation of domestic central heating systems.
Chartered Institute of Building Services Engineers	A professional membership organisation that provides courses and guidance supporting the design and installation of building services including domestic central heating systems.
Energy Saving Trust	An independent organisation that provides energy saving advice to householders, and guidance on the energy efficient installation of central heating systems for installers.

Central heating system components

Boiler	The heat-generating component of a central heating system. The gas boilers that provide the focus of this thesis use the combustion of gas in air to heat water. This caters for both heating and hot water in the home.
Radiator	A heat emitting device that has a series of channels through which hot water passes. This heats the surrounding space via convection.
Hot water cylinder	A tank in which hot water is stored. This is used with a system boiler, but is not required with a combination boiler, which provides instantaneous hot water.
Programmer	A control device that can be used to set time periods for when heating and hot water is desired.
Room thermostat	A room temperature control that initiates the boiler when the air temperature drops below a set point. Programmable room thermostats are also available; these combine time and temperature so that different temperatures can be set for different periods of the day.
Thermostatic Radiator Valve (TRV)	A valve that is attached to individual radiators. These limit the temperature of an individual room by managing the flow of hot water to the radiator.
Cylinder thermostat	A thermostat that is attached to the side of a hot water cylinder. This controls the temperature of stored hot water.

The definitions used in this table are intended to provide a basic introduction to different organisations and to the function of different components of central heating systems (these definitions have been adapted from literature targeted at heating engineers, particularly the *Domestic Heating Design Guide* (CIBSE 2013)). Further detail on these components and the design and operation of central heating systems is provided in Appendices I, II and III.

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1 Introduction

1.1 The significance of central heating

The Climate Change Act, passed in 2008, established a framework to reduce UK greenhouse gas emissions in line with the Kyoto Protocol. Under the Act, the UK Government has set a legally binding target to reduce greenhouse gas emissions to 80% of 1990 levels, by 2050 (Government 2008). Meeting these ambitious aims requires a concerted effort to reduce emissions across all sectors, including power generation, industry, transport, agriculture and the built environment (EC 2011). Of these, the built environment is particularly important. Within the UK there are more than 27 million dwellings (ONS 2014), and in 2013, almost 30% of total UK energy consumption was from the domestic sector (DECC 2014a). Consequently, it is "impossible to meet the 2050 objective without changing emissions from homes" (Palmer & Cooper 2013: 6).

Space heating is the largest single contributor to the energy consumed in domestic properties, accounting for approximately 60% of household energy consumption in 2011 (see Figure 1.1). Furthermore, Figure 1.1 illustrates that the energy consumed through space heating has been increasing since 1970, despite some significant peaks and troughs in consumption, attributed to particularly cold or mild winters. This persistence highlights that, if we are to "make serious inroads in cutting CO_2 from housing, reducing heating energy has to be part of any solution" (Palmer & Cooper 2013: 35).

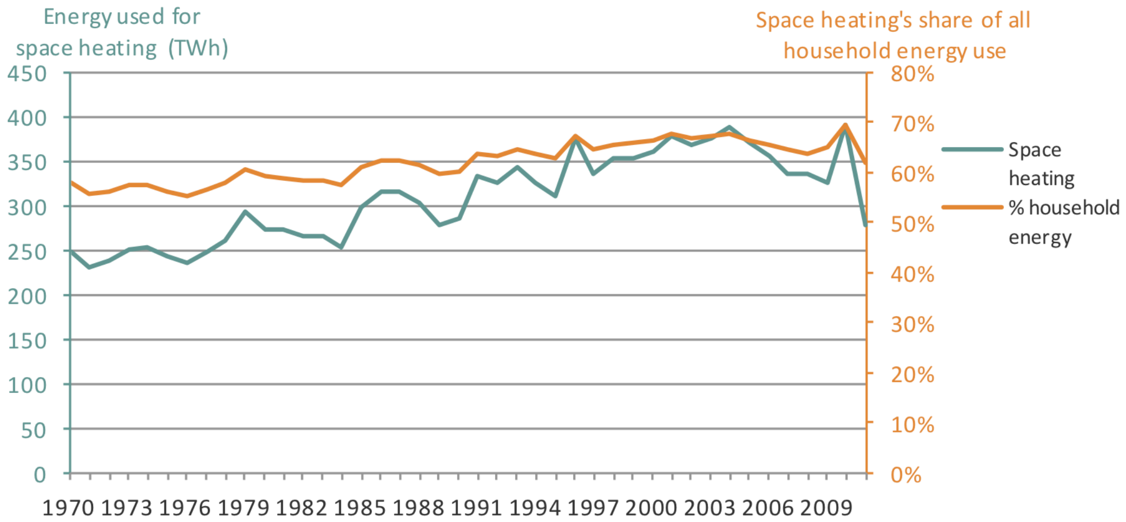


Figure 1.1 Household energy use for space heating (TWh), source: (Palmer & Cooper 2013: 35).

Thus, in order to reduce emissions from the domestic sector, it is essential that we understand more about the way that homes are heated. The 2011 census showed that 98% of all households in England and Wales had central heating, the vast majority of which were gas systems (ONS 2011a). It is this prevalence of central heating that makes this technology a key focus if we are to reduce greenhouse gas emissions from the domestic sector. However, despite central heating being recognised for its important contribution to climate targets, these systems are not always a matter of prominence for those using them. In the following section I look at the significance of central heating beyond this policy arena, before proceeding to outline existing attempts to bring this technology to the fore.

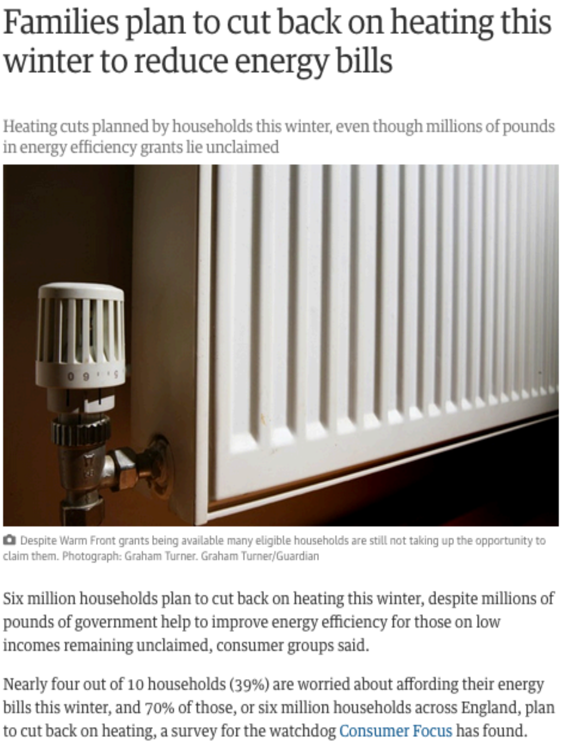
1.2 Central heating is not always central

Central heating technology is embedded in almost every UK dwelling; however, we have not always heated our homes in the way that we do today. In 1945, at a time when domestic central heating was just beginning to become accessible for householders, George Orwell predicted that the comfort and convenience delivered by these systems would change domestic life. He lamented the loss of the coal fire, noting the detrimental impact on "the family as an institution" without having an open fire to gather round at the end of the day:

> "To one side of the fireplace sits Dad, reading the evening paper. To the other side sits Mum, doing her knitting. On the hearthrug sit the children, playing snakes and ladders. Up against the fender, roasting himself, lies the dog. It is a comely pattern, a good background to one's memories, and the survival of the family as an institution may be more dependent on it than we realise."
>
> (Orwell 1945: 6)

In contrast, with central heating systems Palmer and Cooper note: "gone is huddling around the fire in a household's one heated room: in its place stands the potential for all day heating throughout the home" (2013: 46). Whilst they lack the capacity to facilitate social interaction or offer the aesthetic pleasures of the coal fire, central heating systems might be seen as "purely functional and utilitarian", with changes rarely being made whilst they are operating satisfactorily (Mitchell 2008: 1). Thus, despite often occupying every room in the property, once installed, it might be assumed that these energy consuming systems lay dormant in the minds of those for whom they provide heat and comfort. However, amidst the progressing urgency of addressing domestic greenhouse gas emissions there has been an increasing amount of scrutiny directed towards the way in which central heating systems are used. Indeed, although this technology may be deeply embedded in the background of peoples' everyday lives, at times, it becomes an issue of paramount importance.

For instance, in the national press, central heating has featured in articles on the cost of home heating (see Figure 1.2a), and has been a particularly hot topic when energy suppliers have increased or decreased their costs. There have been articles questioning when we should turn our heating on (Kelly 2013), and at what temperatures room thermostats should be set (as illustrated in Figure 1.2b). The potential of new smart central heating controls, which can learn occupants' routines and be controlled away from the home, has also featured (for example in Figure 1.2d). Furthermore, central heating is relevant to discussions around fuel poverty, where occupants struggle to pay for the costs of fuel needed to heat their homes to achieve a sufficient level of warmth (Hills 2012). Meanwhile, heating engineers have been highlighted as intermediaries that could support health professionals in identifying vulnerable people living in dangerously cold homes (see Figure 1.2c). Thus, this supposedly dormant system does not go completely unnoticed.



Families plan to cut back on heating this winter to reduce energy bills

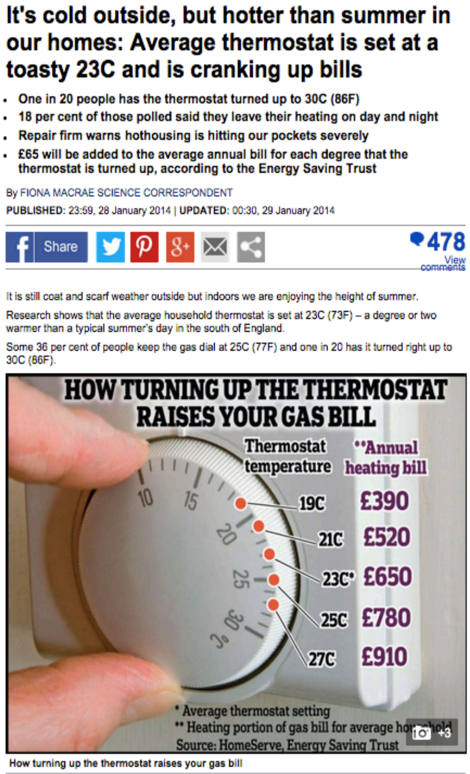
Heating cuts planned by households this winter, even though millions of pounds in energy efficiency grants lie unclaimed

Despite Warm Front grants being available many eligible households are still not taking up the opportunity to claim them. Photograph: Graham Turner. Graham Turner/Guardian

Six million households plan to cut back on heating this winter, despite millions of pounds of government help to improve energy efficiency for those on low incomes remaining unclaimed, consumer groups said.

Nearly four out of 10 households (39%) are worried about affording their energy bills this winter, and 70% of those, or six million households across England, plan to cut back on heating, a survey for the watchdog Consumer Focus has found.

a) The Guardian, September



It's cold outside, but hotter than summer in our homes: Average thermostat is set at a toasty 23C and is cranking up bills

- One in 20 people has the thermostat turned up to 30C (86F)
- 18 per cent of those polled said they leave their heating on day and night
- Repair firm warns hothousing is hitting our pockets severely
- £65 will be added to the average annual bill for each degree that the thermostat is turned up, according to the Energy Saving Trust

By FIONA MACRAE SCIENCE CORRESPONDENT

PUBLISHED: 23:59, 28 January 2014 | UPDATED: 00:30, 29 January 2014

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It is still coat and scarf weather outside but indoors we are enjoying the height of summer.

Research shows that the average household thermostat is set at 23C (73F) – a degree or two warmer than a typical summer's day in the south of England.

Some 36 per cent of people keep the gas dial at 25C (77F) and one in 20 has it turned right up to 30C (86F).

How turning up the thermostat raises your gas bill

b) The Daily Mail, January

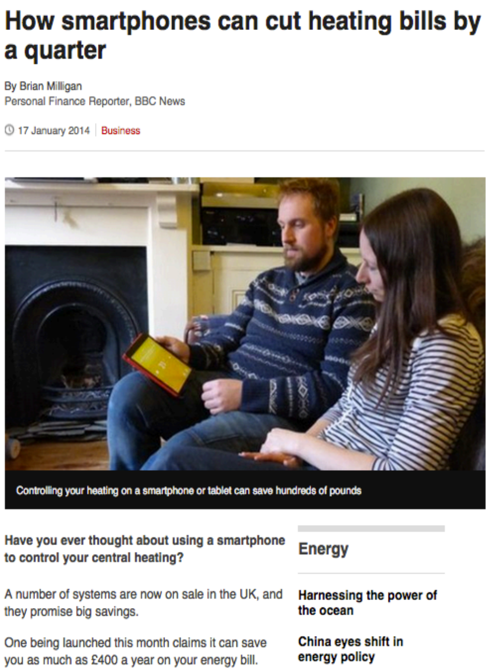
Plumbers and heating engineers 'should sound alarm on freezing homes'

'Hidden army' of non-health workers, including meter installers, could cut winter deaths toll by alerting authorities to dangerously cold homes, say NHS guidelines

Fuel poverty and hard-to-heat homes increase the health risks over winter for many vulnerable people, including the elderly and babies. Photograph: Matt Cardy/Getty Images

Plumbers, heating engineers and meter installers should alert the authorities when they visit a "dangerously cold home" in order to help reduce the toll of winter deaths, new NHS guidelines say.

c) The Guardian, March 2015



How smartphones can cut heating bills by a quarter

By Brian Milligan
Personal Finance Reporter, BBC News

17 January 2014 | Business

Controlling your heating on a smartphone or tablet can save hundreds of pounds

Have you ever thought about using a smartphone to control your central heating?

A number of systems are now on sale in the UK, and they promise big savings.

One being launched this month claims it can save you as much as £400 a year on your energy bill.

Energy

Harnessing the power of the ocean

China eyes shift in energy policy

d) The BBC, January 2014

Figure 1.2 A hot topic in the mainstream media, sources (a: Insley 2012; b: Macrae 2014; c: Siddique 2015; d: Milligan 2014).

As I pursued my enquiry into central heating systems, I found that a wide audience could relate to my research on a very personal level. Snippets of my accumulating data would often be met with anecdotes about people not understanding their own heating controls, or their recent confused encounters with heating engineers. Given the dominance of central heating in the UK, and its contribution to energy consumption, it is perhaps unsurprising that this is becoming an increasingly prevalent topic. Indeed, there have been attempts to investigate and reduce the energy consumed through central heating; however, to date, these have been hindered by a narrow focus. In particular, the process by which this technology is installed has yet to be investigated, despite evidence that this might play a role in shaping energy consumption. It is the limitations of existing academic and policy approaches to understanding and attempting to tackle the energy consumed through domestic central heating systems that provide the premise for this investigation. I detail these existing approaches in the following section, before highlighting the potential significance of central heating installation and the research gap this investigation seeks to fill.

1.3 Bringing central heating to life

As Oreszczyn and Lowe note, current strategies to investigate and address energy in buildings adopt a narrow view:

> "For many years, research into energy performance in buildings has been hobbled by attempts to make it conform to an experimental mode of investigation inherited from the physical sciences. This mode of investigation treats the subject matter as essentially static and attempts, as far as possible, to exclude the influence of people on the results of investigations."
>
> (2010: 115)

Indeed, this exclusion of people has resulted in the privileged treatment of technological solutions within research and policy strategies surrounding central heating systems. The increasing energy consumed through space heating has been attributed to the heating of whole homes rather than individual rooms, along with the growing proportion of centrally heated homes and the addition of heating to conservatories (Palmer & Cooper 2013). It has also been suggested that average internal temperature has increased by 4°C between 1970 and 2011 and that increasing demand temperatures (i.e. higher thermostat set points) have contributed to increasing energy consumption (ibid). Technical strategies to tackle this have resulted in the stipulation of more efficient boilers and advanced heating controls in documents like the Building Regulations. These requirements are discussed in more detail in Chapter 3.

However, energy and buildings cannot be understood from a single academic or professional perspective (Oreszczyn & Lowe 2010: pp.115-6). The Fifth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) identified this complexity, noting that "in addition to technologies and architecture, behaviour, lifestyle, and culture have a major effect on buildings' energy use" (Lucon et al. 2014: 675). Indeed, the energy consumed through domestic central heating is reliant not only on the system and the building, but also the people that interact with these. However, where people have been considered by academics and policy makers, the focus has primarily remained on the end user. Policy makers have targeted end users via information campaigns, based on the understanding that, with the provision of information economically rational end users will act to reduce their thermostat settings in a bid to save money and energy (Burr 2008). Academics have similarly focused on end users, resulting in studies that have identified varied internal temperature settings, different thermal comfort practices, mixed understandings of heat and the restricted usability of control devices. This existing landscape provides valuable, but limited, understandings of the energy consumed through space heating, and is discussed in more depth in Chapter 2. However, whilst the energy consumed through space heating in dwellings remains persistently high, as illustrated in Figure 1.1, it is apparent that these policy strategies and academic insights are not delivering the energy savings or information needed to meet the Government's ambitious climate targets.

To date, neither academic nor policy domains have made any concerted attempt to extend their gaze beyond the central heating technology or the end user. This current focus provides a blinkered understanding of space heating practices, failing to account for the wider cultural context in which these practices take place. There has been little consideration of the way in which central heating systems come to be in the home or the social actors that might shape their use. In particular, the installation of central heating systems has never before provided the focus of any academic research, nor has it been a priority concern for policy makers. This is despite indications that the installer, and the installation process, could be influential in shaping the use of central heating systems. Thus, it could be fruitful to reposition our focus in this direction to more fully understand, and subsequently address, the energy consumed through space heating. This alternative perspective is discussed in the following section, where I also outline the aims of this investigation.

1.4 The role of the installer

In 2000, a piece of research that sought to identify the network of actors implicated in the specification of domestic heating systems in the UK found that:

> "For [the] replacement of heating systems in existing housing, it is clear that decisions about the appropriate system type and make or model are generally left to the installer…[who is]…usually able to suggest more or less what he sees fit."
>
> (Banks 2000a: 8.10)

Although limited to a small number of installers, this piece of research constitutes the only existing effort to investigate central heating installation in any capacity. Despite this suggestion that intermediary heating installers are highly influential in shaping the central heating technologies installed in homes, these insights have not yet been subject to further scrutiny. Furthermore, beyond making decisions about the technologies, heating installers have also been recognised for their potential role in shaping the use of central heating systems. In particular, Rathouse and Young conducted a series of focus groups with end users, during which their participants noted:

> "Asking installers, plumbers and engineers to show them how to use their controls and sometimes to set their programmers"
>
> (2004: 24)

The authors note that experiences with installers varied amongst their participants, but do not elaborate further. Moreover, despite identifying a central role for heating engineers in shaping space heating practices, this has not been investigated in detail. These individuals are tasked with designing and installing central heating systems in homes. In their intermediary role, which is elaborated further in Chapters 2 and 3, they enter properties on a daily basis, potentially influencing both the technology installed and the energy consuming practices of end users. As such, this thesis argues that we need to more fully investigate the role of installers, and the installation process, if we are to understand and hope to influence the energy consumed through space heating. It is this argument that underpins the aim of this thesis, which I now detail.

Addressing the gap

The aim of this thesis is to explore the role of central heating installers, and installation practices in shaping the energy consumed through domestic central heating systems. To this end, an ethnographic approach is used to uncover the different factors that shape the installation and use of central heating systems. This qualitative, interpretivist approach has traditionally been underused within energy and buildings research, but is applied here because an exploratory approach is essential for revealing insights into this topic which we currently know so little about. Methodologically, this research demonstrates the strength of applying these approaches to understand the energy shaping role of building professionals. As such, it provides key lessons in the conduct and contribution of these research methods for understanding the energy implications of building professionals' work, which has not previously been studied in this way.

In doing so, this project also seeks to foster a dialogue between traditional technical and policy approaches, and more social and cultural strategies. This investigation applies the key tenets of the ethnographic approach. These are discussed in more detail in Chapter 4, but importantly include remaining open to different insights as they emerge and the application of different theories as appropriate to illuminate the issues under enquiry. Whilst this approach is quite distinct to the strategies more traditionally applied to energy and buildings research, this thesis remains firmly positioned within this domain. As such, this written account strives to remain accessible for more technical and policy audiences, intending to demonstrate the strength of these approaches to those less familiar.

In addressing these aims, this thesis provides a novel, and much needed, contribution to our understanding of the energy consumed in domestic properties. The way in which I present this original contribution is outlined in the following section.

1.5 The shape of things to come

The remainder of this thesis is structured as follows: ***Chapter 2*** uses evidence from academia and policy to investigate the importance of studying the installation of domestic central heating systems. The chapter sets out by problematising the technological solutions and information campaigns currently preferred by policy makers, and suggests that an alternative approach, accounting for the social and cultural context of installation would be more fruitful. The discussion continues by elaborating on what we currently know about the use of central heating systems, and how the installation process, and installer might shape this. This addresses occupants' varied thermal comfort practices, their mixed understandings of central heating and the usability of these systems. Having identified the importance of studying central heating installation, I then look to literature on intermediaries, in particular identifying the small amount of research that has engaged with heating engineers in any capacity. This chapter closes by identifying the research question that will be addressed through the remainder of this thesis.

In ***Chapter 3*** I reveal the complexity of central heating installation by discussing central heating systems, those tasked with installing them and the installation process. The chapter commences by detailing the components of a central heating system, and some of the key design and installation requirements with regard to energy efficiency are identified. These include the importance of sizing systems and the installation of system controls. The second part of this chapter turns to the installer of the system, in particular, detailing the structure of the heating industry and the training and registration expectations placed on installers. The final part of this chapter outlines the different stages of a central heating installation. Throughout, I draw on industry guidance and current regulations, identifying points where these may be open to interpretation and further problematising existing strategies to influence the energy consumed through space heating. The information in this chapter also provides a vital backdrop for interpreting the empirical material that follows.

Having provided a contextual backdrop for the research, ***Chapter 4*** details a qualitative, exploratory strategy as the most appropriate to answer the research question previously identified. This strategy is also justified against calls for more qualitative approaches within the field of energy and buildings research. This reflexive discussion outlines the research approach, including the use of scoping studies, the identification of research participants and the use of shadowing, observation and interviews for data collection, acknowledging my own role in the research process throughout. I proceed by discussing the practical implications of conducting research on this group and how these have been addressed, including; ethics, risk assessment and data collection procedures. The chapter will conclude by discussing the strategies applied in managing and analysing the data, including the role that theory has played in this process. The empirical chapters that follow are then introduced, these each use a different theoretical lens to explore distinct aspects of central heating installation that emerged as important as the project progressed.

The empirical section of this thesis commences in ***Chapter 5*** by exploring the extent to which heating engineers can be understood as belonging to a 'community of practice'. The chapter opens by introducing communities of practice and the social learning processes inherent in them. The empirical material begins with an exploration of engineers' social learning processes, including how they share information, discuss new ideas, and adapt their practices within this community. Next, I reveal a fundamental aspect of community membership: the engineers' identity. In particular, I look at the ways in which this might impact on user understandings, and on strategies to encourage the adoption of alternative heating technologies. Finally, I turn to degrees of membership, particularly looking at how the varied practices of different individuals might shape the energy consumed through central heating systems. The closing discussion reveals the lessons learnt from these insights, and from the application of a communities of practice approach.

Expanding beyond the engineer, ***Chapter 6*** explores the role of different actors within the engineer's supply chain. Here, I apply ideas of social capital to look at the relationships between engineers, merchants and sales representatives. I commence with an introduction to the concept of social capital, in particular, exploring ideas of tie strength and trust, loyalty and reciprocity. Within the empirical material, I demonstrate the existence of both strong and weak ties amongst actors in the central heating industry. I identify the ways in which these ties operate, and the impact that they have on heating engineers' practices, particularly in influencing the technologies that are fitted in domestic properties. The chapter concludes by discussing the implications of these networks of relations for the central heating technologies installed in homes and the utility of social capital theory in revealing these insights.

In ***Chapter 7***, the point of focus shifts to the materials and the property in which installation takes place. When installed, the boiler, radiators, pipework and controls are not standalone entities, they form a system, or a network. It is during installation, that these entities can come to life. Actor-Network Theory is the lens used to explore the contestations that occur as the components of the central heating system are negotiated into position. This empirical material demonstrates the processes that take place during installation, considering the boiler, radiators, pipework and controls in turn. This chapter closes with a discussion of the implications of these negotiated installations for the energy consumed through domestic central heating systems.

To conclude the empirical section of this thesis, ***Chapter 8*** focuses on engineers' constructions of their customers. In this, I continue the Actor-Network theme, but explicitly apply the idea of scripting to reveal the way in which these constructions may shape energy consumption – how, in effect, engineers' technology choices and accompanying explanations serve to 'script' users' interaction with their central heating systems. Through this empirical material, I identify the types of customer that engineers have developed through their assumptions and interactions, and the implications that these constructions have for the selection and explanation of heating controls. Further, in creating these constructions of users, I explore the extent to which the engineer scripts users' future potential actions with their heating systems, particularly the controls.

Chapter 9 summarises the findings of this investigation, relating back to the research question initially set out. This final chapter will highlight the contribution of this thesis and outline recommendations to different research stakeholders, including industry and policy makers, along with suggestions for further academic enquiry. In doing so, I identify a multitude of ways in which heating engineers, and the installation process play a significant role in shaping the energy consumed through domestic central heating systems. This both highlights the importance of understanding the role of intermediaries in the built environment, and the value of applying cultural approaches to do so.

2 Why investigate central heating installation?

2.1 Introduction

The installation of central heating systems has been the subject of little academic enquiry to date. Nevertheless, it is both an essential, and incredibly rich, subject for exploration. Having outlined the significance of understanding the energy consumed through domestic space heating in Chapter 1, I use this review chapter to explore the existing literature on the topic and refine a direction for this research. This is done in three parts.

Firstly, in Section 2.2 I problematise existing policy approaches which aim to reduce the energy consumed through domestic space heating. I argue that the technological solutions and information campaigns preferred by policy makers fail to account for the complexity of space heating practices and the way these are shaped. Instead, I suggest that alternative approaches, accounting for the social and cultural context of these practices, and their formation, would provide a more appropriate starting point for these strategies.

Secondly, in Section 2.3 I explore the existing focus on the end user within studies of central heating, highlighting the ways in which these investigations have hinted towards the importance of the intermediary installer but not yet attempted to uncover the potential extent of their role. In this, I emphasise the importance of understanding the complexity of heating practices, and in turn, the variety of ways in which heating engineers might play a role. This is an intricate problem that has been studied from a variety of different perspectives, including: sociodemographic factors, occupants' thermal comfort practices, understandings of heat and the usability of heating controls. Elaborating on the contributions from these distinct research approaches uncovers a series of different ways in which the heating engineer, and the installation process, might influence the energy consumed through space heating, revealing the need to investigate these in more depth.

Thirdly, in Section 2.4, I examine the literature on the role of different types of intermediaries in the built environment, uncovering the limited amount research that has engaged heating engineers in any capacity. Intermediary actors have so far received relatively little attention from academics and policymakers alike with regard to their contribution to the shaping of energy consuming practices, yet their potentially influential role has been acknowledged. This final section discusses the variety of ways in which intermediaries, and their practices, can shape domestic energy consumption, particularly emphasising the potential role of heating engineers throughout. The chapter concludes by summarising current knowledge of central heating installation and use, and distilling the limitations that have been identified throughout this review into an overarching research question that will be addressed through the remainder of this thesis.

2.2 Heating policy context

2.2.1 Strategies to reduce the energy consumed through space heating

The UK Government has relied on two key approaches to reduce the energy consumed through space heating: technological strategies, usually setting standards via Building Regulations; and information campaigns, which aim to convince end users that they will make financial savings by reducing their thermostat settings (Burr 2008). This is broadly in keeping with the "physical-technical-economic model" (PTEM) that has dominated energy efficiency research and policy making to date (Lutzenhiser 2014; Moezzi & Lutzenhiser 2010). However, the lack of reductions in energy consumption has demonstrated the limited success of these strategies thus far. Their neglect of the realities of energy use and the social context in which this consumption is shaped and realised has long been recognised by social scientists, and is the subject of on-going dialogue (see for example Lutzenhiser 1993; Shove 1998; Wilhite et al. 2000; and more recently, Moezzi & Lutzenhiser 2010; Lutzenhiser 2014). In the discussion that follows I identify the limitations of these technological strategies and information campaigns within the context of space heating, before I suggest an alternative approach in the following section.

The technical perspective assumes that reducing energy consumption can be achieved through developing more energy efficient products and putting them in homes. For central heating systems, a notable technological strategy was mandating condensing boilers, which were heralded for their improved efficiency. While this technology will be discussed in more detail in Chapter 3, suffice to say here that the efficiency gains from this can be uncertain. For example, all of the forty-three in-situ condensing boilers monitored during a twelve month field trial were found to have operating efficiencies lower than the factory tested efficiencies they were purported to have (Orr et al. 2009). Instead, the in-situ operating efficiency of a condensing boiler is dependent on system design, controls and effective operation. These aspects of design and use are reliant on both the system installer and the user. Furthermore, under the assumption that their installation will result in energy savings, central heating controls are required for compliance with the Building Regulations. These devices are heralded for their energy saving potential, and yet their addition does not guarantee such savings. These are discussed in more detail in Chapter 3; however, here, it is important to highlight that claims regarding the potential energy savings from these devices have been found to lack rigorous supporting evidence, with the suggestion that "policy-makers are struggling to find the data they need on central heating systems controls" (Shipworth et al. 2010: 52). Furthermore, for their success, "occupants must actively program the thermostat and select settings that result in savings" (Peffer et al. 2011: 2535). However, there is a huge amount of variation in the use and understanding of central heating controls, which is discussed in more detail in Section 2.3. This raises questions over the capacity of controls in themselves to reduce the energy consumed through space heating, and highlights the failure of this technological strategy to account for how people interact with these devices.

Attempts to influence the users of these devices have generally involved information campaigns, grounded in an economic individualistic approach to social life. Such approaches assume energy users are individuals who make choices in a rational or semi-rational manner (Chatterton 2011), where the focus is on reducing financial cost. It is under this model that policy-makers assume that the provision of information will lead people to act in a rational way motivated by the desire to save money (Burr 2008). Information campaigns have primarily focussed on the thermostat, encouraging householders to reduce set points by 1°C. For example, the Energy Saving Trust website states: "Turn down your room thermostat by one degree to save about £85 - £90 and 310kg – 360kg carbon dioxide a year", but no citations are given for the advertised savings (EST 2014). Thermostat settings are the primary target of such campaigns because of their potentially significant contribution to household energy consumption; there are two modelling studies that have demonstrated this. Firstly, by modelling the impact of changing heating patterns on household CO_2 emissions, Firth et al. (2010) demonstrated that demand temperature (taken to be the thermostat set-point temperature) is the most important technical factor shaping the energy consumed through space heating, and subsequent household emissions. Secondly, analysis using the Cambridge Housing Model (based on SAP 2009 and extrapolated data from the English Housing Survey) suggests that the behaviour change with the potential to save the most energy is turning the thermostat down by 2°C (from 20°C to 18°C), which is closely followed by turning the thermostat down by 1°C (from 19°C to 18°C) (Palmer et al. 2012). These both suggest that demand temperature is significant and underpin information campaigns; however they are based on modelled assumptions that are not evidenced by empirical data. Furthermore, these conclusions do not attempt to assess "how easy or hard it will be to persuade households to change their behaviour" (Palmer et al. 2012: 10). Indeed, these information campaigns have been shown to result in only 'modest behavioural changes' (Steg 2008) and, although they can increase users' level of knowledge, there is little evidence that they affect actual energy use (Abrahamse et al. 2005). Furthermore, these campaigns fail to account for the ways in which the end user's interaction with these devices might be shaped by external influences. Instead, the "cacophony of voices" from these campaigns can produce misleading information and confused users (Moezzi & Lutzenhiser 2010: 215).

It has long been recognised that the rational actor model creates conceptual 'blind spots' in analysis (Stern 1986; Lutzenhiser 1992a). Despite evidence of "irrationality in energy-user behaviour (by economists' standards)" being documented more than 20 years ago (Lutzenhiser 1992a: 52), this continues to be the prevalent policy strategy to influence the use of heating controls. As will be discussed in Section 2.3, occupants often do not understand, cannot use, or even identify their central heating controls. If this is the case, how can we reasonably expect that, following the provision of advice, end users will be willing or able to modify the settings on these devices in a bid to save energy?

The reliance on these segregated disciplinary perspectives, that is technological strategies and individualistic models of users, does not provide the depth of knowledge required to understand, and subsequently effectively influence, the way people actually interact with energy consuming technologies (Stern 2014). This general reliance on techno-economic approaches has, to date, blocked the development of more sophisticated understandings of energy use (Moezzi & Lutzenhiser 2010: 207). Both strategies are likely to remain futile endeavours given the inherently social nature of consumption (Lutzenhiser 2014). If, as social theories posit, individuals' actions with regard to technology are shaped by a much wider number of factors, including their own beliefs and understandings, the information, advice and practices of those around them, and wider social norms, to name a few, then an alternative approach is required.

2.2.2 Alternative approaches

The complexities of buildings, and the use of the energy consuming technologies within them can be revealed through a sensitivity to alternative disciplinary approaches (Guy & Shove 2000). Moezzi and Lutzenhiser highlight the value of sociology, anthropology and social studies of technology (also known as Science & Technology Studies, STS) in addressing broader questions, including the identification, explanation and interpretation of patterns of variation and change in energy use with respect to society, culture, technology and history (2010: 210). For example, more socially-oriented approaches are useful for understanding the complexities, structures, and processes that create and maintain practices (Chatterton 2011). Meanwhile, ideas from STS, which view technology as a socio-technical product, help us to understand the interaction between physical arrangements and social practices within the built environment (e.g. Shove 1998; Rohracher 2001; Chiu et al. 2014). It is the ability of these disciplines to account for the complexities of energy consuming practices that make sociological, anthropological and STS perspectives well suited to unearthing the realities of the way in which the use of central heating systems is shaped. As Lutzenhiser notes:

> "Within these traditions, everyday energy-involved action is seen as multi-faceted, complex, nuanced, and interpretively challenging. It involves (at least) a composite of social actors, technical devices, meanings, energy flows, institutions, and organisations in heterogeneous systems"
>
> (2014: 142)

Not least, these alternative approaches allow for consideration of a much wider variety of stakeholders, potentially broadening the technology policy agenda (Williams & Edge 1996; Rohracher 2001). According to Chatterton, this array of actors includes households, those involved in making, selling, promoting and installing energy efficiency products, along with those involved in 'home improvements' and building work (2011: 8). Through socio-technical analysis, Crosbie et al. (2008) identify those involved in the manufacture, marketing and design of household lighting as intermediaries which shape the practices surrounding these technologies, and the energy they consume. Meanwhile, actors performing design, installation and hand over practices have been noted for their potential role in shaping socio-technical configurations in dwellings (Chiu et al. 2014: 288). With regard to central heating systems, one vital actor is the installer of the system – the central heating engineer.

The evidence presented in the following sections suggests that heating engineers may contribute to determining, configuring, and providing advice about central heating systems, all of which are likely to influence space heating practices. However, to date, there are very few studies that have focused on either the installer or the installation of these systems. Currently, both policy and research on this topic have been dominated by a focus on end users and their interaction with central heating technologies (Schweber & Leiringer 2012). Given that studies focusing on the end user constitute the most significant body of evidence for understanding the energy consumed through space heating, it is most logical to proceed by reviewing this. Through this, I will uncover any existing understandings of the installer and installation process in shaping the use of central heating. The following section first introduces this variation in the use of central heating, demonstrating the complexity of central heating use, before exploring the different factors that influence this in more detail. At each turn, I identify the limitations in our knowledge of how central heating use is actually shaped, and highlight the potential influence of the installer and installation process.

2.3 People use their heating in different ways

A wide variance in the energy consumed through domestic space heating has been identified. Academics have investigated the sources of this variation, including the type of heating system, dwelling age, household income, and the practices of building occupants (Pimbert & Fishman 1981; Hunt & Gidman 1982; Kempton & Krabacher 1984; Vine 1986; Conner & Lucas 1990; Nevius & Pigg 2000; Rathouse & Young 2004; Woods 2006; Karjalainen 2009; Shipworth et al. 2010; Peffer et al. 2011). The impact of these different factors has also been modelled in attempts to establish which are most important in influencing the energy consumed through space heating (Firth et al. 2010; Meier & Rehdanz 2009; Kelly et al. 2013). Through this modelling approach, Firth et al. (2010) indicate that temperature settings and heating durations are the two most important factors shaping annual dwelling CO_2 emissions. Both of these are determined by the way in which the system is used, or the practices of the building occupants, both of which are subject to wide variation and can be hard to predict. Explanations for this variance have focused on the user, including sociodemographic factors, diverse thermal comfort practices, mixed understandings of heating and the limited usability of control devices. In this section, I detail the findings from each of these perspectives in turn, highlighting throughout that a potential role for heating engineers and the installation process has been identified, but that the exact nature of this has not yet been explored. To better understand the complexity of this problem, and the role that installation might play, I first detail what we know about the way that people use their central heating systems.

Both measured internal temperatures and reported thermostat setpoints suggest that occupants' temperature settings are highly variable (Hunt & Gidman 1982; Kempton & Krabacher 1984; Conner & Lucas 1990; Rathouse & Young 2004; Shipworth et al. 2010; Huebner et al. 2013a; Vadodaria et al. 2014). In particular, Huebner et al. (2013a) present measured average weekday winter temperature data for each of the 248 individual homes in their sample, demonstrating both the highly individual nature and broad range of temperature settings - between 10°C and 30°C. These extremes have also been found in qualitative studies; for example, in focus groups, participants reported thermostat settings ranging from 6°C - 30°C (Rathouse & Young 2004). Aside from temperature settings, the duration of heating has also been found to vary between households. For example, using measured internal temperatures, Shipworth et al. (2010) identify a range between approximately five and thirteen active hours per day, whilst Huebner et al. (2013b) highlight a wide variation amongst households in the average number of hours spent at, above and below the 21°C assumed in UK building stock models. Finally, how actively occupants manage set points, and interact with their controls is also subject to variation. Using observed thermostat settings in 96 Californian houses, Woods (2006) found that few households used a single, constant set point method. He suggests that frequent temperature adjustments are the rule, and identifies a three-set-point method for heating: when someone is at home, one for night-time, and one for when the house is vacant. Focus group discussions revealed five patterns of thermostat adjustment amongst users: occasional, as an on/off switch, adjusting the temperature (but not necessarily until it *'clicked'*), making frequent changes, and not using the device at all (Rathouse & Young 2004 pp.11-12). Meanwhile, in the Finnish context, a nationally representative quantitative survey found that approximately 60% of people reported either not using their thermostat at all, or using it less than once a month (Karjalainen 2009: 1240).

Indeed, despite the assumptions made in technological strategies (detailed in Section 2.2) the addition of heating controls does not always result in reductions in the energy consumed through central heating systems. It has been identified that individuals do not always recognise that they have particular controls (Revell & Stanton 2014), and that they are not always able to distinguish the controls that they do have (Rathouse & Young 2004). Through literature review, Peffer et al. (2011) identify several studies where no significant savings were found in households using programmable versus non-programmable thermostats. Within these studies, the authors have found people operating programmable thermostats in the same way as manual thermostats, or using the *hold* setting to transform the functionality of the programmable thermostat into a manual thermostat, thus limiting the potential to achieve savings through these devices (Peffer et al. 2011). Through internal temperature measurements, Shipworth et al. (2010) find no statistically significant differences between average maximum living room temperatures in homes with and without thermostatic control. The authors also note that it should be no surprise that they found central heating systems operated via timers to be on for a longer duration than those operated manually; while not statistically significant, this finding supports those of other studies that have found that the addition of programmable thermostats does not necessarily result in more efficient settings (Shipworth et al. 2010: 65). Thus, whether or not central heating controls result in energy savings is highly dependent on how they are actually used. As Conner and Lucas note "behaviour relating to thermostat control can often be seemingly erratic and may not conform to simplified assumptions" (1990: iv).

Attempts have been made to identify some of the patterns in, and reasons for, this variation, with potential explanations including:

- sociodemographic factors;
- thermal comfort practices;
- mixed understandings of heat;
- and limited usability of control devices.

In the following sections, I detail our knowledge of each of these aspects in turn. Looking at the problem from these different angles reveals a series of limitations in our current understandings, in particular, a neglect of the way in which each is shaped. In order to advance our understanding of these variations in use and the subsequent energy consumed through these systems, I emphasise the importance of looking to the installation of central heating systems, from each of these perspectives.

2.3.1 Sociodemographics and how different types of people might come to use their heating in different ways

Investigations into the sociodemographics of heat suggest that different types of people heat their homes in different ways. It is possible that these differences can be explained by the quality (i.e. thermal properties) and type of buildings that different tenures inhabit, or by sociodemographics in themselves (i.e. that a social housing tenant cannot afford to heat their home to a higher temperature). However, there are some ambiguities in our current understandings, suggesting that there is ample scope for further explanation. To date, the wider factors feeding into potential sociodemographic segregations have not been considered. In particular, the potential influence of the installation process and system installer on the variability amongst sociodemographic groups has not been investigated. In order to understand this potential role, I first detail our current knowledge of the variation in heating practices amongst different sociodemographic groups.

In a nationally representative UK sample, spot-temperature measurements and a participant survey suggested that household income was a major source of variance in temperature settings, with higher income groups using higher internal temperatures. However, in a key limitation, the authors noted that gross household income was unknown for one third of the sample (Hunt & Gidman 1982). This study also found that homes with children were warmer than those without, while households with older people were cooler (Hunt & Gidman 1982). In their sample of low income dwellings that had been in receipt of energy efficiency interventions, Oreszczyn et al. (2006) used half-hourly living room temperatures which showed that in some cases occupants over sixty set higher demand temperatures than those under sixty, but noted no significant difference in the hours of heating for these groups. Furthermore, a predictive model based on measured internal temperatures and sociodemographic data from a nationally representative sample demonstrated that the number of occupants, household income and occupant age are all associated with higher internal temperatures (Kelly et al. 2013). This analysis also found that privately rented, council-owned and housing association properties had higher mean internal temperatures than owner-occupied homes. The authors attribute this to a larger proportion of owner-occupiers being employed, and living in larger, harder to heat dwellings (Kelly et al. 2013). However, a much earlier analysis found contrasting results, suggesting that owner-occupied dwellings are warmer than local authority ones (Hunt & Gidman 1982). It is worth noting that during the thirty year interval between these two studies, local authority and housing association owned properties have both received concerted attention to improve their thermal efficiency. Analysis of the Home Energy Efficiency Database (HEED), which catalogues installed energy efficiency measures in England, found that between 2000 and 2007 areas with lower incomes showed higher rates of uptake of measures, reflecting the success of government programmes that target vulnerable households (Hamilton et al. 2014). Despite these improvements, other studies have found low mean internal temperatures amongst social housing tenants (Oreszczyn et al. 2006; Love 2014).

Further, cluster analysis has been used to organise measured internal temperature data into meaningful groups. This approach has identified four internal temperature profiles for English living rooms: 'steady up', 'steep up', 'flat-line', 'two-peak' (see Figure 2.1) (Huebner et al. 2014). 'Steep up', where internal temperature rises steeply throughout the day, and falls at night, has an older household composition.

Meanwhile, two on-off settings per weekday ('two-peak') were present with higher income households, and 'flat line' (with a fairly consistent temperature throughout the day) was more prevalent amongst flats and social housing tenants (ibid).

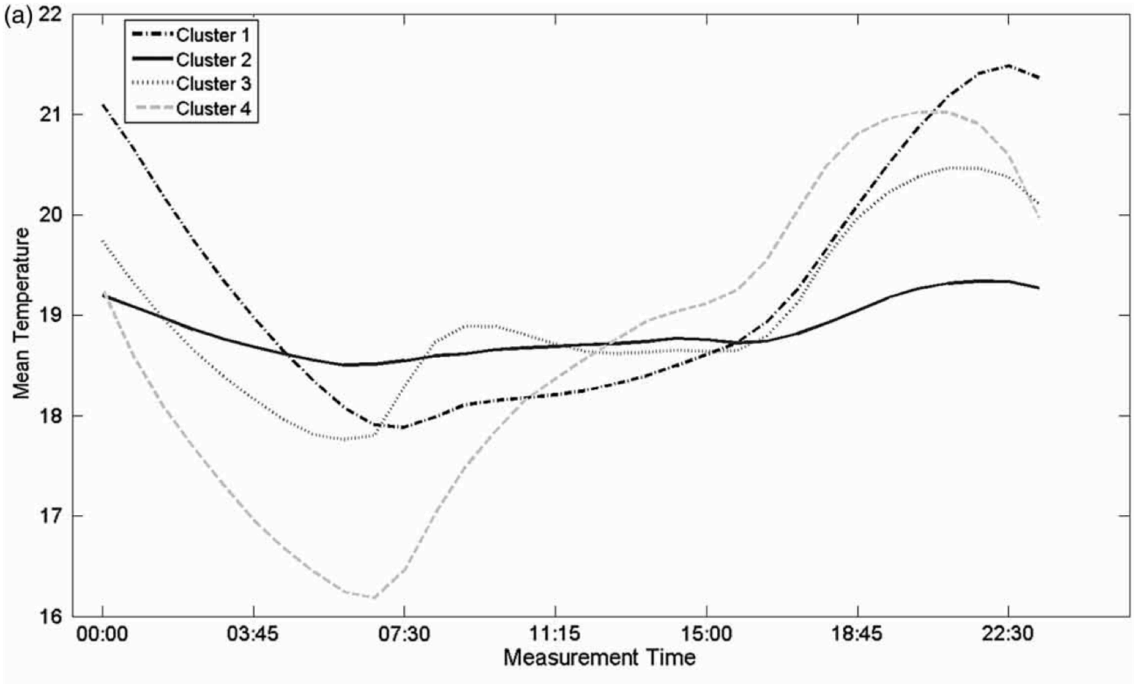


Figure 2.1 Average temperature profiles of the four clusters for weekdays, source: (Huebner et al. 2014: 6).

Although these temperature profiles are derived from internal temperature measurements, not control settings; they demonstrate distinct differences in heating patterns amongst different sociodemographic groups.

However, despite all of these studies identifying relations between heating and sociodemographic factors, none has explored why these variations might emerge. For example, a pertinent question would be whether different types of people, or tenures, receive different central heating technologies or have their practices shaped in different ways. In this way, there could be a role for the installer in influencing these sociodemographic distinctions; however, we do not know what this is.

Instead, attempts to explain this variability have focussed on the occupants themselves, their varied thermal comfort practices, and the use and usability of heating controls. For example, in explaining their findings Huebner et al. (2014)

suggest that older people might experience rapid decreases in internal temperature at night (Cluster 3 on Figure 2.1) due to their thermal comfort practices, and in particular the night-time ventilation practices identified by Day and Hitchings (2011). Indeed, thermal comfort practices do vary amongst individuals, and within dwellings, and this is often associated with the use of the central heating system. Because of this, I now turn to the concept of thermal comfort, its relationship with central heating systems, and the role that their installation can play in shaping and maintaining thermal comfort practices.

2.3.2 Thermal comfort and the potential importance of intermediaries

Thermal comfort has traditionally been explained by focusing on the physiological responses to different thermal environments, it is defined as "that condition of mind which expresses satisfaction with the thermal environment" (ASHRAE 2010: 4). A huge amount of variability has been identified in how people manage their thermal comfort (see Brager & de Dear 1998; Chappells & Shove 2004 for reviews). The diversity of thermal comfort strategies in the home includes wearing more clothing, the use of blankets, and moving to different rooms in the house (e.g. Kempton & Krabacher 1984; Brager & de Dear 1998; Gram-Hanssen 2010; Day & Hitchings 2011; Karjalainen 2009). These strategies can also vary amongst different cultures (Wilhite et al. 1996).

Indeed, the meanings and definitions of comfort are not set in stone. In particular, intermediary actors can be "purveyors of ideas and images as well as standards, regulations and technologies of indoor climate control" (Shove et al. 2008: 307). Ideas of comfort, and the consequent practices associated with these, have been appropriated by building practitioners (Guy & Shove 2000), and those involved in delivering thermal comfort technologies into homes. For example, a study by Gram-Hanssen (2010), which undertook qualitative, in-depth interviews with ten households related to water, electricity and heat consumption revealed that intermediaries can influence knowledge through the production and dissemination of their own rules, knowledge and language. These intermediaries include governmental bodies, NGOs, local authorities, schools, the media and utilities. However, this was carried out in a Danish context and the participants lived in homes supplied with district heating (Gram-Hanssen 2010). In the UK context, where homes are primarily heated through individual gas boilers, fitted by heating engineers, the system installer is likely to constitute another of these intermediaries. In this position, heating engineers could have a significant impact; indeed, with regard to the role of intermediaries, Shove et al. note:

> "The practical implication of this insight is clear: since all these actors and more are actively involved in making and shaping the future of comfort, all represent possible, variously effective points of influence"
>
> (2008: 307)

In their intermediary position, the installer has the potential to act as one such 'effective point of influence'. It is thus pertinent to ask whether ideas and images of thermal comfort are portrayed during the installation process and, if so, whether these shape the energy consumed through the subsequent use of the system.

Indeed, there is some evidence to suggest that the installation of central heating systems can lead to shifts in thermal comfort practices. In particular, changing practices have been recognised following energy efficient retrofit, including the installation of domestic heating systems. For example, cross-sectional comparisons were carried out on 2399 English dwellings in receipt of Warm Front interventions. This scheme provided grants for the installation of energy efficiency measures including insulation and gas central heating systems. Pre- and post-retrofit comparisons identified increases in self-reported Comfort Vote (that is, occupants' subjective thermal comfort based on a descriptive seven-point scale ranging from 'much too cool' to 'much too warm') and room temperature (+1.89 °C) following the addition of central heating (Hong et al. 2009). The Warm Front scheme specifically targeted energy inefficient, low-income households living in fuel poverty in the private sector. However, as discussed in Section 2.3.1, these households may have originally been heating their homes to lower than normal temperatures. The authors do not, however, clarify whether these effects were universal across those that originally had no central heating (75% of the sample), and those receiving upgrades to their original heating. However, these reported changes do suggest that the installation of a central heating system provides a moment of disruption in peoples' existing thermal comfort practices.

During this disruption a new technology comes to be physically embedded in the property and household practices and the role of technologies within them are negotiated. Indeed, with regard to the freezer, Hand and Shove (2007) have demonstrated that its role is subject to realignment, in particular with changes in lifecourse, for example the arrival of children or retirement. In the case of the central heating system, one such shift might occur during its replacement or installation. For example, the general increase in energy consumed through space heating (introduced in Chapter 1) has been attributed to the addition of central heating systems, which have changed peoples' aspirations about how warm they can be at home, and their expectations of how to achieve this (Palmer & Cooper 2013). The intermediary heating engineer is central to this process, in particular their involvement in designing the central heating system (as discussed in Chapter 3) can also play a role in shaping thermal comfort.

Energy consuming technologies, such as central heating systems and air conditioning, are increasingly being used to assist in achieving thermal comfort (Shove 2003). Indeed, the aim of central heating system design is to achieve a standardised, single internal temperature across a whole building, despite seasonal fluctuations in external temperature (the target design temperature is usually 21°C; the design of central heating systems is discussed in Chapter 3 and Appendix II). This reflects the 'self-fulfilling momentum' of thermal comfort standards, as Humphreys has highlighted:

> "If the standard says you ought to have 22°C, you design for 22, run at 22 and people adapt to 22 and you find that people are happy at 22°C. However, this does not mean that 22°C is necessary, you could have gone for 20 or probably 24°C"
>
> (Humphreys 1994: 71)

Consequently, the central heating system can be considered a technological solution to the problem of producing pre-defined 'comfortable' conditions in the home (Chappells & Shove 2004). Thus, domestic central heating systems play their part in the global convergence of comfort standards, and the expectations and conventions of comfort associated with this (Shove & Moezzi 2002). Not only does a single design temperature reinforce the standardisation of the meanings and definitions of comfort

(Chappells & Shove 2004), it also assumes that all building occupants desire the same internal temperature from their central heating system. Despite the fact that the realisation of these standardised internal temperatures relies on the designer and installer of this system, their design practices have not previously been investigated.

Thus, evidence suggests that both the installer and installation process can be influential in shaping the thermal comfort practices surrounding central heating systems. As such, uncovering this point of influence would be beneficial for identifying some of the factors shaping variations in thermal comfort practices. As Hitchings (2013) has highlighted, it is only with an understanding of this variation that we can look at how to change thermal comfort practices for the better, and identify ways to make them more sustainable. However, along with thermal comfort aspirations, this variability in the use of central heating systems is also associated with occupants' different understandings of their control devices. Delving into our knowledge of users' understandings in the following section reveals further evidence that the role of the system installer needs to be investigated.

2.3.3 Understandings of heat and how they might be influenced

Studies have revealed mixed understandings of central heating controls and efficient system operation amongst users. Furthermore, there is some evidence to suggest that heating engineers could have an influential role in shaping these understandings, and occupants' subsequent interaction with their central heating system. However, to date, there has been very little concerted effort to identify where occupants' understandings originate. In the following section, I elaborate on these understandings and highlight what we know about their origins.

Occupants' have been found to have diverse theories of home heat, that is, varied conceptualisations of their central heating systems, and how these work. These relate to the operation of individual system components, but also to what is considered the 'correct' operating strategy for the system as a whole (Peffer et al. 2011). These do not always correspond to 'conventional technical wisdom' (Kempton 1986; Lutzenhiser 1992b), or what experts consider technically 'rational' behaviour, instead heating practices might depend on folk theories (Chappells & Shove 2004). The word "folk" is intended to denote theories "acquired from everyday experience or social interaction" (Kempton 1986: 75), as opposed to through more formal channels, for example. Kempton identifies that information about thermostats is "communicated almost entirely through folk channels" (1986: 77), highlighting that these devices are not formally studied in school, for example, but he does not elaborate on what these folk channels might be. The system installer could potentially act as a channel of this folk knowledge. However, in order to understand the role they could play in this, it is important to first identify what we know about the theories of home heat that exist amongst occupants.

Rathouse and Young (2004) highlight the reluctance of their focus group participants to explain the functioning of their controls. The authors note that, whilst "on the whole people understood what programmers do" (2004: 16), they had more difficulty explaining room thermostats, boiler thermostats and Thermostatic Radiator Valves (TRVs). In particular, research has shown that room thermostats are recognised and used as on/off switches (Rathouse & Young 2004; Caird et al. 2007). Using in-depth interviews about home heating and thermostat setting behaviour, and measured thermostat settings, Kempton (1986) has identified two ways in which occupants conceptualise the operation of their thermostats: feedback and valve theory. Feedback theory posits that the thermostat senses temperature and turns the furnace on and off to maintain an even temperature, whilst valve theory suggests that the thermostat operates like a gas burner, or tap, with a higher setting causing a higher flow (more heat) (Kempton 1986). Semi-structured interviews accompanied by a mapping exercise have been used to build diagrams of participants' heating system use, and elicit their mental models of home heat control (Revell & Stanton 2014). Amongst a small sample of six participants, both valve and feedback theories were identified. The authors note that thermostat set point adjustment was 'less prevalent than expected' and both the programmer and thermostat were omitted from some participants' accounts of their mental models (Revell & Stanton 2014). If users do not identify their controls within their models of operation, the information campaigns discussed in Section 2.2 are likely to be of little use in actually altering heating practices (Revell & Stanton 2014).

However, Kempton also suggests that inefficient operating theories do not always result in inefficient system operation (1986: 87). Mental models do not need to be technically accurate, instead, it has been suggested that models taught to the user should fulfil three criteria: learnability, functionality and usability (Norman 2014). For simple devices (such as a dial room thermostat, detailed in Appendix III) "a 'functional', simplified or even lack of mental model may be effective", whilst for more complex devices (for example, digital heating controls with several buttons, detailed in Appendix III), a more accurate mental model could be more suitable (Revell & Stanton 2014: 364). Regardless of whether customers' mental models are technically accurate, it would be valuable to understand whether heating engineers have a role in their formation. If this is the case, it is important to identify whether such mental models facilitate the energy efficient use of central heating systems, and why it is that some customers do not use, or cannot identify, particular heating controls.

Furthermore, these mental models can extend beyond the functioning of controls, to understandings of the whole central heating system. Rathouse and Young (2004) have commented on the 'considerable disagreement' amongst focus group participants about the most efficient way to operate a central heating system. Some people favoured using the system intermittently, whilst others said they kept it on constant - under the understanding that it takes more energy to heat the home from cold than keep it at a constant temperature (Rathouse & Young 2004). Meanwhile, 'quite a number' of the forty-three participants qualitatively interviewed for a recent DECC study based in the North East of England reported being uncertain about which operating mode was more efficient, and whether turning radiators off in particular rooms would save them money or not (Rubens & Knowles 2013: 17). Again, there is a need to question where these understandings of what constitutes an efficient operating mode are coming from.

Rathouse and Young found that those with a detailed understanding of their controls had generally gained it through "their jobs or carrying out DIY", whilst those with less understanding were influenced by "family, friends, official information [sic]" (2004: 17). The authors do not identify what, or who, this 'official information' might be, but later reported that their participants cited heating engineers as a source of information (ibid: 24). Another study showed that friends and heating engineers were identified as influential sources of information by occupants questioning the most efficient operating strategy for their central heating system (Rubens & Knowles 2013). A randomised control trial, designed to test whether the provision of advice about heating controls (via leaflet or engineer) could reduce energy consumption, found that some tenants altered their thermostat settings (to between 18°C and 25°C) in accordance with the advice provided by engineers. Prior to this, some participants had been operating their thermostats as valves - setting them to 30°C in order to quickly warm the house, for example (DECC 2014b: 24).

Thus, heating engineers have been repeatedly identified amongst the different sources of information that end users might turn to for advice about the operation of their central heating systems. Despite this, the role that heating engineers might play in shaping end users' understandings has not previously been investigated. This discussion has demonstrated that occupants have a range of mental models of home heat control, and the efficient operation of their systems. However, these understandings are not always conducive to them interacting with their controls or actually operating the system efficiently. As such, it would be valuable to explore how the installation process and system installer configure occupants' mental models and subsequent use of their central heating systems. Beyond understandings, another issue that can contribute to the variation in the use of central heating systems is the usability of heating controls. Again, this is an aspect of use that the system installer could have a potential role in, which I detail in the following section.

2.3.4 The usability of heating controls and who might be selecting them

Usability is defined as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (BSi 1998: 2). The usability of heating controls is shaped by factors relating to their design, including the way that people interact with these devices (thinking, vision and dexterity requirements), as well as their positioning (Focus 2012). Poor usability can mean that controls are rarely adjusted, or simply not used (Caird & Roy 2008; Rathouse & Young 2004). The energy implications of this make it important to explore the role of installation in ensuring that usable products are fitted in homes.

As part of a preliminary investigation into the use of thermostats in the United States, an on-line survey found that the majority of thermostats were not selected by the respondent or someone in their household (Meier et al. 2011a). This leads the authors to conclude that "most thermostats were selected by previous residents, landlords, or other agents" (Meier et al. 2011a: 1892), although this is based on a preliminary survey, with eighty one responses but no details on the sample characteristics. However, it does suggest that we should be looking beyond the user to understand the selection of heating controls. There is some evidence that heating engineers have a hand in determining the products fitted in homes (see Section 2.4), if this is the case, it is important to investigate whether 'usable' devices are being fitted. In the following, I discuss two usability considerations with regard to central heating controls. The first is the design of the device, and whether this is suited to its intended user. The second is the positioning of the device, and whether it is accessible for use. Through their potential role in selecting and installing heating controls, both of these are aspects that the heating engineer could contribute to.

With regard to device design, central heating controls have shifted from being a "simple wired appendage" to the heating system, to a "separate product resembling software or consumer electronics" (Peffer et al. 2011: 2530). Through literature review, Peffer et al. identify a shift towards push buttons and touchscreens rather than dials, single push buttons controlling multiple features, and physical switches being replaced with virtual ones. In particular, they note that conventions can be borrowed from the computing domain, for example the use of OK, Back and Save buttons (Peffer et al. 2011: 2533). This shift in design has resulted in a move towards unusable central heating controls. The use of small buttons and fonts (Rathouse & Young 2004; Combe et al. 2012), a lack of feedback confirming user settings (Karjalainen 2007) and difficulty in understanding the abbreviations, terminology and symbols (Combe et al. 2012; Karjalainen 2007), have all been identified as problems by users of the devices. Usability testing of three programmable thermostats, which asked participants to set each device to heat the home during specified hours, was carried out with a mixed sample of fourteen self-selected participants aged 24-75 (Combe et al. 2012). Of this sample, 66% were unable to perform the programming task set, with the authors noting that both mental demand and frustration were high whilst completing the task. None of those aged over sixty were able to successfully complete the task (Combe et al. 2012). This reflects the increasing body of evidence that older people are vulnerable to exclusion from heating controls (Caird & Roy 2008; Sauer et al. 2009; Combe et al. 2011; Combe et al. 2012; Combe et al. 2013). Indeed, different people might find different types of control easier to use than others, and mixed views have been identified amongst users of different demographics about the complexity of programmers, with no clear consensus on whether digital or dial devices are easier to use (Rathouse & Young 2004). In-home interviews with forty three households recruited in and around London and Manchester about heating practices and controls identified different priorities and preferences amongst participants (Rubens & Knowles 2013). These have been used to propose tentative 'emerging user types' with different control needs, for example it is suggested that 'planners' might want to interact with controls more frequently, whilst 'reactors' saw the ability to have zonal control as beneficial (Rubens & Knowles 2013). This suggests that it is important to consider whether, in the selection of controls, these variabilities amongst users are accounted for.

Finally, inaccessible positioning has been noted for its detrimental impact on usability (Rathouse & Young 2004; Meier et al. 2011b). It is for this reason that the regulations and guidance surrounding the installation of controls recommend that they be fitted in a 'readily accessible' location (this is discussed in more detail in Chapter 3). With regard to the positioning of controls, Peffer et al. (2011: 2536) discuss anecdotal reports of people installing programmable thermostats sideways to match the "footprint" of the old manual thermostat, thus avoiding the need to repaint the wall (although they do not identify a particular source). Further, interviews with the recipients of advice about the efficient use of heating controls found that their capacity to implement the advice was influenced by the location of controls. Changing the device settings was impeded when thermostats were behind doors and in less visible corners (DECC 2014b). Given the implications of location for the use of controls, it is important to understand the extent to which this is determined during the installation process, and whether they are fitted in such a way to enable the user to interact with them.

2.3.5 How installation might shape space heating practices

Taking different aspects of space heating practices in turn, I have demonstrated how the installation of central heating systems is likely to be influential in shaping their use. This section of the review has identified how heating engineers are potentially 'effective points of influence' in shaping occupants' ideas of thermal comfort, their understandings of heating controls and the operation of their central heating systems. There is a clear need to investigate the role of the installer and installation process in shaping space heating practices, and yet these have not previously provided the focus of academic enquiry. Although the legacy of academic research rests on the end users of these systems, there is an emerging body of investigation that has identified the importance of intermediaries in the built environment. For the final section of this literature review, I turn to this field of study. In doing so, I highlight the ways in which intermediary heating engineers are likely to be influential in shaping energy consuming practices and further evidence the need to study the installation of central heating systems.

2.4 The role of intermediaries

Within energy and buildings research, the 'social' has been largely limited to the study of building occupants and, as I have shown above, this has revealed information about several different aspects that influence the use of central heating systems. However, Schweber and Leiringer (2012) note that occupants do not act independently; their consumption practices are mediated by a range of stakeholders. These intermediaries can be individuals, or an organisation or group of actors that act to influence others. It is the character of the work they do, rather than of the actor or organisation, that constitutes it as an intermediary (Moss et al. 2009). Through literature review, Moss et al. arrive at a definition of intermediaries that includes their role in "enabl[ing] the uptake of new technologies and changed social practices within the production/ consumption nexus" (2009: pp.21-2). The key here is that the intermediary has the ability to influence others, and as Guy et al. note "intermediaries do not occupy a neutral position in dealing with other actors. They may well mediate or facilitate, but are by no means benign in the work they perform" (2011: 6). Intermediaries operate in a wide range of contexts, including areas as diverse as the provision of energy advice (Maby et al. 2007), water efficiency advice (Bowden et al. 2012), shaping household lighting practices (Crosbie et al. 2008), the design of private gardens (Hitchings 2007) and innovation processes (Howells 2006). Of most relevance to this investigation is the role of intermediaries in shaping the energy consumption in the built environment. Janda and Parag argue that we need to address the role of building professionals and practitioners in encouraging and discouraging change, noting:

> "Building professionals and practitioners neither produce nor consume energy, but through their work they shape and can alter the ways in which it is used. Building professionals are a critical part of the system needed to create zero-carbon homes, buildings and refurbishments."
>
> (2013: 42)

In defining building professionals and practitioners, these authors include "any person or group whose work involves the construction, refurbishment, management, letting or valuation of buildings, as well as businesses that supply materials and technologies to support these services" (Janda & Parag 2013: 42). Thus, with potentially influential roles in the built environment are numerous and diverse. They include architects (Janda 1999; Fischer & Guy 2009), property agents (Schiellerup & Gwilliam 2009), builders (Killip 2011), plumbers (Bowden et al. 2012), low carbon technology installers (Rohracher 2002), and – of critical importance to this thesis - heating engineers (Banks 2000a; Banks 2000b; DECC 2014b). In their middle position, these intermediaries tend to perform a 'wider, more varied and holistic role' than the narrowly defined jurisdictions that are often assumed of them (Howells 2006: 726). Indeed, the agency of these individuals has been recognised by Janda and Parag (2013), who suggest the term 'middle actors', and recognise their multiple potential directions of influence: upwards to government, sideways to both similar and different professions, and downwards to customers and clients. Despite their multiple routes of influence, it has been suggested that those involved in low carbon retrofit are currently 'outside the influence' of policy interventions (Owen et al. 2014). That is to say, these actors are peripheral to existing policies that often focus on influencing technologies and end users, as detailed in Section 2.2. Indeed, in order to make the objectives of policy deliverable, we need to account for "the ways in which building tradespeople operate" (Janda & Killip 2010: 123). However, in order to develop successful policies to influence these groups, it is important to first investigate the ways in which they work.

With regard to the specific role of heating engineers as intermediaries, or middle actors, it is revealing to note that prior to a study published by DECC in 2014

(DECC 2014b), the only piece of research addressing heating engineers in any capacity was conducted in 2000 (Banks 2000a; Banks 2000b). Both of these studies were conducted in the British context, and offer insights into the potential role of heating engineers (and are discussed in more detail in Sections 2.4.2. and 2.4.3.); however, it is clear that there is a dearth of information on the extent of the engineer's influence. In the following sections, I draw on these studies, along with investigations of comparable intermediaries, to identify the potential role of heating engineers in shaping the energy consumed through central heating systems. Exploring this emerging research emphasises the need to investigate the practices of heating engineers, and positions my timely contribution within this nascent field. In this, I identify four aspects of intermediary actors' practices that can play a role in shaping the energy consumed in domestic properties. Firstly, I explore intermediaries' role in influencing the technologies installed in homes. Secondly, I address intermediaries' application of their own preferences and priorities in the selection of domestic technologies. Thirdly, I consider intermediaries' 'expert' status and how they can act in an advisory capacity, potentially shaping the use of energy consuming technologies. Finally, I address the wider socio-technical networks that affect intermediaries' ability to promote particular agendas.

2.4.1 Intermediaries can shape the products installed in homes

As argued by Schiellerup & Gwilliam, the designers and developers of buildings can "significantly set the agenda for the behaviour of building occupants" (2009: 801). The specification of suitable technologies might be included as a formal part of this design process, but it can also develop iteratively, and involve different actors as the design progresses (Owen et al. 2014), or once the building is already established. The specification of building technologies is consequently not confined to building design, rather technologies are added and replaced throughout its lifetime. Building practitioners have been highlighted for their role in enabling technology adoption, for example allowing or promoting the use of a particular product (Janda & Parag 2013). Conversely, their selections and preferences are also capable of disabling or restricting technology adoption. In the market transformation of fridges and freezers in the UK, retail sales staff were identified as the most influential actors in determining the products that consumers purchased (Killip 2011).

However, other domestic technologies cannot be purchased 'off the shelf'. Owen et al. (2014) argue that tradespeople including builders, heating engineers, plumbers and electricians will collaborate, sometimes with the householder, to identify technology solutions. While relevant to this thesis, it is important to note that this finding was based on the authors' investigation of five English low carbon technology retrofit projects, rather than gas central heating systems specifically. Banks (2000a; 2000b) investigated the market penetration of condensing boilers in the UK, which involved both a quantitative survey with householders and qualitative interviews with stakeholders including householders and heating engineers. He reports that over half of householders surveyed left the system choice, make and model to the installer, but that a 'substantial fraction' make these specifications without the input from the installer. However, he provides no detail on the survey, sampling methods or characteristics of these respondents so it is impossible to know the applicability of this information (2000b: 10). Meanwhile, a field trial measuring the efficiency of condensing boilers installed in properties in the United Kingdom found no correlation between boiler size and the heat demand of the forty three properties in the study, indicating that "boiler size is based on decisions by the boiler installer" which do not necessarily reflect the requirements of the property (Orr et al. 2009: 41). However, this study commenced only after the boilers had been installed, so whilst there is evidence to suggest the installer may be influential, their actual role remains unknown. Despite this, the requirement to be 'Gas Safe registered' to install a central heating system (as detailed in Chapter 3), means that heating engineers act as key intermediaries between customers and manufacturers. Indeed, in a study of the market penetration of condensing boilers within the European Union, Weber et al. suggest that "the role of installers cannot be overestimated" (2002: 313).

Furthermore, a rapid evidence review which focused on how heating controls affect energy demand in the UK context found that "installers, rather than domestic consumers frequently make decisions about which central heating controls to install and where to install them" (Munton et al. 2014: 7). However, this finding requires further investigation, and the authors note that during the review they found "very little robust empirical evidence with regard to questions of when, why and how new heating controls are installed" (Munton et al. 2014: 29). This highlights that, while it is suggested that heating engineers are influential in determining the products fitted in homes, there is little research on this potentially key role. This further emphasises the importance of exploring what role heating engineers have in shaping the central heating technologies fitted in homes. However, beyond considering the technologies installed, it is important to understand the ways that decisions are made about which devices to fit. In particular, the strategies that intermediaries might apply to this process, as discussed in the following section.

2.4.2 Intermediaries might be risk averse

Intermediaries apply their own preferences when shaping decisions about the technologies installed in homes. For example, instead of offering a universal set of technology options, professionals might choose from those they are familiar with (Scheuer 2007). This risk averse strategy has been identified amongst building professionals more generally (Schiellerup & Gwilliam 2009; Janda 1999; Killip 2013; Owen et al. 2014), and while it can limit the products that they suggest or encourage consumers to purchase, those operating in the built environment have good reason to adopt this approach.

Installers and advisers retrofitting low carbon technologies were found to operate "according to their own heuristics of risk and acceptability" (Owen et al. 2014: 176). Meanwhile, Killip (2013: 526) identified that construction SMEs perform a decision making process that includes an "informal but multi-faceted risk assessment" when considering new technologies. This includes the cost, the potential for disruption if the technology went wrong, and their knowledge of the technology. Related to this, Janda (1999) has argued that the priorities of both engineers and heating engineers also include a concern for call backs and reliability, leading them to suggest tried and tested solutions and products. For plumbers, this hesitance to change successful strategies and scepticism of new products and unfamiliar brands has been attributed to their dependence on reputation (particularly for those who are self-employed) (Bowden et al. 2012: 38). This is likely to be true of many within the construction sector, especially those working for SMEs who are more reliant on word-of-mouth for their business (Killip 2013). Banks' research provides some evidence that heating engineers share these risk averse tendencies, and he identified a reticence to fit condensing boilers at a time when they were new to the market, even when they were requested by the customer (2000b). However, this information is based on a sample of six heating engineers, and very little information is provided about their characteristics, for example, the types of property they install in. Therefore, we do not know how widespread this practice is. Further, this study was conducted fifteen years ago, so it is impossible to know what the implications are for the current social, policy and technological context. Despite this, it is important to consider how this practice might limit the deployment of new or alternative technologies in buildings, contrasting with the 'high-tech components and expertise' that are required to transition towards a more sustainable built environment (Rohracher 2001: pp.138-9). This is particularly relevant when evaluating the success of existing approaches to encourage the use of advanced technologies, particularly controls, in the installation of domestic heating systems (see Section 2.2.). Further, being risk averse can extend beyond the selection of technology and into the advice provided by intermediaries. For example, in their discussions, estate agents have been found to adopt a conservative position, acting to constrain environmental innovation with regard to the low-carbon building agenda (Schiellerup & Gwilliam 2009). Thus, this section has identified that intermediaries apply risk averse strategies in both product selection, but also the information they provide. Indeed, the extent of intermediaries' reach can be shaped by their own expertise and the ability that others perceive in them, this is particularly true if they are regarded as authoritative voices on particular subjects. As such, it is this advisory role that provides the focus of the following section.

2.4.3 Intermediaries as expert advisors

Intermediaries' advice can carry authority, making them crucial 'conduits for information' advising and facilitating the choices of others (Schiellerup & Gwilliam 2009). Intermediaries have more potential to exert an influence if they are considered experts by those they are advising (Bowden et al. 2012: 36), suggesting that it is likely to be important that intermediaries maintain their expert position. It has also been noted that some intermediaries (particularly SMEs) develop long standing and trusted customer relationships that might support their expert capacity, although this relationship has not yet explicitly been the subject of investigation (Bowden et al. 2012; DECC 2014b). The timing of their interaction with clients can also be influential. Killip (2013: 523) uses the notion of 'trigger points', arguing that particular domestic retrofits can act as intervention points to encourage additional retrofitting activity. Indeed, the installation of a central heating system is likely to provide one such trigger point. As discussed in Section 2.3.3, using focus groups, Rathouse and Young (2004) found that installers have a role in explaining and setting heating controls. However, they also highlight variable experiences and degrees of satisfaction with the advice provided, noting that:

> "There was widespread agreement that installers did not have the time to explain properly. People recognised that training up households was not really part of an installer's job but wondered whether someone else could visit or phone later to explain the controls to them."
>
> (Rathouse & Young 2004: 24)

This reveals ambiguity about the role of the installer in the provision of advice about the use of heating systems, particularly the controls. These participants did not feel that providing advice about heating controls was part of the installer's job; although this task is actually stipulated in guidance for installation, as detailed in Chapter 3. Instead they felt it was perhaps the responsibility of someone else, although suggestions for who this may be were not provided. However, despite this, studies continue to identify heating engineers as suitable messengers of operating information, under the assumption that they are in the property at 'an appropriate time' (proposed to be during the servicing of a boiler) and they are "seen as competent independent sources of advice" (DECC 2014b: 8). This study used a randomised control trial to test whether providing advice to social housing tenants about the use of heating controls could reduce energy consumption. This included a control group, a group that received advice via a leaflet, and a group obtaining advice from heating engineers who had received training on this. Through follow up interviews, tenants were found to value the tailored and individualised advice provided by engineers more than the generic advice provided in a leaflet (DECC 2014b: 21). The authors propose three 'ingredients' required for the engineer to be considered as a trusted messenger: a neutral or objective affiliation that gives them credibility; relevant and demonstrable skills and expertise; and, a friendly and personable manner of delivery (DECC 2014b: 41). This provides important insights, as it suggests that heating engineers can act as trusted efficiency advisors, and shows what end users might require from an intermediary. However, it does not tell us whether intermediaries themselves perceive this trusted messenger role to be a part of their job. The engineers taking part in this trial were explicitly tasked with providing energy efficiency advice during a boiler check and they were equipped with training and specific information ahead of performing the intervention. Thus, whilst there is some evidence that installers could act as advisors, whether they are actually doing so is unclear. Although this study suggests that heating engineers are important in the provision of advice it tells us little about the everyday practices of heating engineers who have not been trained in this way, and whether, for example, their day to day work includes this task.

The evidence presented in this section has demonstrated that intermediaries, in particular heating engineers, can act in an advisory role. However, we do not know the extent to which they actually do this, or whether any advice they may provide is sufficient in enabling occupants to use their central heating systems. Furthermore, to understand the potential extent of the engineers' role, it might be important to extend our consideration beyond the intermediary and the customer. Indeed, there is evidence to suggest that these individuals operate within more extensive networks that can influence what happens in the home. Consequently, these wider networks provide the focus of the final part of this review.

2.4.4 Intermediaries are part of wider networks

Janda and Killip (2010) argue that a systems approach is essential to understand the active role of different actors within construction networks. Retailers and other businesses in the supply chain might be considered 'middle agents' within the built environment, particularly when they offer expertise (Janda & Parag 2013). Based on interviews with customers, heating engineers, boiler and controls manufacturers, housing developers and housing associations, Banks (2000a; 2000b) proposed a network of actors involved in the specification of heating equipment. However, he does not provide detail on the characteristics of this sample, nor how they were recruited, so it is difficult to know whether this work is applicable to today's multi-faceted central heating industry (Chapter 3 will address the structure of the industry in more detail). Further, this research was specifically focussed on the dissemination of condensing boiler technologies, and we know nothing of how this network may have changed in subsequent years, particularly amongst shifting policies and technologies. More recently, Killip (2013) used qualitative interviews with sixteen actors working within construction SMEs to identify the importance of their relationships with other tradespeople, sub-contracting practices and supply chains. Middle actors' 'sideways' influences potentially extend to those within their own practice, but also those of 'compatriots and competitors' (Janda & Parag 2013). In particular, Janda and Parag (2013: 48) note the enabling role of these actors in transferring innovations and practices through 'social learning and professional norms and requirements'. However, action research with plumbers found that they consider other independent plumbers as competition, instead they navigate within broader professional networks that comprise other trades such as electricians or builders (Bowden et al. 2012). In keeping with the heterogeneity of these networks, Janda and Killip (2010: 121) position manufacturers and suppliers as 'key stakeholders' in meeting the low-carbon refurbishment agenda. Thus, wider networks are likely to have a role in shaping the actions of building professionals. Against this backdrop, it becomes clear that we cannot consider middle actors, in this case heating engineers, as stand-alone entities. There is evidence that these individuals operate within wider networks, and there is a clear need to develop our understanding of how these networks operate, and their influence. In particular, it would be fruitful to explore the influences that shape engineer practices, and how these operate.

2.4.5 How heating engineers might be important intermediaries

This final section of the literature review has identified a series of ways in which the system installer could be influential in shaping the energy consumed through space heating. Intermediary building professionals and practitioners neither produce nor consume energy, but they can shape the way it is used. Despite heating engineers being one such intermediary, their role has been largely overlooked to date. There is some evidence that heating engineers make decisions about the heating devices and controls installed in homes, that they provide advice about the use of these technologies and that they share the risk averse tendencies of other intermediaries. However, we lack rigorous information on exactly how this role is performed. In particular, this review has noted the small amount of information we currently have on the potentially significant role of heating engineers and emphasised the need to collect further detail on the ways in which they might shape the energy consumed through space heating. Against this backdrop, I now delineate the findings of this review, and turn to identifying a research question that can advance our understanding of this.

2.5 Summary and research question

This chapter commenced by problematising current policy strategies that attempt to reduce the energy consumed through space heating on the basis of technological and economic rationale. Here, I argued that alternative disciplinary perspectives, in particular, sociology, anthropology and STS are valuable in understanding and interpreting the complexities of energy consuming practices. Yet, whilst these approaches have the capacity to reveal extensive insights, our current understandings of the energy consumed through space heating focus on technologies and end users. In particular scholars have identified variable internal temperatures and settings amongst occupants. These variations have been attributed to sociodemographic factors, different thermal comfort practices, mixed understandings of controls and the limited usability of control devices. However, interrogating the problem from these multiple perspectives reveals limitations in our understanding of each. No matter which approach we use, the role of the installation process and system installer in shaping the energy consumed through space heating has been overlooked. Having identified this potential significance, this review then presented evidence that intermediaries can be influential in the built environment. In particular, intermediaries shape the products installed in homes, and there is evidence that they apply their own risk assessment strategies to this process. Further, they can act as expert advisors and they do not act alone; they are part of wider networks. However, aside from Banks' now dated and more limited investigation, we know little of the intermediating role that heating engineers might have in shaping the central heating technologies installed in homes, and their use.

Throughout this discussion, I have highlighted the ways in which the central heating installer, and installation process, might be influential. However, because this has not previously been subject to significant academic investigation, it is essential to proceed with an open mind to understanding the ways in which installation can shape the energy consumed through space heating. With an awareness that there are numerous ways in which the installer, and installation process, could shape space heating practices, there is one overarching research question informing the remainder of this investigation:

How do heating engineers, and installation practices, shape the energy consumed through domestic central heating systems?

Given the limited knowledge we currently have of the role that central heating installation plays in shaping space heating practices, it is important that my research strategy remains open. As such, what follows in the remainder of this thesis is an emergent, interpretive approach to answering these research questions, and Chapter 4 will discuss the research methodology in greater detail. It is as a result of this strategy that new literatures are introduced and engaged with throughout the remainder of this thesis, as they are appropriate to the topic under discussion. For example, theoretical literatures are discussed and utilised within the empirical chapters to which they apply. Before proceeding to the empirical portion of this thesis, it is important to first examine the regulatory expectations surrounding central heating technologies, installers and the installation process. This information is essential for understanding the context in which these actors operate, and some of the factors that may shape the installation process.

3 The system, the installer and the installation process

3.1 Setting the scene

The first stage in answering the exploratory research question previously identified is to outline what we currently know of central heating systems, the installer, and the installation process. Given its significant contribution to the energy consumed in buildings (highlighted in Chapter 1), it is perhaps unsurprising that domestic central heating is currently an important target in several facets of UK policy making. The Committee on Climate Change (CCC) have identified the replacement of boilers with new energy efficient models as one of their key indicators for achieving significant emissions reductions in buildings. They highlight the success of this strategy in the UK, noting that:

> "Boiler replacement continued at a steady pace throughout the first carbon budget period, with an annual average of 1.6 million new efficient boilers installed from 2008 to 2012. In 2013, a further 1.5 million A-rated boilers were installed which means that cumulative uptake by 2013 was 1.8 million higher than our indicator"
>
> (CCC 2014: 164)

With this replacement rate, the uptake of new boilers is the only one of the CCC's (2014) indicators for buildings that is on track or outperforming the targets set to meet the Government's ambitious emissions reduction goals (outlined in Chapter 1). This high rate of installation is buoyed by current strategies to deliver energy efficiency improvements to domestic properties, in particular the government's Energy Companies Obligation (ECO) and Green Deal schemes (CCC 2014). Although these schemes include numerous technologies, including wall insulation, double-glazing and micro-generation, the replacement of gas boilers has proven to be a popular strategy adopted under them. By September 2014 over 200,000 boilers had been installed under Green Deal and ECO since their launch (DECC 2014c). In addition, the installation of advanced heating controls is encouraged through the Building Regulations (this will be discussed in Section 3.2) and the adoption of smarter heating controls[1] is building momentum. For example, the Department of Energy and Climate Change (DECC) are currently undertaking the Smarter Heating Controls Research Programme, which aims to gather robust evidence on the energy saving potential of these devices (DECC n.d.). Moreover, in advancing the next step in the transition from mechanical to electronic controls (see Section 2.3.4 and Peffer et al. 2011), the majority of controls manufacturers now have a smarter control proposition infiltrating the market, including Nest (from Nest), Lyric (from Honeywell), Hive (from British Gas), and Wave (from Worcester Bosch), to name a few.

It is clear then, that central heating technologies are receiving significant attention within current policy and industry contexts. This provides an important opportunity to more fully understand what happens at the critical moment of central heating installation. As discussed in Chapter 2, the success of these policies and technologies rests significantly on the users, but also potentially the installers of these devices. In this chapter, I provide a more detailed introduction to central heating systems, and those tasked with installing them. For this, I draw on the foundation of legislative and regulatory documents underpinning the installation process, highlighting ambiguities and limitations within the regulations that might leave technology choices and installation procedures open to interpretation. Drawing on these documents, this scene setting chapter commences by detailing the technical requirements of central heating systems. Following this, I turn to the installers of domestic central heating systems and how their suitability for this job is defined, before outlining the different stages of the installation process. Revealing the complexities of the system, the installer and the installation process further emphasises the need to explore what happens during installation, and provides an essential backdrop to the empirical material presented in Chapters 5-8.

3.1.1 Legislative, normative & informative documents

[1] Smart controls may connect with other electronic equipment (for example, phones and laptops), allow remote control from outside of the home, and 'learn' occupants' routines to determine and manage heating patterns (DECC n.d.).

The installation of central heating systems is shaped and governed by a vast number of regulations and guidance, detailed in a Legislative, Normative & Informative Document List (L, N & I List) (GSR 2014c), which is updated quarterly. It is Gas Safe Register, who oversee the standards of those working on domestic gas, that compile this list. This organisation is central to the work of heating engineers; their role is discussed in more detail in Section 3.3. The L, N & I List is numerous, including documents that apply to all aspects of domestic gas work, and the different technologies that those working in this area may have to manipulate. However, for the purposes of this discussion, I consider only those documents relating to gas central heating systems. These systems are complex; they combine several different components, all of which have to be aligned during the installation process. For example, the boiler alone contains gas, water, and fire, all of which have their own requirements to be accommodated. Because of this, there are an extensive number of documents (over 80) informing the installation of gas central heating systems. Further, the complexity of these regulatory foundations is intensified by the involvement of numerous organisations in writing and implementing these requirements (the core organisations are identified in Table 3.1).

The work of heating engineers is shaped by these complex requirements; however, many of these are tangential to the energy considerations of this thesis. For example, safety is one of the industry's key priorities, providing the focus of several items of regulation and guidance, and forming a significant consideration in the tasks that heating engineers perform (this is addressed more in Sections 3.3 and 3.4). However, of most importance to this research are those documents concerned with the technical system requirements relating to energy efficiency and those stipulating the responsibilities placed on the installing engineer. It is these that are of primary relevance to this thesis, and have been consulted to inform the remainder of this chapter (and indeed, this thesis). Table 3.1 provides a summary of these documents, with a brief description of the purpose of each.

Document type	Document Name	Author[2]	Contents
Legislative documents - statutory acts and regulations that are legally enforceable	Building Regulations (England and Wales) 2010	HM Government	The Building Regulations set out requirements for the "provision or extension of a controlled service or fitting", including the installation of a "heat producing gas appliance" (HM Government, 2010, p.7 and p.45).
	The Gas Safety (Installation and Use) Regulations 1998 (England, Scotland & Wales)	HSE	This document sets out the requirements for the installation of gas systems, making "provision in respect of the installation and use of gas fitting for the purpose of protecting the public from dangers arising from the distribution, supply or use of gas" (HSE, 1998, p.23).
Second Tier documents - provide practical guidance on ways to comply with the functional requirements of Regulations	L1A: Conservation of fuel & power (New dwellings)	HM Government	Part L stipulates that "reasonable provision shall be made for the conservation of fuel and power in buildings" (HM Government, 2010 p.39). This includes providing fixed building services which are; i) energy efficient, ii) have effective controls; and iii) are commissioned by testing and adjusting as necessary to ensure they use no more fuel and power than is reasonable in the circumstances." (HM Government, 2010, p.39).
	L1B: Conservation of fuel & power (Existing dwellings)		
	P: Electrical Safety (dwellings)		These documents provide guidance on how to comply

	J: Combustion Appliances & Fuel Storage Systems		with Part P and Part J of the Building Regulations, respectively.
	Domestic Building Services Compliance Guide	DCLG	This guide outlines the minimum energy efficiency standards, and guidance to aid compliance with the energy efficiency requirements of the Building Regulations.
	L56 - Safety in the installation & use of Gas Systems & Appliances (fourth edition)	HSE	Approved Code of Practice and guidance to aid compliance with the Gas Safety (Installation and Use) Regulations 1998.
Normative documents - gas industry standards aimed specifically at the installation, commissioning or maintenance of gas equipment	BS 6798: 2009 - Specification for installation of gas-fired boilers of rated input not exceeding 70 kW net	BSi	Specify the requirements for the design, selection, installation, inspection, commissioning and maintenance of gas-fired boilers for central heating.
	BS EN 12828: 2012 - Heating systems in buildings - Design for water-based heating systems		
	BS EN 14336: 2004 Heating systems in buildings. Installation and commissioning of water based heating systems		

<table>
<tr><td rowspan="4">Informative documents - information that provides "invaluable and useful information to help enable Registered Businesses to comply with their obligations and assist them in carrying out their day to day activities"</td><td>CIBSE Domestic Heating Design Guide</td><td>CIBSE</td><td rowspan="3">All of these documents are written to help installers in the selection, installation and commissioning of central heating systems. In particular, offering guidance to help ensure compliance with the Building Regulations, and achieve energy efficient systems. These are targeted at heating engineers, they interpret the relevant legislation and regulations, and present it in a more accessible format.</td></tr>
<tr><td>CE30 - Domestic heating by gas: boiler systems - guidance for installers and specifiers</td><td>EST</td></tr>
<tr><td>HHIC Code of Practice for the installation, commissioning and servicing of domestic heating and hot water products</td><td>HHIC</td></tr>
<tr><td>All published Gas Safe Register Technical Bulletins</td><td>Gas Safe</td><td>These provide updates on the standards and procedures outlined in the above documentation to gas engineers. They are published in Registered Gas Engineer magazine, a monthly publication that is sent to all engineers registered with Gas Safe.</td></tr>
</table>

Table 3.1 The legislative, normative and informative documents detailing the technical requirements of central heating systems, and the responsibilities of the system installer, adapted from (GSR 2014c).

These documents have been used in the following discussion to identify the technical requirements of central heating systems, and the expectations placed on the installer. In this, I will identify salient points for the energy efficiency of the systems, and areas where this guidance might be open to interpretation.

3.2 The central heating system

In order to understand the energy consumed through space heating, it is first important to know what a central heating system is and how it operates. The system's energy consumption is determined by the way in which it is used, for example duration of heating and control settings, but also its technical configuration and the building in which it is positioned (as discussed in Chapters 1 and 2). In this section, I focus on the technical aspects of the central heating system, in particular, the way in which energy efficiency is influenced by the system design. Central heating systems are constituted of a complex array of individual components; these may be arranged in different ways to cater for the requirements of a specific property and its occupants. Important design factors include: power output of the boiler in relation to its design heat load and radiator sizes; flow and return water temperatures; and the system controls (CIBSE 2013). Moreover, each system component is subject to its own requirements, along with individual guidance on how to install it. Initially, I will introduce the major components of a central heating system (see Glossary for definitions of the key components discussed) before elaborating on the design and positioning requirements of these items. It is essential to be aware of these requirements, and the ways in which compliance shapes the energy consumed through central heating systems, before exploring whether or not they are fulfilled during the lived realities of heating installation.

3.2.1 The system components

A gas boiler usually provides both space heating and hot water to the household. Hot water can be provided either directly via a combination boiler, or indirectly, via a regular boiler. A combination boiler provides instantaneous hot water by heating mains water as it is demanded at an outlet (i.e. a tap or shower). This is the simplest system type, with only the boiler, radiator circuit and controls managing the heating to consider (see Figure 3.1).

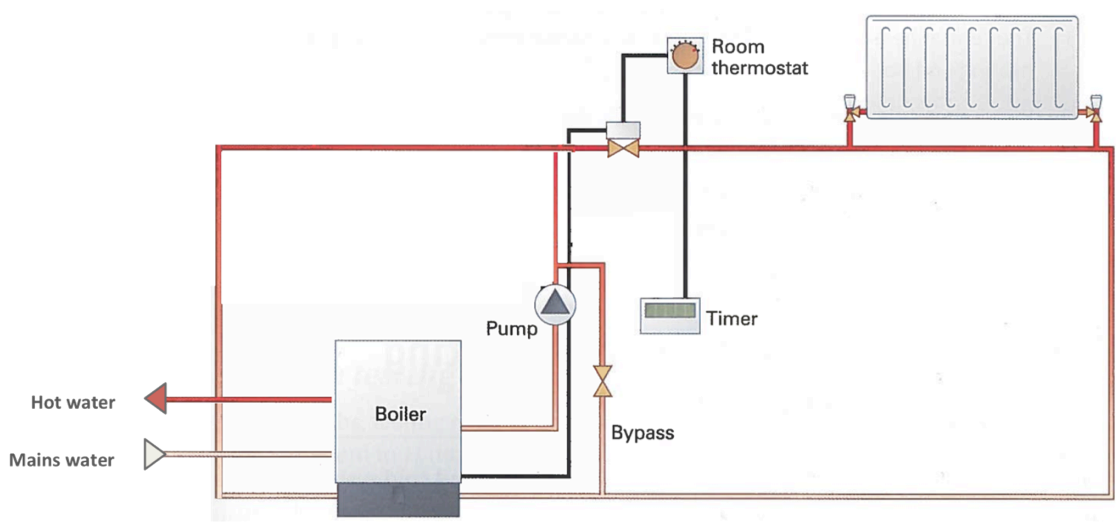


Figure 3.1 Components of a fully pumped system with a combination boiler. Adapted from (JTL 2008: 295).

Alternatively, hot water is sourced indirectly, via a system boiler combined with a hot water storage cylinder (see Figure 3.2). The cylinder contains a heating coil through which hot water from the central heating circuit flows, this acts as a heat exchanger, increasing the temperature of the water stored in the cylinder as it passes through. Thus, with a system boiler, additional considerations are the cylinder and a series of motorised zone valves (labelled '2 port valve' in Figure 3.2) which direct the flow of the water through the circuit as it is required.

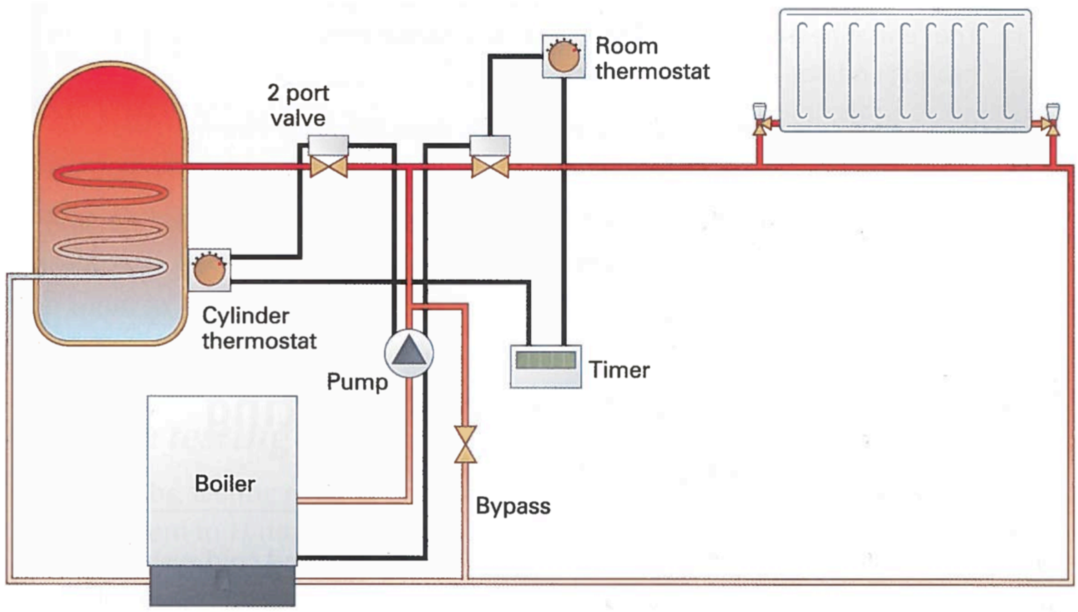


Figure 3.2 Components of a fully pumped system using two 2 port zone valves to direct the heating and hot water flows. Source (JTL 2008: 295).

With regard to the control of these systems, Part L of the Building Regulations stipulates that fixed building services must "have effective controls" (Government 2010: 39). The minimum control requirements for a system boiler are: a programmer with independent controls for heating and hot water, a room thermostat (these can be combined in a programmable room thermostat), Thermostatic Radiator Valves (TRVs) on all radiators except in rooms with a room thermostat, a cylinder thermostat and boiler interlock (DCLG 2013) (these are introduced in more detail in Appendix III). The same applies for a combination boiler, but neither independent hot water controls, nor a cylinder thermostat are required in this instance (EST 2008). Boiler interlock is a wiring arrangement that prevents the boiler from firing (generating heat), and turns the pump off when there is no demand for heat and hot water (EST 2008: 24). This arrangement, achieved using a programmer, thermostat and motorised zone valve (which directs water in the system around the heating and/or hot water circuits), is essential for maximising system efficiency. Electric temperature control is required to manage the temperature of the hot water (where this is not provided by a combination boiler); this is achieved through use of a cylinder thermostat and accompanying zone valve. In addition, it is regarded as 'good practice' to zone any property with a total floor area above 150m^2 (DCLG 2013: 18). Zoning is the provision of multiple independently controlled space heating zones, for example, the separation of upstairs and downstairs. All of these controls and wiring arrangements are detailed further in Appendix III. Designing a central heating system includes consideration of numerous components, the main ones discussed here are the boiler, radiators, water tank and controls. A key design factor shaping the energy consumed by these systems is their sizing, that is the heat output of the boiler and radiators, which I will address before proceeding to discuss the positioning of the system.

3.2.2 Sizing the system

Regardless of whether a combination or a system boiler is used, it is required to be condensing, with a SEDBUK[3] 2009 efficiency rating of at least 88% (DCLG 2013: 15). It is suggested that central heating systems with condensing boilers should be designed to have primary return water (that is, the water returning to the boiler after flowing through the radiator circuit, indicated by the pale red pipes in Figures 3.1 and 3.2) temperatures of "less than 55 °C" (DCLG 2013: 15). For the boiler to work in condensing mode, the return water has to be cool enough for the water vapour in the flue gases to condense, hence this specification (see Appendix I for detail on the operation of condensing boilers). Newer boilers have an improved operating efficiency, regardless of whether they are operating in condensing mode or not. Thus, whilst it is not essential that the boiler operates in condensing mode all the time to achieve improved efficiency, maximising this is desirable (EST 2008).

[3] The Seasonal Efficiency of Domestic Boilers in the UK (SEDBUK) is calculated for every model of boiler by taking laboratory tested full -load and part-load boiler efficiencies and correcting with factors including 'boiler type, ignition arrangement, internal store size, fuel used, and knowledge of the UK climate and typical domestic usage patterns'. This estimate of the average annual efficiency achieved is used to provide a fair comparison of the energy performance of different boilers (BEPA 2014). This calculation, and the associated SEDBUK rating, form part of the Standard Assessment Procedure (SAP) methodology used to compare the energy performance of dwellings.

The correct sizing of both the boiler and radiators are crucial for achieving an efficiently operating system. A method for the sizing of boilers and radiators is detailed in BS EN 12831: 2003, and a summary of this procedure is provided in Appendix II. If a boiler is under-sized it may not have sufficient output to meet its maximum load (i.e. it will be unable to heat the property to the desired temperature on a cold day). The maximum load includes the heat used by the radiators, the hot water system, and that lost through the pipework. The biggest load on the boiler is usually hot water, rather than heating, and so this may be the determining factor in selecting the boiler size for both combination and system boilers (EST 2008). System boilers need to be of a sufficient output to heat the contents of the hot water cylinder rapidly, and the recommended allowance for this is estimated according to the size of the water cylinder (CIBSE 2013). For combination boilers, because the water is heated as it is demanded it is important to ensure that the output is sufficient to achieve an acceptable flow rate and pressure at the outlet. Because of this, the power required for hot water is usually in excess of that for space heating (CIBSE 2013). In both cases, the size of dwelling, number of occupants and potential demand for hot water at multiple outlets are all significant considerations. However, it is also important that the boiler is not over-sized, which may cause excessive cycling[4], and reduce the overall operating efficiency (CIBSE 2013: 64).

Additionally, size-for-size replacement of existing boilers is not recommended, because the thermal properties of the dwelling may have changed (for example, increased insulation and more thermally efficient windows) and the original sizing is not always correct (EST 2008). Moreover, to achieve the low return temperatures required for condensing operation, the radiators must also be correctly sized (DCLG 2013). Under-sized radiators may not heat rooms satisfactorily, and may lead to

[4] This is a process where the boiler detects that stored water in its heat exchanger is cooling and fires up to re-heat it, even though the system is not calling for heat - this means that the boiler is wasting energy to heat water that is not needed in the home. This can be prevented by ensuring that the correct system controls are in place, in particular boiler interlock.

excessive boiler cycling and reduced condensing operation if the water flowing through them does not reduce in temperature sufficiently (EST 2008). Meanwhile, over-sizing radiators may lead the property to overheat. Whilst thermostatic radiator valves (TRVs) attached to each radiator can help to manage the temperature in each room (their function is elaborated in Appendix III), they are not a replacement for appropriately sized radiators. Thus, sizing calculations are required to ensure that both the boiler and radiators are correctly sized for the property.

The basis for sizing calculations is that, to achieve a particular temperature within a property (the 'internal design temperature'), the heat output of the system must equal the property's heat loss through the building fabric. Calculation of heat loss requires measuring the room dimensions, inputting standard U-values[5] for the building elements, and assuming an internal design temperature for each room (in Chapter 2, I discussed how the use of these standardised internal design temperatures reinforces conventions of thermal comfort and energy consuming practices). Radiators should be sized to cater for the heat load of each room, individually. The boiler should be sized to cater for heat load of the property, but also hot water requirements, including the volume and flow rate[6] of hot water that might be needed (CIBSE 2013). Beyond sizing, the positioning of the system components is a key consideration during the design of the central heating system, and positioning constraints therefore also influence the products installed.

3.2.3 Positioning the system

[5] A U-value is a measure of the rate at which a building element (for example, a wall, window, floor or ceiling) conducts heat. It is the number of Watts that will flow through an area of one square metre when subjected to a temperature difference of 1 Kelvin (CIBSE 2013).

[6] This might also shape system choice, combination boilers are subject to lower hot water flow rates than stored hot water tanks, because mains water is heated as it is demanded.

In positioning the boiler (or selecting a boiler appropriate for the available space), thought must be given to the physical space, access requirements, and all of the pipes that connect into and out of the boiler. These include the central heating flow and return, hot water pipework, the flue pipe, condensate drain, overflow pipe and gas inlet (see Appendix I). Boilers are usually wall-mounted but they can also be situated on the floor. Either way, they must be sited in a position that is "readily accessible for operation, inspection and maintenance" (HSE 1998: 15). The boiler has to be positioned so that a flue can be extended outside the building, providing an adequate supply of air to the system and for the expulsion of combustion products. The acidic condensate has to be disposed of safely via connection to specified drainage pipes (for example, into an external drain or rainwater downpipe), whilst the length of pipe run and number of bends have to be minimised in order to prevent the trapping and freezing of condensate (BSi 2009). The gas inlet pipe runs between the gas meter (where gas enters the property) and the boiler, this must be of a sufficient diameter to ensure that the correct gas operating pressure[7] can be achieved at the boiler (HSE 2013). The purpose of each of these are discussed in Appendix I, which elaborates on the operation of condensing boilers. If an indirect system (with a system boiler and separate water tank) is being used, the water tank also needs to be allocated a position. Finally, the length of hot water pipework to taps and other outlets ('dead legs') should be minimised, this is with the aim of reducing the amount of cold water drawn off (and potentially wasted) before the arrival of hot water to the outlet (CIBSE 2013: 72). Thus, the boiler is not a stand alone entity, it is connected to the property, and devices such as the gas meter, as well as to the remainder of the system. This includes the radiators, for which location is also an important design consideration because it can influence their operating output. It is "normally recommended" that radiators are placed below windows to reduce cold down draughts (CIBSE 2013: 8; BSi 2013a: 63). It is also recommended that radiators should be located on outside walls, and should be of "such a length that [they] occup[y] the full width of the window" (BSi 2013a: 63), whilst also accounting for the probable layout of furniture, and factors that could affect the radiator's output,

[7] The pressure of gas at which the boiler is designed to operate.

such as full-length heavy drape curtains (which could cover the radiator) (CIBSE 2013).

Finally, it is important to consider the positioning of central heating controls, which can influence not only how they are used (see Chapter 2), but also the way in which the system operates. This is particularly true of thermostatic controls. For example, if the thermostat is placed in a location which is colder than the rest of the property (such as a north facing room), it could activate the boiler when heat is not needed elsewhere, leading to potentially excessive use of the boiler and over-heating. Consequently, as described by the BSi:

> "Care should be taken when siting an air temperature sensor to ensure that the position chosen is representative of that part of the system which it controls. It should be sited so as not to be exposed to draughts or cooling effects and away from any heat sources, e.g. radiators and direct sunlight. The sensor should be fitted 1,5 m from floor level and in a position readily accessible to the user."
>
> (BSi 2013b: 46)

The Energy Saving Trust (EST) also notes that thermostatic devices should be positioned where there is free movement of air, and where there is no supplementary heating (EST 2008). However, when considering the use of controls, the significance of location extends beyond thermostatic devices, to all controls, which should be accessible for "setting and servicing" (BSi 2013b: 7), or where they "can be easily reached, read and altered" (EST 2008: 47). It has also been noted that units should not be "hidden away in a cupboard or behind furniture", with the EST specifically advising "[d]o not fit them in places inconvenient for the householder (e.g. in an airing cupboard)" (2008: 47). However, this advice on the positioning of controls is not required by the Building Regulations, instead it is contained in supplementary guidance and advice. With this in mind, it is pertinent to consider the degree to which the requirements and guidance discussed in this section are met in practice. In Chapter 2, I presented evidence that they may not be, and discussed the implications of this for the usability of controls. As the current discussion has highlighted, there are many factors to consider in the design and positioning of a central heating system, and some of the guidelines are somewhat ambiguous and could be open to interpretation. This again points to the key role of the installer in the choice, positioning and installation of a central heating system. In the next section I elaborate on the expectations placed on the system installer, and on the tasks placed within their remit.

3.3 The system installer

Considering the individuals tasked with installing these systems reveals a series of complexities that might feed into the installation process. Further investigation of heating installers reveals a varied group of individuals, along with a series of training, assessment and monitoring processes at play in the heating industry. As potential sources of variation in the installation process, it is essential to elaborate further on the installer and the factors that shape their work. The first stage in understanding the job of the system installer is to detail the composition and scale of this workforce. Heating engineers are numerous, disparate and hard to monitor. According to the Gas Competence Review, the Gas Safe Register is composed of 73% sole traders, 19% small businesses and only 8% large business (GSR 2011: 22)[8]. Interestingly, the same document later contradicts itself, noting that 81% of the Register are sole traders (GSR 2011: 28). Whilst this difference is perhaps indicative of the difficulties in monitoring this workforce, the estimates do highlight the dominance of micro[9] and small enterprises in the sector. Similarly, there is ambiguity in the exact scale of the industry. Recent census data identifies 153,000 people in England and Wales who are employed as 'plumbers and heating and ventilating engineers' (ONS 2011b). Meanwhile, Gas Safe Register (Gas Safe) provided me with an estimate of registered gas engineers:

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[8] These estimates are based on an on-line survey completed by 6580 operatives registered with Gas Safe (GSR 2011).

[9] A microenterprise is defined as "those employing fewer than 10 persons and whose annual turnover and/or balance sheet total does not exceed EUR 2 million" (EC 2003: 39).

> "The number of businesses and engineers on the Register ebbs and flows on a daily basis as people retire and join and it is not something we publish formally but the most recent figures I have are just under 70,000 business registrations and just over 135,000 engineer registrations (Worth noting that does not mean 135,000 engineers as a percentage will hold multiple registrations if they work for multiple companies)."
>
> (Gas Safe, email comm. 2013.12.04)

That the number of registrations changes frequently makes it difficult, even for Gas Safe (the body responsible for maintaining a database of registered engineers), to derive an accurate figure. The 135,000 registered gas operatives do not necessarily all install domestic gas central heating systems because, according to the *Gas Safety (Installation and Use) Regulations 1998*, any individual working on downstream gas[10] must be registered with Gas Safe. This means that someone solely fitting gas meters would be included in the 135,000 registered members but feasibly never touch a boiler. Furthermore, some individuals may work both independently and for an organisation (e.g. subcontracting) and, as a result, they may be registered twice, making it difficult to accurately ascertain the number of individuals installing domestic central heating systems. These statistics are further complicated by a number of individuals working on gas illegally. Without being registered, these individuals fall under the radar of Gas Safe, making them something of an unknown entity. A Gas Safe representative estimated 7,500 illegal gas installers, based on extrapolations from the number of illegal installations they inspect (fieldnotes, Gas Safe meeting, 2013.11.28). Finally, this industry is male dominated; 2011 census data revealed that approximately 98% of people employed in the skilled construction and

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[10] The UK onshore gas industry covers transmission, distribution and utilisation. The point of change from 'upstream' gas (transmission and distribution) to 'downstream' gas (utilisation) is the gas emergency control valve (ECV) (used for shutting off the supply of gas in an emergency) in a dwelling (GSR 2011: 15). Therefore, downstream gas accounts for the gas used in properties, but not the transmission and distribution network.

building trades are male[11] (ONS 2011c). This was a key consideration in the conduct of this research and will be elaborated in Chapter 4, where I discuss my experience of recruiting and interacting with the participants of this research.

The statistics presented, and their accompanying caveats, reveal the challenges involved in identifying, monitoring and shaping the practices of those who install domestic heating systems. Further, the composition of this male dominated workforce, made up of a majority of sole traders, who can be difficult to monitor, presents a particular challenge with regard to ensuring that central heating installation is performed in ways that meet the technical requirements previously outlined. For a better understanding of this, I now turn to the industry's strategies to standardise the installation work performed by these individuals through registration, training and assessment.

3.3.1 The competent heating engineer

The central document governing the action of heating engineers is the *Gas Safety (Installation and Use) Regulations 1998* (GSIUR), which states that:

> "No person shall carry out any work in relation to a gas fitting or gas storage vessel unless he is competent to do so."
>
> (HSE 1998: 5)

This requirement to be competent, and the definition, acquisition and demonstration of competence, are what underpins the management and operation of the gas industry. Domestic gas safety is overseen by the Health and Safety Executive (HSE), the government body responsible for the prevention of death, injury and ill health in workplaces (HSE n.d.). Gas Safe Register was appointed by the HSE in 2009 to

[11] In keeping with this, all of the participants of this research are male. As such the masculine pronoun is used throughout when referring to heating engineers.

operate a registration scheme for competent gas engineers. The organisation has an officially defined remit, dealing "with the registration, inspection and complaint investigations concerning registered businesses and investigations involving unregistered/ illegal gas workers" (GSR 2011: 15). Gas Safe inspections are conducted by 76 Regional Inspection Officers located throughout the UK (Gas Safe meeting, 2013.11.28). During these inspections, the engineer's work is checked to ensure that it complies with both the GSIUR and the manufacturer's installation manual. The limited number of officers means that inspections can only be conducted on a small portion of installations and tend to focus on those individuals that are new to the industry, although the handful of the large organisations operating have a dedicated inspection team because of the significant proportion of engineers that they employ (Gas Safe meeting, 2013.11.28). The overarching aim of inspecting gas installations is to assess whether a person is operating 'safely and competently' (Gas Safe meeting, 2013.11.28). It is worth emphasising that the priorities of these inspections, and the documents that the quality of the installation is examined against, are safety and competence. Thus, the focus of this thesis, energy efficiency, may sit somewhat tangentially to the priorities of the gas industry; this is explored further in subsequent empirical material.

Defining competence

The key requirement to perform gas installations is to be competent. Competence can only be attributed to an individual by being "a member of a class of persons approved for the time being by the Health and Safety Executive" (HSE 1998: 5). As the only body with approval as this 'class of persons', registration with Gas Safe is an essential requirement to demonstrate competence (HSE 2013: 23). In order to be registered as competent, an engineer must first prove that they possess competence. This is achieved through gaining experience, along with formal training and assessment. There are, in fact, several elements to competence, which is defined by the industry as:

> "A combination of practical skill, training, knowledge and experience to carry out the job in hand safely, and ensuring the installation is left in a safe condition for use. Knowledge must be kept up-to-date with changes in the law, technology and safe working practice."
>
> (HSE 2013: 22)

Therefore, competence is obtainable with training, which can deliver both practical skill and knowledge, and experience, which can only be accumulated over time working in a particular profession. Thus, obtaining competence is not as straightforward as sitting an exam. Furthermore, the definition also recognises the changing nature of competence; the engineer is required to remain informed of changes, maintaining and updating his competencies as the aims and expectations of installation shift. Finally, within the definition, safety is mentioned three times, again emphasising its significance in the regulations, training, guidelines and registration within the gas industry[12]. This prioritisation also suggests that other aspects to a successful installation, for example, energy efficiency, may be less of a priority for the industry.

Acquiring competence

In order to register with Gas Safe, an engineer must first prove their competence through assessment. However, within this assessment there are a myriad of ways in which the individuals installing gas central heating systems can come to possess different knowledge, skills, and installation practices. The only assessment route is through the Nationally Accredited Certification Scheme for Individual Gas Fitting

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[12] CORGI, the first gas registration scheme was established in 1970, with the first Gas Safety Regulations in 1972 (GSR 2011: 13). The inception of these was in response to a gas explosion at Ronan Point tower block in Newham in 1968, which resulted in four deaths and the partial collapse of the building (GSR 2011). This incident was cited several times by participants and industry representatives during my time in the field.

Operatives (ACS). New entrants must sit this following initial training, whilst practicing engineers must repeat the assessment every five years (HSE 2013: 21). This assessment is overseen by E&U Skills[13], who are tasked with the development of competence standards (that is, standards of training and assessment that are written to ensure compliance with GSIUR) (GSR 2011).[14] The assessment is modular and there are 117 individual assessments that a gas operative can sit (GSR 2011: 34). Further, it is through sitting different combinations of these assessments that individual gas engineers might have very different skill-sets to one another.

With specific reference to domestic gas engineers, all are required to complete CCN 1 (Core Domestic Gas Safety). To work specifically on central heating, the engineer is also required to complete CENWAT (Central Heating Boilers & Water Heaters), which is accompanied by CPA 1 (Combustion Performance Analysis) (SMB 2011: 4). Following this, the engineer can specialise depending on the other technologies they wish to work on, for example CKR 1 (Domestic Cooking Appliances) and MET 1-2 (Domestic Natural Gas Meters) would be required to perform any work on cookers and gas meters. The 117 available assessments also cover different fuel types (for example, LPG) and non-domestic work. A gas engineer's specialisation becomes formalised when he is issued with a Gas Safe Register photo licence (Figure 3.3). The licence is valid for one year, it contains a licence card number, an image of the engineer, and details the specific areas that the engineer is qualified to work in.

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[13] The distinction between accreditation (E&U Skills) and registration (Gas Safe) is often not recognised by those working in the industry (GSR 2011), with many of my own participants referring to ACS as the 'Gas Safe assessment'. Whilst Gas Safe may feed information about training to E&U Skills, they do not possess responsibility for this (fieldnotes, Gas Safe meeting, 2013.11.28). This is likely to be a legacy from Gas Safe's CORGI predecessor, who were involved in registration, training and assessment.

[14] E&U Skills manage professional development and employment in the energy and utilities industries, encompassing gas, power, waste management and water (EUSkills 2015).

Figure 3.3 A competent, Gas Safe registered engineer is required to carry a double sided Gas Safe Register photo licence, source: (GSR 2015).

This assessment structure means that the 135,000 registered gas operatives are not a homogeneous group, they each have varied skills and specialisations. This variability is another potential challenge in identifying, monitoring and influencing those installing domestic central heating systems.

Further, variation amongst this workforce stems not only from different assessments, but also from the different training trajectories that engineers pursue. In order to reach the assessment stage, an engineer must possess the qualifications and experience necessary to be classed as acceptable for entry to the ACS assessment. This is applicable to both existing engineers (who are required to undertake re-assessment every 5 years) and new entrants (undergoing initial assessment). Candidates are classified by one of three categories according to their ability to demonstrate prior learning and possession of suitable qualifications. Category 1 candidates are experienced gas operatives seeking to renew their certificate, Category 2 candidates hold a nationally recognised qualification, whilst Category 3 candidates are classed as new entrants to the industry, they are not deemed to have the appropriate qualifications or experience, and would be advised to seek relevant training before sitting the ACS exam (CSkills 2012). The engineer's 'competence journey', with these different categorisations and routes to entry is outlined in Appendix IV. Of particular significance is that, prior to April 2014[15], there was no national standard or monitoring of the quality of training received by individuals before reaching assessment (GSR 2011: 32). This meant that, an operative undertaking a (non-regulated) fast track course over 2-6 weeks, and able to demonstrate on-the-job experience, and someone completing a modern apprenticeship over 2-3 years could both be considered as similarly competent engineers providing they completed the ACS accreditation and registered with Gas Safe (see Appendix IV). The modern apprenticeship route, which fosters the acquisition of experience alongside training, tends to be more highly regarded than shorter, fast track courses, which may yield very little on-site experience (GSR 2011). Difficulties for new entrants in gaining practical experience, and the lack of apprenticeships with experienced engineers, have been recognised as factors restricting the access of new entrants to the industry (GSR 2011). This means that the current workforce is made up of individuals who have received training of varying lengths and quality, potentially resulting in them having a wide range of experience and expertise. It is this heterogeneous group of individuals that then visit properties and perform the installation of central heating systems, perhaps in quite different ways.

3.4 The stages of installation

Installation is a process encompassing a series of individual tasks. Again, at each stage of installation, there are ways in which the industry attempts to ensure uniformity in this process, and points at which it may vary. Outlining the installation

[15] In April 2014, IGEM and E&U Skills published new 'Standards of training in gas work', requiring all training programmes to be reviewed and recognised by the Standards Setting Body. All new entrants are now required to undertake an industry recognised training course (IGEM 2014).

process is key for understanding who is installing central heating systems and how there might be scope within the regulations and guidance for the involvement of different actors in this. Moreover, this discussion reveals how some stages of installation are governed by regulation and inspection, whilst others may be more open to interpretation. In order to scrutinise the installation process, it is important to first understand the tasks that fall within the previously defined competent engineer's remit, as stipulated by industry documentation and guidance. Following training, assessment and registration, the competent engineer should be able to perform:

> "The safe installation, purging, commissioning, testing, servicing, maintenance, repair, disconnection, modification and dismantling of the gas systems, fittings and appliances with which they are working."
>
> (HSE 2013: 21)

In this list, we already see the range of technical skills that the engineer is required to possess; however, this does not encompass every aspect of the job. Consideration of the full installation process reveals that other skills are necessary, but not formalised in the same way. The full process will include: the survey and quotation, product purchase, physical installation, wiring of electrics, commissioning, handover, and registration of the system, along with any making good (this describes any finishing carried out, for example, cementing around the flue or boxing in new pipework) and quality control procedures that may be in place. Of these, only the physical install, commissioning and registration have to be completed by our previously defined competent engineer (HSE 1998). Those stages that do not involve working directly with, or reporting on, gas works, may be performed by an individual who does not hold the same status. A self-employed engineer may need to possess all of these skills and is likely to perform all stages himself. Meanwhile, within organisations a specialisation strategy might be used, with a different employee exclusively performing each stage of the installation; this can be more time and cost effective than ensuring that all employees possess the full range of skills and qualifications. As the next sub-sections demonstrate, each stage of central heating installation places different requirements on the engineer. Further, the industry regulations and guidance defining these stages might be open to interpretation.

Survey

The initial stage of the installation is the survey, during which prospective central heating technologies are identified. This is usually a process of visiting the property, and perhaps speaking to the occupant, in order to deduce the appropriate boiler, radiators, controls and pipework required. There is no formal requirement that it must be a competent heating engineer performing the survey. In some organisations there may be an individual specifically tasked with performing surveys, but since this does not involve interrupting any gas works, this individual does not have to be Gas Safe registered. However, it is at this stage that the design of the central heating system should take place, in particular the sizing processes outlined in Section 3.2 and Appendix II. It is suggested that in order to develop the heating system specification, "the requirements, preferences and expectations of the client must be discussed and understood" (CIBSE 2013: 4). This discussion should include heating and hot water requirements, opportunities to improve energy efficiency, explanation of controls, and whether any of the existing system can be incorporated into the new system (CIBSE 2013). Further, this might include the consideration of "any special needs such as may be required for the frail and elderly" (CIBSE 2013: 5). Thus, the survey should be a process of discussing requirements with the customer, but also assessing the building, any existing central heating system, and performing measurements of the rooms and water flow rates for use in sizing calculations. Any decisions are usually documented through a survey sheet (see Appendices XIII and XIV for examples) and formalised with the customer through a written quotation.

Product purchase

Once design decisions are finalised with the customer, the required products will be sourced from a plumbers' merchant, or online. Here, more actors are recruited into the installation process. In Chapter 2, I suggested that these wider networks might shape intermediaries' practices and the products installed, but little is known about the exact role that plumbers' merchants might play in this. Regardless, it is only through these interactions that products can be sourced ready for installation.

Installation

The priority during installation is to create a system that can be "left in a safe condition for use" (HSE 2013: 22). Since the boiler is the gas burning component, regulations and guidance place emphasis on this element of the central heating system during installation. Boilers should be installed "in accordance with the manufacturer's installation instructions" (BSi 2009: 8) and appropriate standards, as detailed in the L, N & I List. As the point at which toxic gases are emitted from the system, the flue is a second priority area, and must be safe for use (HSE 2013: 53). These tasks are firmly placed within the remit of the competent engineer, and should not be performed by anyone who is not registered with Gas Safe. Again here, it is worth highlighting that it is the safe installation of the system that is most heavily prescribed and monitored. The installing engineer is also responsible for ensuring that the appliance fitted is suitable for the property, and the location in which it is positioned. The engineer must also ensure that there is a sufficient permanent supply of air, adequate flueing arrangements, and test the appliance in situ (HSE 2013: 84). Additionally, if fitting a new boiler onto an existing system, it is best practice to flush the radiators and pipework (EST 2008: 18). This is a process of removing any corrosion products which settle in radiators, and have a detrimental impact on system efficiency. Finally, corrosion inhibitors, filters and cleaning products, should be added to prevent future build-up of debris, as this can damage the boiler.

Wiring

Following the installation of the boiler, water tank, radiators and pipework, the final system component to be added is the controls. This is no longer the domain of the competent gas engineer, in fact, the installation of controls is explicitly written out of the GSIUR:

"Under regulation 2(6)(c), **work on any control device associated with an appliance which is primarily intended for use by the consumer (eg removal/ replacement of electric thermostats on/off timer switches) is excluded from the Regulations** if this does not involve breaking into a gasway, ie where there is no risk of gas escape. **People carrying out such work are not, therefore, required to be members of an HSE-approved class of persons, eg Gas Safe registered** (see regulation 3), nevertheless competence to ensure any such work is done safely is required under the HSW Act."

(HSE 2013: 19 emphasis added)

The installation of domestic heating controls, which, as an electrical appendage to the boiler, is unlikely to involve breaking into a gas pipe, is therefore excluded from the GSIUR. Furthermore, the above clause clearly states that anyone installing heating controls is not required to be Gas Safe registered, thus they are not required to demonstrate any competence with regard to heating systems. Instead, heating controls must be installed in accordance with Part P of the Building Regulations (Government 2013c). Aside from the installation of a new circuit, consumer unit (the distribution board containing trip switches for the different electrical circuits in the property) or work taking place in a special location (within a particular radius of a bath or shower), the installation of electrical work in a domestic property is not notifiable (that is to say, it does not need to be reported to Building Control) (Government 2013c). Therefore, the installation of heating controls is broadly defined as non-notifiable, unless an installation is taking place within the defined space around baths or showers. Any electrical work that is notifiable can be self-certified by a registered competent person, in this case defined as "a person registered with a Part P competent person self-certification scheme" (Government 2013c: 11). For the electrical industry one such scheme is the National Inspection Council for Electrical Installation Contracting (NICEIC[16]). The ambiguous nature of the wiring

[16] The National Inspection Council for Electrical Installation Contracting (NICEIC) is a voluntary regulatory body for the electrical contracting industry. They assess electrical

of heating controls means that it can be performed by a variety of actors; a self-employed engineer is able to perform non-notifiable work without any formal electrical qualifications, or perform notifiable work after registering with a Part P scheme. In some cases, an electrician is contracted to perform this work, and installations are notified via a body like the NICEIC. Whilst the installation of heating controls is non-notifiable, it is not subject to any legislative mechanisms that ensure it has been performed correctly. Although the wiring of controls is not formally checked or documented, the requirement to install particular controls is included in the engineer's checks that are to be performed during the commissioning process.

Commissioning

Immediately after installation and connection to the gas supply, the system, in particular the boiler, must be commissioned (HSE 1998: 16). This is a process of conducting "the necessary checks and tests to ensure that the appliance, and any associated flue, is safe for use" (HSE 2013: 55), but also to ensure that the system uses "no more fuel and power than is reasonable in the circumstances" (DCLG 2013: 21). The Heating and Hotwater Industry Council (HHIC), have developed a Benchmark Commissioning Checklist (see Appendix V for a copy of this), which aims to raise the standards of installation, commissioning and servicing of central heating systems (HHIC 2014b). The British Standard for boiler installation requires "a notice signed by a suitably qualified person that includes a declaration that the manufacturer's commissioning procedures have been completed satisfactorily" (BSi 2009: 31). The Commissioning Checklist constitutes this notice and is usually

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competence of operatives in this sector, and maintain a register of these individuals (NICEIC 2015). In this way they might be considered the electrical equivalent of Gas Safe, however, unlike Gas Safe, demonstrating competence with the NICEIC is not a legal requirement to work on electrics. Certain electrical works, as defined in Part P require a 'competent person' to carry them out. To this end, there is a Competent Persons Register of electricians, managed by DCLG.

contained in the back of the manufacturer's installation manual, the 'suitably qualified person' required to complete this is someone registered with Gas Safe. Not only is completion of the Checklist the predominant method of compliance with the notice requirement, failure to do this invalidates the product warranty[17] (HHIC 2014a; HHIC 2014b). During commissioning, the system should be checked by the installing engineer to ensure that it is operating in line with the manufacturer's instructions (BSi 2009: pp.32-3). This includes putting the system into operation and testing the gas rate, flow and return temperatures, checking the integrity of the flue, performing flue gas analysis, and checking the boiler controls, safety devices and system controls (see BSi 2009: pp.32-3 and Appendix V).

Handover

Further, the Commissioning Checklist asks the engineer to confirm that:

> "The operation of the boiler and system controls have been demonstrated to and understood by the customer"
>
> (HHIC 2014a, also see Appendix V)

The Checklist itself should also be "explained and left with the customer" (HHIC 2014a). However, the Checklist provides no further detail on either the demonstration of controls, or explanation of the document, leaving the exact nature of this process open to interpretation. This demonstration and explanation is required for compliance with the Building Regulations, which also stipulate the need for advice on the "energy efficient" operation of the system to be provided (DCLG 2013). This demonstration should include the "correct operating procedure for the boiler, any safety shut-off controls and ancillary controls" (BSi 2009: 34). Guidance from the EST also suggests demonstrating how to set the programmer clock, the use

[17] This is a recent modification to the Benchmark scheme, and applies to those boiler manufacturers that are members of the HHIC. This includes all of the UK's major brands.

of the override function, how to separate space heating and hot water time settings, how to set room and cylinder thermostat and how to set TRVs (EST 2008: 49). However, this is a recommendation, and as such does not constitute a formal requirement of the job. The exact demonstration process and how to establish whether the customer has understood the operation of the system are not stipulated, leaving these procedures to the discretion of the individual performing the task. According to the BSi, the engineer should also advise, in writing, that there is a requirement to have "adequate and regular maintenance" (2009: 34) (annual servicing) of the heating system performed by a competent person. The Benchmark Checklist includes a Service Record, to be kept with the boiler, and updated annually when the boiler is serviced (CIBSE 2013: 132). Upon completion, both customer and installer should also sign the Checklist. Following handover, any user manuals provided by the manufacturers should remain with the customer (DCLG 2013: 17; HSE 2013: 59). However, simply leaving the instructions might be considered as a "bare minimum" (EST 2008: 49). It has also been suggested that engineers should "respond promptly to calls from a customer following completion of work", including the provision of advice over the phone or a complementary return visit (HHIC n.d.). Finally, CIBSE suggest that the customer should be instructed on how to light the boiler, the correct procedure for venting the system, and re-balancing circuits in the event of radiator removal (CIBSE 2013: 131). However, again, these pieces of advice are best practice scenarios, they are not stipulated in the British Standards or Building Regulations, leaving the handover process subject to variation. For example, how this takes place in practice may depend on the relationship between the installer and householder.

Registration

The final stage of installation is the registration of the boiler. Gas boilers are classed as a controlled service and, as such, for compliance with the Building Regulations, their installation is required to be notified to Local Area Building Control within 30 days of completion (DCLG 2013: pp. iii and 22). The Competent Persons Scheme allows a person classed as competent to self-certify the work, via the completion of a series of approved forms and online registration (CIBSE 2013: 132). The Benchmark Commissioning Checklist can be used to demonstrate satisfactory completion of the commissioning process (BSi 2009: 31). Following this, the engineer can register the boiler online through the Gas Safe website, providing he is registered with Gas Safe. As of 2014, each registration incurred a charge of £2.20 + VAT (GSR 2014b); upon completion the householder receives a certificate to confirm compliance of the appliance with the Building Regulations (EST 2008: 9). In completing this process the engineer has created a paper trail that links him (or the organisation) to that specific gas installation, which is used to monitor and inspect the central heating installations that take place across the UK.

3.5 Summary

With registration, the process of installing a central heating system is finalised. Although the registration stage is a standardised procedure, this chapter has demonstrated that the installation of central heating systems is likely to be far from uniform. Through considering the central heating system, the installer and the installation process, in turn, I have revealed the scope for significant variation in what gets installed, and how. An initial discussion of the central heating system revealed the importance of the correct design for its efficient operation, but also the relatively open-ended nature of much of the regulation and guidance that surrounds these devices. Further, a central heating system is, through its very essence, formed through the amalgamation of different components, which may result in very different individual configurations installed in homes. It is the system installer that is tasked with aligning these components. In the second part of this chapter, I revealed the heterogeneous, disparate workforce that performs this job. The central heating industry has training, assessment and registration structures in place for regulating and maintaining installation standards. However, this varied group may follow different training trajectories and possess specialised skills, creating the potential for a variety of installation practices to emerge. Indeed, as the final section of this chapter elaborated, the different stages of installation may be open to involvement from a variety of different actors, and they are regulated and monitored in different ways (if at all). Again, these all reveal potential points of flexibility and divergence in the process of installing a central heating system. For example, an engineer who has completed a traditional apprenticeship, and accumulated several years of experience may have acquired quite different practices to a new entrant who has completed a fast track training course. Similarly, an installation performed by a self-employed engineer may have quite distinct characteristics to that performed by an organisation employing different tradespeople to complete each stage.

It is clear then, that the installation of domestic central heating systems is anything but straightforward. The nuances and complexities discussed in this chapter suggest that my research question; '***how do heating engineers, and installation practices, shape the energy consumed through domestic central heating systems?***' does not have a single answer. Instead there are potentially multiple ways in which the installer, and the installation process, can influence this. The backdrop presented here not only provides an essential background to the empirical material that follows, it also points towards the need for a detailed, contextually grounded study. In view of the diverse set of trajectories and guidelines that I have identified, it would be pertinent to question the ways in which engineers' learning processes and practices converge or diverge. Although a qualified heating engineer can be recognised through a series of qualifications and possession of a Gas Safe Register card, this tells us little of the identities, learning processes or practices of this group. It is only through investigating these complexities, ambiguities and variations in depth that we can uncover how these individuals operate, and how their practices can shape the energy consumed through space heating. The detailed empirical approach necessary to reveal the realities of engineers' practices provides the focus of the following chapter. In this, I identify the qualitative, exploratory strategy appropriate to answer this research question, and detail the conduct of this.

4 Exploring installation

4.1 Introduction

A qualitative, exploratory strategy is the most suitable way to proceed given how little we currently know about the installation of domestic heating systems, and the practices of heating engineers. This chapter sets out by identifying ethnography as the most appropriate method to reveal the potential complexity of central heating installation. In this, I argue that to develop any understanding of central heating installation, it is vital to be situated within the context of this practice, and engaging directly with those performing it. Not only is this strategy the most appropriate to address the research problem identified, it also provides a timely contribution to the field of energy and buildings research. In situating this contribution, I engage with recent calls to more fully incorporate insights from social science within this domain. In particular, ethnographic approaches are desperately needed to understand the energy consumed through buildings in more detail.

Following the explication of *why* ethnography is an appropriate approach, I will proceed to detail exactly *how* this research strategy has been applied. Throughout this account I adopt a reflexive stance, acknowledging, for example the way that my background and characteristics have affected both the way that I proceeded with this investigation and how I was received by my participants. By immersing myself in the social world of heating engineers, acting within it and recording what I saw and heard, I have undoubtedly shaped the products of this research. The ability to apply a certain degree of reflexivity is consequently an essential tenet of the ethnographic approach (Pillow 2003; Hammersley & Atkinson 2007). The first step in this journey is acknowledging my academic background, in a traditionally positivist discipline: chemistry. We are not always aware of or encouraged to discuss our own epistemological or ontological background (Van Maanen et al. 2007). Despite ethnography being at the antithesis of the approaches I am accustomed to, as the most appropriate strategy to proceed in this investigation, it was essential to familiarise myself with this approach. This transition from a positivist to an interpretivist approach has involved repositioning my perspectives of the world and how it can be studied. Further, in seeking to develop a dialogue between traditional policy approaches and this more cultural strategy, I have maintained an awareness of delivering policy relevant findings throughout. What follows is the story of why an ethnographic approach is most appropriate, and how I ventured into this territory that was unknown on so many fronts.

In this, I outline how my approach was initially shaped by a number of scoping studies. I will proceed to detail how I overcame challenges in identifying and accessing my research participants before turning to my time in the field. In this section, I identify the flexible strategies I applied to data collection, including shadowing, observation and interviewing. I will describe the settings in which I spent time, and how I adopted different roles and data collection strategies within them, from hastily jotted notes to recorded interviews. In this, I will acknowledge the ethical considerations of this work, particularly informed consent, my safety in the field, and my position as a researcher in these multiple environments. The chapter closes by outlining the interpretive, emergent nature of my data analysis, with particular reference to the role that theory has played throughout the research process. Through this, I arrive at an introduction to the subsequent empirical material, outlining the type of data that will be presented and the theoretical approaches on which I will draw in the four chapters that follow.

4.2 Why ethnography?

4.2.1 The suitability of ethnography for this investigation

The exact direction of an ethnographic investigation is not clearly defined at the beginning of the research process. Instead, ethnography is an approach whereby the researcher participates in people's lives for an extended period of time, the study proceeds by spending time with the group of interest and:

> "Watching what happens, listening to what is said, and/or asking questions through informal and formal interviews, collecting documents and artefacts - in fact gathering whatever data are available to throw light on the issues that are the emerging focus of inquiry."
>
> (Hammersley & Atkinson 2007: 3)

Key to the ethnographic approach is therefore the emergent nature of the research findings; it is only through being immersed amongst the people and situations of interest that the researcher can develop an understanding of them. For Baszanger & Dodier, ethnography is the method of choice for conducting research with three requirements: "the need for an empirical approach[18]; the need to remain open to elements that cannot be codified at the time of the study; [and] a concern for grounding the phenomena observed in the field" (2004: 10). All of these are true of my investigation of central heating installation, as the following section elaborates.

Firstly, the scarcity of existing knowledge on the process of central heating installation means that this phenomenon can be illuminated through empirical observation. With such a dearth of empirical evidence regarding heating engineers and installation processes (as discussed in Chapter 2) it is not currently possible to draw deductions about the role that these might play in shaping domestic energy consumption (Baszanger & Dodier 2004). Consequently, for this nascent research topic, ethnographic observation, through being grounded and open, is a fruitful way to identify important dimensions of central heating installation and installer practices that have not yet been considered. Furthermore, this approach can provide knowledge on how to infiltrate this particular cultural group and highlight avenues for future enquiry.

[18] In this, empirical is taken to mean verifiable by observation or experience, rather than by theory (OD 2015).

Secondly, the potential for complexity and variation in the installation process (identified in Chapter 3) suggest that my research question requires remaining open to different insights and perspectives. By way of reminder, this research asks: ***How do heating engineers, and installation practices, shape the energy consumed through domestic central heating systems?*** This is an exploratory question, asking 'how', which can be addressed using an ethnographic approach. Indeed, it is their concern with questions of 'how' and 'why' rather than with quantifications and correlations, that distinguish interpretivist from positivist approaches (Schweber & Leiringer 2012). Further, this open-ended research question can be usefully addressed using a method that facilitates exploration. With its relatively unstructured approach to data collection, which does not follow a strategy fixed prior to fieldwork, ethnography is most appropriate for this (Hammersley & Atkinson 2007: 3). Given that central heating installation has received such little prior investigation, it is difficult to develop appropriate pre-defined ideas and categories that would be required for both qualitative and quantitative survey or structured interview design (Babbie 2000). To apply these alternative methods with such little grounded evidence would create a limited view of central heating installation, focused on aspects determined to be important *a priori*, rather than those that engineers might prioritise, or might emerge throughout investigation. Instead, with the ethnographic approach, categories for interpreting what people say and do, along with appropriate theoretical concepts, emerge iteratively as data is collected (Hammersley & Atkinson 2007).

Thirdly, an exploratory study of engineers' practices must be grounded in their sites of work. With a sensitivity to the fact that people's actions are influenced by the settings in which they occur, ethnography investigates these actions within their everyday contexts (Marshall & Rossman 2006). Ethnographic methods are ideally suited to unearthing "tacit knowledge and subjective understandings and interpretations" (Marshall & Rossman 2006: 53). This is vital considering that many work practices are tacit; indeed, this is one of the reasons that increasing amounts of ethnographic investigation are being called for by scholars working in the construction context (Pink et al. 2010; Phelps & Horman 2010). As with construction workers, uncovering the 'local' knowledge of heating engineers can only be achieved by studying "their everyday practical activities, common beliefs, values and discourses in which this knowledge is manifested" (Pink et al. 2010: 651). It would be difficult to glean these grounded insights through methods that are reliant solely on self-reporting or where the researcher is not present to witness social interactions first hand, such as focus groups and surveys (Sarantakos 2004; Babbie 2000).

Finally, given that my research is focused on a technology, it is important that this investigation is approached with a sensitivity to the materiality of social relations (Wajcman 2002). Beyond merely assessing the 'social impacts' of this technology, I am looking to examine what shapes central heating systems and the way these impacts are arrived at (Williams & Edge 1996: 868). In order to gain an understanding of "what technologies mean to actors, and how they are actually used in everyday life" (Lutzenhiser 1992a: 55), it is imperative that such studies of the technical are positioned in the sites and relations of their everyday use (Suchman et al. 1999: 397). It is only through engaging with the technology as it is negotiated into position, watching engineers' interactions with it, and seeking explanations in their words that we can identify, understand and ultimately influence those aspects of installation that contribute to determining the energy consumed through these systems.

Through considering my research question, and the shortage of existing knowledge about central heating installation, it is clear that an exploratory, interpretivist approach can provide valuable insights for this investigation. Ethnography offers an open-ended research strategy that can facilitate the collection of rich and grounded empirical information on the installation of domestic heating systems. Furthermore, this strategy contributes to the growing number of qualitative, interpretivist approaches being applied in the field of energy and buildings. In particular, contributing to cultural approaches which have, to date, rarely been used for understanding how building professionals shape energy use.

4.2.2 Situating the investigation within the energy and buildings context

Attempts to reduce the amount of energy consumed in buildings have traditionally relied on data gathered using positivist strategies inherent in the engineering and physical sciences. This has been attributed to historic policy approaches, and related funding priorities and preferences within this field (Oreszczyn & Lowe 2010). Amidst this prioritisation, contributions from the social sciences have been underutilised and underappreciated (Sovacool 2014; Sovacool et al. 2015). Yet it is only through simultaneously considering the role of people and technologies that we can design and implement effective policy to reduce the energy consumed in buildings (Rohracher 2001; Skea 2012).

To this end, in both its inaugural and one year anniversary editions, the new journal of *Energy Research & Social Science* has been used as a platform to incorporate a fuller range of social science approaches in advancing energy research (Sovacool 2014; Ryan et al. 2014; Moezzi & Janda 2014; Sovacool et al. 2015). Stern (2014) identifies the multidimensional nature of "the social" within the energy research, including the need to consider the human causes, effects and understandings of energy phenomena. Highlighting this complexity, Sovacool et al. (2015) outline a variety of social phenomena that remain under-researched, including:

> "The factors under-lying demand for energy services and the acquisition and use of technology; perceptions and judgements about energy risks; energy attitudes; persuasion and communication about energy choices; energy decision-making processes in individuals, organizations and communities; and energy ethics."
>
> (2015: 96)

In such a multi-faceted field there is space for contributions from a variety of social science disciplines, and yet "the human elements of energy systems and their consequences are frequently neglected" within energy research (Sovacool et al. 2015: 96). Furthermore, where the social sciences have been applied in this domain, they have traditionally been those reflecting positivist preoccupations, with economic 'rational actor' models dominating (Moezzi & Lutzenhiser 2010; Shove 2010). In Sovacool's sample of over 9,000 articles published in leading energy journals between 1999-2013, he found that only 0.7 per cent of the authors had disciplinary training in sociology, geography, history, psychology, communication and philosophy (Sovacool et al. 2015: 97).

Whilst a variety of social research approaches can contribute to our understandings, it is arguably the rich, context-specific data delivered by qualitative strategies that can fully reveal the complexities of energy consuming practices. Within the field of energy and buildings, there have been a growing number of contributions from social and cultural approaches. In particular, highly detailed ethnographic approaches have been applied to understand domestic thermostat management (Kempton & Krabacher 1985), the reasons for the limited uptake of domestic energy efficiency interventions (Wilk & Wilhite 1985) and cultural differences in energy use behaviour (Wilhite et al. 1996). However, Sovacool's extensive review of leading energy journals found that only 12% of the articles used qualitative methods (Sovacool 2014). Within the energy and buildings context, approximately a tenth of 'non-technical' articles published in 'construction research' and 'business and social science' journals between 2000-2011, along with a series of 'specialist environmental and building' journals sampled for the year 2011, were identified as applying interpretivist approaches (Schweber & Leiringer 2012: 488). Thus, although the application of qualitative, interpretivist approaches in this field is increasing, these are still less often used.

Despite the insights that they can deliver to energy research, the lack of contributions from those affiliated with both anthropology and STS disciplines has been noted (Sovacool 2014). Those that have previously applied these approaches have both demonstrated their value and rallied for further applications of them within energy and buildings research (cf. Wilhite 2005; Henning 2005; Rohracher 2002). The role of contextualised studies in understanding "the importance of social relations, culturally determined practices and changing material culture" has been highlighted (Wilhite 2005: 2). However, studies that apply these approaches to understand the energy implications of the work of building professionals are yet to come to fruition. Pink et al. (2010) have highlighted the value of ethnography for understanding the 'workplace realities' of construction sites, whilst Henning (2005: 8) identifies the role of anthropologists in addressing the complexity of intermediaries, including tradespeople, and the 'cultural consequences' of energy consuming technologies. Thus, by exploring the installation of central heating systems through ethnography, and applying ideas from sociological and STS traditions, this thesis uses a relatively under-applied method to study a never before investigated cultural group, providing a significant contribution to the 'methodological expansion' of energy research (Sovacool 2014). Finally, in addition to answering widespread calls for interpretivist approaches within the energy field, this strategy is also the only way to provide fully grounded answers to the research question identified in Chapter 2. The starting point for discussing this investigation is by detailing the scoping studies that informed its initial stages.

4.3 Scoping studies: initial exploration and refining my approach

The purpose of the scoping studies conducted in the early stages of this research was two-fold. Firstly, they helped to introduce me to the central heating installation process (something that I previously had little direct experience of), and to understand at which points I might be able to engage with this process. Secondly, these studies were used to test the feasibility of applying an ethnographic approach to the investigation of central heating installation. These tentative first steps were a vital part of the ethnographic process, helping me to think through initial access and fieldwork approaches (Delamont 2007).

Initial scoping consisted of fifteen informal interviews with colleagues (in their capacity as residents) about their recently completed central heating work (see Appendix VI for an interview schedule). For this preliminary information seeking exercise, colleagues were a readily accessible group who were able to share their installation stories. My initial literature review had identified the potential significance of the interaction between heating engineers and end users (as discussed in Sections 2.3 and 2.4). Thus, from the outset, I was focused on observing and understanding this interaction, particularly the points at which decisions were made about the system and any explanation of its operation. During interviews with colleagues, I was thus seeking to understand the installation process, the extent to which customers had contact with their heating engineer as heating works were taking place, and the points at which this happened. The interviews revealed a series of complex installation stories, with the involvement of different actors (including landlords, tenants, owners, organisations and individual installers), varied timeframes (anything from one to nine weeks between initial contact and the completion of the work), and ad hoc, often fleeting moments of interaction between engineers and customers. It quickly transpired that it would be difficult to specifically target these brief moments amongst the variety of installations taking place. Further, revelations about the often short-lived interactions between engineers and occupants suggested that there would be more to investigate about engineers' assumptions and installation practices that seemingly didn't rely on interaction with the end user. This raised questions about how central heating systems were determined, how their suitability for the property and the customer was established, and the extent to which guidance to offer advice to customers on the use of their central heating systems (as outlined in Chapter 3) was being adhered to. Moreover, it revealed a methodological challenge; attempting to capture these brief, often unplanned interactions as they took place would be difficult. Instead, the only way to understand installation practices, including these interactions, would be to shadow the engineers themselves.

Here, the research began to take a slightly different shape, with the focus shifting from the interactions between engineer and customer, to a more general understanding of the practices of the heating engineer. Now came the time to test the feasibility of using ethnographic methods to investigate heating engineers and installation practices. During this initial foray into the heating industry, I identified two heating engineers (both individuals who had carried out work for colleagues) to visit on site, and attended two training sessions from a leading controls manufacturer (with whom a colleague had contacts).

Whilst negotiating my position in this unknown space, my initial field visits were, at best, uncomfortable, and at worst, downright awkward. The first shadowing session took place whilst the engineer was physically installing a system. Every time I asked a question, the engineer would pause from his work meaning I was delaying his progress. Conversely, when the engineer was physically engaged, I felt uncomfortable watching him work and left wondering whether I should have turned up with a greater arsenal of questions and conversation topics to fill these awkward silences. The second session was better, this time, the engineer had already completed the work, but had arranged a follow-up visit, during which he talked me through what he had done. Following these visits, I concluded that 'hanging around' during the physical installation was neither useful for me nor the engineer. Instead, I would have to adapt my approach to disrupt their work as little as possible, targeting or creating moments when they would be able to take time for explanations. Finally, I attended two manufacturer training sessions. For these, I spent the day with approximately ten heating engineers. Here, the conversation flowed a little easier. Whilst I clearly did not fit in (a young woman at one of these events is very rare), I felt a little more comfortable amongst the participants as a course attendee; after all, I was there to learn alongside them, as well as from them. Further, during these sessions, engineers would talk about their work, their customers and the industry more generally, which proved to be a fruitful source of data. Like Brockmann (2011), who used multi-sited ethnography including short-term observations in both workplaces and college environments to study apprentices in retail and motor maintenance, I concluded that an approach encompassing multiple contexts would be necessary for capturing data on heating engineers.

It was with this refined perspective that I embarked on identifying participants and settings in which I could study heating engineers. My scoping studies led me to target heating engineers during particular aspects of their work (especially when the decisions were being made, for example, during surveys), in moments when they had the opportunity to talk through their work, or when they were in more social settings, such as the training sessions. Moreover, given the importance of seeing socio-technical phenomena as they unfold, and the individual nature of each heating installation, I sought to ensure that an element of this investigation remained positioned with both the engineer and the system as installation took place. However, gaining and maintaining access to these moments and these individuals with very little prior knowledge of, or contact with, the heating industry proved to be an incredibly challenging aspect of this investigation. Indeed, the strategies I adopted in recruiting participants were shaped by the nature of this industry. This, in turn, influenced the individuals and situations I was afforded access to for data collection, and will now be elaborated.

4.4 Identifying participants and gaining access

In contrast with traditional ethnographies of work environments (see for example, Brannan 2007) or construction sites (Tutt et al. 2013; Thiel 2007; Sykes 1969a; Sykes 1969b), I knew I would not find heating engineers situated in a readily accessible location for any length of time. Engineers often work individually in a closed setting – the private home. In an industry dominated by self-employed individuals and micro enterprises (introduced in Chapter 3), there were also very few organisations to locate myself within (although I elaborate on one attempt in the following section). This created a particular challenge in applying the ethnographic approach, which traditionally involves the researcher being immersed in a particular setting or culture for an extended period of time (Hammersley & Atkinson 2007). Additionally, as my scoping studies had demonstrated, central heating installation takes place over varying timeframes and can be ad hoc. Further, Killip notes the difficulty of studying SMEs within the construction sector using qualitative methods because potential informants "lack the time to participate" (2011: 188). Finally, this ethnography necessitated spending time with heating engineers as a lone researcher, often on a one-to-one basis in private properties. As a young female studying a male dominated environment, my safety during these moments was a key consideration from the outset, and shaped the access routes I used. Against this backdrop, it is perhaps unsurprising that gaining access to heating engineers was a time consuming and often frustrating process.

4.4.1 Initial strategies

The pursuit of access took over the early stages of this project (I am not alone in this challenge, for some examples see Hammersley & Atkinson 2007: 41). In particular, van der Waal (2009) notes the difficulties in accessing organisational settings for ethnographic research. He identifies that this process can be time consuming, often involving numerous negotiations, and highlights that making initial contacts and establishing trust are key for success, particularly because organisations can be protective of their reputation (ibid). For me, this process of continual negotiation involved understanding the socially embedded conditions of my participants (Bondy 2012), something that could only be achieved after a certain degree of initial exposure. Indeed, my eventual success in accessing this elusive group came through employing a variety of strategies and learning how to interact with heating engineers.

Initially, I attempted to gain access through my colleagues' contacts within the construction industry. This reliance on existing personal networks is a common strategy for the ethnographic approach (Hammersley & Atkinson 2007). Access to research participants is often easier to negotiate through personal contacts (Reeves 2010) and, in this case, would contribute to my safety in the field (see risk assessment in Appendix IX). Early ambitions to purposively select my sample (for example, targeting moments of decision making, as discussed in Section 4.3) were soon replaced with the necessity of adopting a convenience approach. In these early stages I had some success in accessing one small (between 5-10 employees) and one medium-sized (approximately 55 employees) organisation, both working on large council-led contracts. However, this route still met with significant delays. In one case, I made initial contact in September 2012 and it was only through repeated follow up communication and a certain degree of tenacity that I secured my first field visit for February 2013. Another strategy involved accessing both boiler and controls manufacturers. I had initially targeted these organisations with a view to gaining access to their accredited installers;[19] however, they were unable to provide any kind of gatekeeper role (I would have to target the individuals via publicly available online databases) or support my safety with these individuals. Instead, it was through this route that I secured opportunities to attend installer training days.

A further strategy was to target the handful of large organisations which perform central heating installations on a daily basis - namely, energy suppliers who have a

[19] These are individuals who have received training from a particular manufacturer, making them 'qualified' to install that product. Accredited installers are only loosely affiliated to a particular manufacturer, and their installation practices are in no way managed by the manufacturer. These types of industry affiliation are further elaborated in Chapters 5 and 6.

branch of installing engineers. With this plethora of installations taking place, surely there would be opportunities here for me to shadow engineers? Indeed, through this avenue, I experienced some initial interest in the project, but found that once I tried to secure shadowing opportunities the negotiations would fall through. For example, in one instance, I made initial contact with a large organisation in July 2012. Following a failed attempt to meet my potential collaborators, and delays in communication, I eventually received agreement to proceed with the project. However, this came with a request to sign a non-disclosure agreement (which, as it was written, would have limited my ability to publish even anonymised data sourced from this company), which I attempted to negotiate. This was unsuccessful and eventually, in November 2012 the organisation withdrew their involvement citing "organisation change and re-calibration" (installing organisation, email comm., 30.11.2012). The reticence to be involved in this project is further illustrated by another case, which involved a medium-sized organisation that had shown initial interest in the project:

> "It appears that the reason for the slow down is that their directors have expressed concerns about information being made publicly available that might prove detrimental to Conti Installers. They also referred to potential insurance issues, but I think the crux of the problem is that if they have dirty washing, they don't want it publicly aired."
>
> (contracting organisation, email comm., 2013.02.25)

This fear of 'dirty washing' being exposed was reflected in other failed attempts to gain access - and even some of those that were successful. Potential gatekeepers might show initial interest in the project, but as I attempted to secure fieldwork opportunities their responses would dwindle. I would make every effort to reassure participants that I would fastidiously comply with data protection requirements, ensuring that their data would be aggregated with those of other participants' and anonymised[20]. I also offered to provide reports and brief summaries of the project findings that could be beneficial for improving their customer service and business proposition. However, after repeated follow-up emails and phone calls without replies, I would reluctantly give up to pursue other, more promising possibilities. Despite the delays and frustration these setbacks caused, they were not entirely futile; indeed, "failed access attempts are 'data' just as successful ones are" (Delamont 2007: 213). These issues of access do not stand apart from the research process; rather, as an integral aspect of the investigation, it is fruitful to consider them in relation to my findings (Bondy 2012). Not only is the heating industry very insular, but its members are also highly aware of regulation, guidance and the importance of 'correct' installation practices. Furthermore, heating engineers are protective of their expertise and the ways in which they are externally perceived. With hindsight, I now know that all of these factors contributed to my initial difficulties in attempting to gain access, particularly as an outsider requesting to observe and document these practices. Indeed, the nature of the heating industry, and of those operating within it, has significant implications for the way in which central heating systems are installed, and provides much of the focus of Chapter 5. Moreover, these initial access issues, and the understandings of heating engineers that accompanied them, shaped my subsequent sampling strategy, as detailed in the following section.

4.4.2 Successful snowballing

Consistent with these understandings of heating industry culture is my success at recruiting participants once I was able to demonstrate some degree of 'membership' within this community (which also provides a key aspect of discussion in Chapter 5). I found that, having acquired some fieldwork experiences, I was able to support my

[20] Indeed, all of the individuals, organisations and brand names mentioned in this thesis have been replaced with pseudonyms. My data is labeled according to how it was collected (fieldnotes or interview), the individuals' role (self-employed engineer (SE), a member of an installing organisation, a training instructor or a sales representative), and the date it was acquired.

interest in engineers' work with examples from the data I had collected, and to be more specific about the things I was most concerned with. This entailed demonstrating my understanding of, and empathising with, the requirements of the job. For example, discussing the recently announced changes to flue gas testing when commissioning a boiler (this announcement is included in Appendix XII). Displaying this high level of personal, and sincere, interest was particularly beneficial in gaining access (Marshall & Rossman 2006: 74). These discussions helped to build rapport, and I was able to recruit participants through direct contact, but also through asking them to identify people within their networks who may be willing to participate in the research. Gaining access to heating engineers was consequently an ongoing endeavour and one that continued throughout my data collection, as I met new people and spotted new opportunities. My contacts did not stem from a single source, instead, I would be simultaneously pursuing multiple avenues of enquiry (this is illustrated in Figure 4.1). At times this was challenging to manage, and I recorded these numerous points of contact in a call log (Delamont 2007). This 'running account' of how I spent my time allowed me to track this complex fieldwork (Russell Bernard 2006), and to evaluate the sources of the data I was gathering.

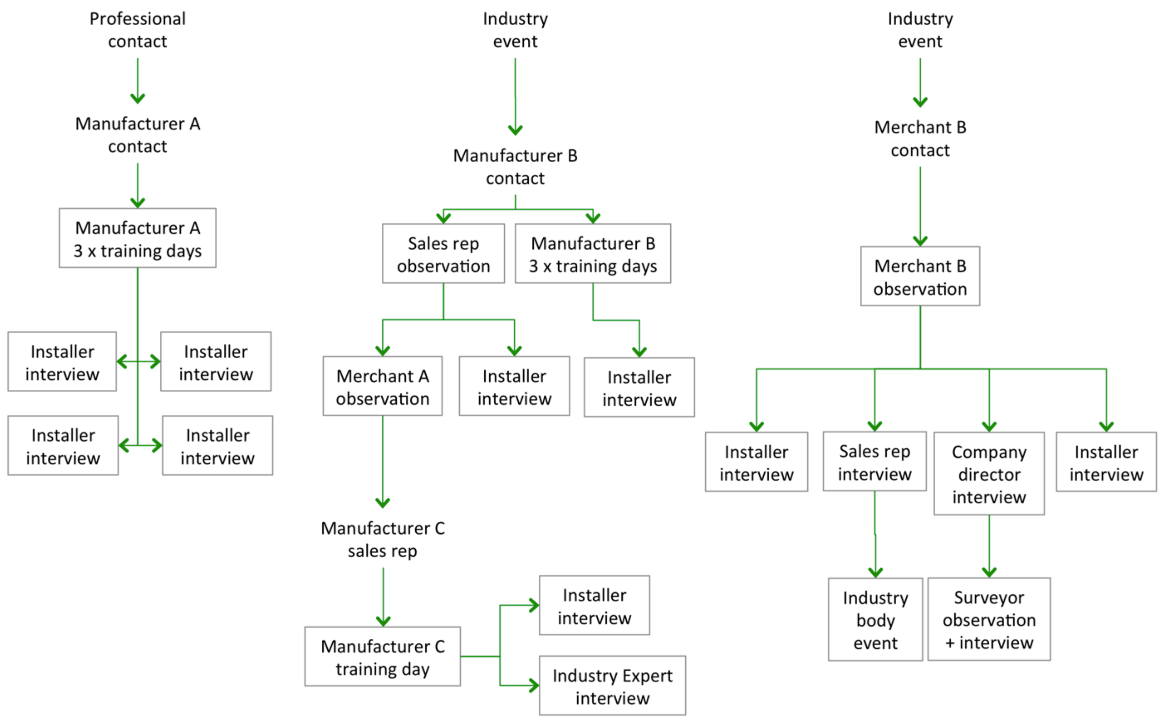


Figure 4.1 Snowballing through multiple lines of enquiry. The captions with boxes were fieldwork events, whilst the captions without boxes were points of contact. This is intended to be a representation of my snowballing strategy, it accurately accounts for a portion of the data collected.

A snowballing strategy was to use manufacturer training days as an opportunity to chat to engineers and to recruit them for subsequent research. Similarly, it was through attending industry events, in particular EcoBuild in March 2013 and the Plumbing and Heating Exhibition (PHEX) in November 2013, that I was able to make contacts within the industry. I attended PHEX with an existing participant, Jack. We had met at a training session, and he was particularly enthusiastic about his work and keen to discuss his job with me (indeed, on one occasion, Jack's passion to talk about his work led to some concerns with my safety in the field and is discussed more in Section 4.5). When I mentioned my ambitions to go to PHEX, he suggested that I could go along with him, and that he would introduce me to some people in the bar. It was here that Jack introduced me to a manager from Installer Spares, who subsequently secured informal interviews with two of his customers on my behalf. During the day, Jack had also attempted to introduce me to some other engineers at the event, with the intention of helping me to secure some informal conversations about their work. However, Jack did not know the other engineers, who were apprehensive about talking to me and would quickly disappear. Instead, the engineers that Jack's merchant contact had approached on my behalf were more than happy to extend their stay at the bar whilst I asked a few questions. This experience taught me that to gain access within this industry, homophilly is not sufficient; the gatekeeper must also know the potential participants on a personal level. As I became more familiar with this group, I realised that one of the engineer's primary contacts is the merchant, not their fellow heating engineers. Beyond emphasising the process of access as one of negotiation and re-negotiation, through this experience, I realised that I would also need to rely on different types of gatekeeper (Reeves 2010). Indeed, it was through pursuing this route into the industry that I experienced more success in my snowballing strategy.

During a visit to an industry event, Ecobuild, I secured an opportunity to spend time in a plumbers' merchant (this particular 'snowball' route is depicted on the right hand side of Figure 4.1). I was introduced to Seb, a branch manager, over email and arranged to spend a few days with him in-branch. Seb and I quickly built a relaxed relationship, he was open to answering my questions and comfortable introducing me to his customers and welcoming me into conversations. He provided a desk space for me to use during my visits and promptly acquainted me with his colleagues. During my time in his branch, Seb organised an informal interview with the owner of a large company (who later granted me access to several fieldwork opportunities with one of his employees), and one of his close customers, Brian (who I subsequently visited on-site). With Seb vouching for me, these participants did not hesitate to get involved in the research and, in fact, went out of their way to participate. Here, I had established a strong rapport with an influential gatekeeper, which is essential for negotiating access in ethnographic work (Reeves 2010).

Beyond being able to identify who to approach, it is essential to recognise how to interact with them. The role of swift relationship building is particularly important in this context, where I could not be embedded with this group for an extended amount of time. As a consequence of the limited time that engineers could provide and their hesitations to be involved in this research, I met the majority of my participants only once or twice. Whilst this stands apart from the extended exposure advocated with a traditional ethnographic approach, it was not impossible to establish rapport and insights into the lived experience of my participants within these timeframes (Brockmann 2011). However, learning how to establish my researcher role and build these relationships took some time. My original slightly reserved approach proved to be insufficient in my initial forays. Heating engineers, and the industry more generally, are a highly personable group. They would share anecdotes about their personal lives as freely as they would about their working lives. At first, I was a little affronted to be asked personal questions from people that I had known for little more than a few minutes - I am not naturally so forthcoming with people I do not know. Moreover, to reveal personal information stands against the literature I had read on ensuring my safety as a lone researcher in the field (for example, SLT 2015; SRA n.d.); this is discussed more in Section 4.5. However, with time, and exposure, I realised that I would quickly have to become more comfortable sharing my personal stories alongside my professional ones. By the time I met Seb, I had lost my originally contrived approach and was far more comfortable rapidly building a friendly relationship with him (and many of my later research participants). His consequent perception of me certainly helped in gaining further access. The success of this strategy again demonstrates the importance and strength of relationships within this industry.

It was through this snowball sampling approach that I gained access to the majority of the self-employed individuals that I worked with during this research. Again, this insight is not only valuable in relation to access, but also to the results of this research; these relationships are so important in shaping the central heating technologies installed in homes that they provide the focus of Chapter 6. My gatekeepers included merchants, but also instructors at training days, and individuals who coordinated engineers within larger organisations. Contacts, introductions and endorsements from these gatekeepers were my "best ticket into the community" (Fetterman 1989: 43), however, they did not come without caveats. As many ethnographers have found, gatekeepers may "exercise some degree of surveillance and control" or "shepherd" the research in a particular direction, usually one that is favourable to them (Hammersley & Atkinson 2007: 51). This was certainly the case in my work, for example within an organisation I might be directed towards a trusted engineer who had been with the organisation for some time. One gatekeeper provided a synopsis of the individuals that he had identified as being able to contribute most fully to my research, along with their contact details:

> **"Mr Doug Roper, DRT Roper**. Doug is another engineer who promotes and makes it his business to fully understand the latest system technologies. A long standing customer of ours who will always strives [sic] to influence and educate the consumer into making the right choices, exploring all possibilities available to them."
>
> (Merchant gatekeeper, email comm., 2013.11.25)

Understandably, my gatekeepers were concerned with the picture of the industry that I would paint (Hammersley & Atkinson 2007: 51). This gatekeeper selected Doug as a conscientious individual who had an active interest in the latest technologies, particularly renewables. As someone who 'strives to influence and educate the consumer', my gatekeeper clearly believed that Doug would be an upstanding member of the community for me to talk to. Inevitably, recruiting engineers at training sessions led to a certain degree of self-selection, with only those that were amenable to my presence, and willing and able to make time for further research participation, providing their contact details. Whilst not always the case, those attending training sessions were likely to be the most interested in updating and maintaining their expertise. Thus, my sample contains those who regard themselves, and are regarded by others, as performing a high quality of work. At the very least, all of my participants are practicing within the law (see Chapter 3 for Gas Safe registration and Chapter 5 for a description of the 'cowboys' that I have not interacted with). Such participants might be considered as exemplary members of the community, having built a wealth of knowledge, and perhaps being individuals that others might turn to. This was beneficial to my research, since many of my participants had been operating in the industry for some time, and were able to draw on a wealth of experience when telling their tales of installer practices, and how these have changed over time. These merits especially contributed to my understanding of engineers' identities within the community and of their changing job requirements. These highly regarded individuals provided a host of insights into the ways in which heating engineers shape the energy consumed through domestic space heating systems. Further, the sample includes representation from a number of different types of installer, both self-employed and those working for organisations, with varied backgrounds, as detailed below.

4.4.3 The sample

Several of my participants are self-employed heating engineers (or operating their own micro-enterprises with between 1-5 other employees).[21] These individuals primarily worked in private homes. I spent time with staff from several medium-sized organisations, who had contracts with Registered Social Landlords (RSLs) to perform heating installation and maintenance work across their housing portfolios. I also conducted observations with one organisation that had over 100 employees, and worked primarily in the private sector. Beyond this, I attended training sessions, industry events and spent time in plumbers' merchants. During all of these I interacted with countless heating engineers, both self-employed and employees working for organisations. I also had extended meetings with representatives from Gas Safe Register and the Heating and Hotwater Industry Council (HHIC).

The majority of shadowing and observation took place within Greater London, however, some training sessions led me to also visit Somerset and the West Midlands. Through this and attendance at industry events, I encountered and secured interviews with engineers working outside of London, including Peterborough and Taunton. My participants were all male, and aged between 25 to 65 years old. Within this, the engineers had a variety of backgrounds, qualifications and routes into the industry (see Chapter 3, and Appendix IV for more on the variety of training and

[21] These might include their wives and girlfriends, who would often play an administrative role. Some worked in partnership with another qualified engineer, or employed an apprentice.

qualifications amongst heating engineers). The younger participants were more recently qualified, often through a modern apprenticeship, whilst some of the older participants had learnt 'on the job' before the gas industry was regulated in the way it is now. This range of training backgrounds, ages and organisation types reflects the diversity in the composition of Gas Safe registered heating engineers, identified in Chapter 3. From this varied sample, the empirical material that follows reflects a range of heating installation practices. For example, I have captured insights into the installation process within both social and private housing, and the different strategies that self-employed individuals and organisations use to complete an installation. Furthermore, through speaking to these different individuals and spending time in a variety of settings, I have been able to identify common issues and different perspectives on these. This rich sample provides the initial, exploratory information that is essential to begin to make headway in understanding and subsequently shaping installation practices. Through shadowing, observing and interviewing heating engineers, I have been able to understand the culture of this group, and how aspects of their installation practices shape the energy consumed through space heating systems.

4.5 Shadowing, observing and interviewing

In keeping with some key tenets of the ethnographic approach, and the exploratory nature of this investigation, my fieldwork was not limited to particular strategies or settings. Whilst I did have an area of focus (in particular, wanting to look at installations as they took place in homes), I knew that to understand engineers' culture and their practices, I would have to follow their lead. Further, my difficulties in gaining access resulted in me having to modify my approaches to fit with engineers' schedules and the time that they were willing and able to give me. My fieldwork thus comprised shadowing, observing and interviewing engineers in different settings, including:

- Shadowing heating engineers in domestic properties. This captured the different stages of the installation process (survey, installation, wiring the electrics and commissioning - see Chapter 3).
- Attendance at training sessions delivered by four different controls and boiler manufacturers. These were all day sessions that included between three and ten heating engineers.
- Semi-structured interviews ranging from 45 minutes to 3 hours in length. To conduct the interviews, I would arrange to meet the engineer at a train or tube station local to him, and the interview would usually take place on site, or in a pub or cafe of the engineer's choosing.
- Time spent in plumbers' merchants, attendance at various industry events, and meeting representatives of both Gas Safe and the HHIC.

These different strategies resulted in spending approximately 400 hours over the course of a year in different settings with heating engineers, a full fieldwork schedule detailing the different activities I engaged in is included in Appendix XI. Participant observation involves getting close to people, and observing and recording information about their lives (Russell Bernard 2006). In detailing exactly how I went about my observation, I would broadly agree with Delamont's description of the process:

> "Essentially an ethnographer observes everything she can, writes the most detailed fieldnotes she can, takes time to expand, elaborate and reflect upon them outside the field and/or as soon as time permits, constantly pesters those being observed to explain what they are doing and why, and sweeps up any documents, pictures or ephemera available."
>
> (2007: 213)

Throughout this process, my gaze was directed towards understanding the process of central heating installation. In this, I was interested in what engineers said, but also the physical space and artefacts within that space. I would record the details of the properties I visited, sketch layouts of the space and the location of heating equipment, along with makes and model numbers for the products being installed. I would also observe engineers' actions (how they measured a space, used a particular tool, or reacted to a comment), and their words (both the things they said to me, and to one another). These observations were conducted in conjunction with a series of semi-structured interviews. In keeping with the ethnographic approach, these were flexible, with discussions flowing naturally (Hammersley & Atkinson 2007). Interviews are a useful tool for allowing participants to "speak in their own terms about issues that are pertinent to them" (Phelps & Horman 2010: 63). Informed by themes arising from analysis of my initial data (which is discussed in Section 4.7), the interview schedule included background questions about the engineer's job, the installation process, any commissioning and handover of the system, customers, as well as more general questions about the engineer's route into the industry and how they maintained their expertise (this is included in Appendix X). The interviews provided a platform for engineers to air their views, and it was in these moments that their opinions about their work, their customers and their networks really came to the fore. This method contributed hugely to my understanding of their culture and how this informs the installation process. As Hammersley & Atkinson note:

> "While it is true that the perspectives elicited in interviews do not provide direct access to some cognitive and attitudnal base from which a person's behaviour in 'natural' settings is derived in an unmediated way, they may still be capable of illuminating that behaviour."
>
> (2007: pp.108-9)

Furthermore, my participants, particularly self-employed individuals were more amenable to being interviewed in the pub at the end of a day's work than for me to join them on site whilst they were working. Through adopting these complementary approaches, I have been able to build a nuanced picture of engineers' installation practices, and the multiple facets of this. Before proceeding it is important to detail how I conducted this data collection. In particular, my identity throughout the fieldwork, how I captured data and managed the ethical considerations of this research. Finally, I discuss the fragility of my fieldwork and leaving the field.

4.5.1 My identity in the field

All of my fieldwork was conducted overtly, for both ethical reasons (see Appendix VII for my ethics application), and through necessity. My unavoidable 'ascribed' characteristics (Hammersley & Atkinson 2007) as a young woman meant that I was a prominent outsider in the male dominated heating industry (which is described in Chapter 3). I clearly did not belong and my presence was often commented on and questioned, particularly in group settings such as the training sessions and industry events. Further, the heavily regulated nature of the industry (which is detailed in Chapter 3), and my lack of prior knowledge of central heating systems acted as significant barriers to me claiming membership within this community (the identifiers of community membership are discussed more in Chapter 5). My obvious presence as a researcher shaped both what I was able to do in the field, and the way in which heating engineers responded to me. During my research, I took on a variety of roles on the 'observer-participant continuum' (Mason 2002: 92), depending on the setting I was in. Without any training or qualification in this field, I was unable to offer any kind of work or assistance to engineers whilst they physically fitted the systems, meaning that I was very much an observer in the domestic setting. However, during training sessions, I was able to participate and learn with the engineers by joining with wiring exercises and dismantling boilers. These activities advanced my understanding of both central heating systems and engineers' work. Throughout, I tended to adopt a friendly, inquisitive, non-judgemental and relatively incompetent stance, all contributing to the way that I was received in the field.

Within observational research, the gender of fieldworkers can be a crucial factor, with participants responding differently to males and females (Silverman 2006: 84). Female researchers may be taken less seriously by their male participants, but they may also be seen as unthreatening, and informants may be forthcoming if they are trying to impress (Hammersley & Atkinson 2007: 74). Like Reeves (2010), it is difficult for me to know the extent to which my time in the field was mediated by my gender. However, my femininity was most certainly received in all of these ways and more by my participants. I was, at different times, an energy expert, a spy, a student, a daughter or sister figure (to be protected), someone with a university education, the daughter of a painter and decorator, and a potential romantic conquest. My fieldwork included a certain degree of my own 'impression management' (Hammersley & Atkinson 2007), and work to turn these responses to my advantage. At times, I was met with suspicion: a roll of the eyes when I mentioned my research ambitions or requests for me not to divulge information to 'Rogue Traders'[22]. In these moments, I would understate my university education, instead highlighting my working class background[23] with the promise that I would maintain confidentiality and anonymity. Further, as a female outsider, I would be granted additional time and patience in ensuring that I had understood what I was being told. In Chapter 8, I discuss how heating engineers sometimes regard female customers as unable to understand central heating systems. At times, I think I was placed into this category, for example, in demonstrating the fault finding process on a boiler, one course instructor noted: 'it's so easy - even Faye could do it!' (fieldnotes, manufacturer training, 2013.11.26). To be affronted by these comments would have alienated my participants, instead I would receive them in good humour and play along with the role expected of me. In the majority of my later fieldwork, particularly when my access was granted through gatekeepers, I was someone to be impressed and accommodated. Engineers would be keen to demonstrate their expertise, but also open doors, buy drinks, ice creams, breakfast, lunch and dinner and give up their seats for me.

I think that my participants perhaps held back on some technical detail regarding the operation of these systems. They would assess my level of understanding before

[22] A UK television programme, aired on BBC One, which exposes fraudulent, dishonest and illegally operating tradespeople, including heating engineers. My participants' perceptions of programmes like this are discussed in more detail in Chapter 5.

[23] It would be an omission not to acknowledge that my upbringing, in a household dominated by male manual labourers, has shaped my ability to conduct this research. The majority of discomfort I experienced in the field was usually a result of my position as a researcher and outsider, rather than as a woman embedded in this masculine environment. This contributed to my ability to approach engineers in a non-judgemental and good humoured manner, but also shaped my perception of the way that I was received.

commencing with technical descriptions, which were often kept quite basic. Given the male-dominated nature of the profession, it is reasonable to hypothesise that a male researcher may have been assumed to hold a higher level of technical understanding. I also found some of my participants to be forthcoming about the emotions they attach to their work and relationships with their customers. In one case, a heating engineer was almost brought to tears as we discussed a recently deceased older customer with whom he had a close working relationship. I do not know whether a male researcher would have been privy to these kinds of insight. Inevitably then, the empirical material presented in this thesis has been shaped by who I am and the way that I was received by my participants. My presence as a researcher was no doubt most apparent as I physically recorded data, a process that had to be adapted according to the different settings I found myself in.

4.5.2 Capturing data

In capturing fieldnotes, I had to remain open and flexible, often adopting different approaches in the different settings in which I found myself (Emerson et al. 1995). For example, in the 'classroom' environment of the training sessions, it was more natural to have my notebook in front of me, but it would stay at my desk during break times. In these moments, informal, vibrant conversations ensued, and I would jot down a few reminders of the conversation when I returned to my desk. Similarly, the non-stop nature of a heating installation or day spent with a surveyor was more conducive to quick note taking when I had chance. In all cases, I established a "note-taker" role, mentioning that I would be making notes and allowing this to become part of what my participants expected of me as a researcher (Emerson et al. 1995: 22). I think that my participants were largely comfortable with me making notes, with many of them taking an active interest in this. They were intrigued by the Livescribe pen I was using (which has audio recording capability and a digital screen) and often asked me to explain it, or tried it themselves. At times my participants would highlight particular things for me to note down, with comments like 'you should put this in your book, Faye!' (fieldnotes, manufacturer training, 2013.08.21), when detailing the meaning of particular acronyms or sayings (see section 5.4.3. for an example). I also received the opposite, for example when I asked one engineer about an incorrectly wired programmer, I was told that I did not need to note it down because it 'wasn't relevant' to my work. In both scenarios I complied with my participants' wishes whilst in the field, but documented my thoughts later. These encounters provided a renewed awareness of both what my participants' priorities were, and what they thought mine might be. For example, whilst my focus was energy efficiency, heating engineers might be more concerned with the safe functioning of the system (the significance of safety within this industry is detailed in Chapter 3). These divergences played an important role in alerting me to the priorities and issues that were pertinent to heating engineers, and they proved to be valuable for revealing unanticipated insights into this group.

My fieldnotes tended to be brief; I would note a particular word or comment in order to act as a reminder when I later came to writing up. As soon as possible after leaving the field, I would write these into full field notes, pages of continuous prose that detailed as much as I could remember about the events that I had jotted. I would often write my notes in chronological order, whilst I pictured myself back in a particular space (i.e. the cafe, the workshop, the kitchen, the living room) (Wolfinger 2002). These full notes vary in length depending on the setting, a training session could amount to 10,000 words, whilst a few hours at an installation might only be 4,000. Throughout my fieldwork I also kept a field diary, which was used to capture thoughts, feelings and methodological issues both before and after any fieldwork events. This essential part of the ethnographic process (Russell Bernard 2006) allowed me to iteratively take stock of the successes and failings of my field visits and the data I was accumulating. My fieldnotes were supplemented by photographs and copies of documentation used where I was able to collect them. Again, I would request to take pictures and openly do so, and again, engineers would sometimes point out things that I might want to capture (one engineer even took the photographs on my behalf). All of my interviews were recorded and transcribed verbatim. My interview participants were largely relaxed about being recorded, although they would sometimes intercept themselves if they revealed something that could be seen as unfavourable. In these instances, a reminder that the data was completely confidential and would not be attributed to them was usually sufficient to put my participants at ease. The overt nature of my data collection was a significant aspect in the ethical and safe conduct of this research. These are fundamental considerations in any research investigation, but there are some issues specifically arising from my ethnographic approach that I will now address.

4.5.3 Ethics and risk

The ethical implications of this research were considered thoroughly at the outset, and a copy of the ethics application, addressing deception and the potential for harm, is included in Appendix VII. A primary consideration is informed consent. Whilst I used an informed consent sheet where possible (see Appendix VIII), within ethnographic research it is not always practical to obtain formal written consent (van der Waal 2009). In the field, I would ensure that my participants were aware of my role as a researcher (indeed, as I previously noted, this was difficult to hide). However, I was often reliant on others for introductions, and my ability to detail the research and capture formal consent was limited by the setting I was in, what my gatekeepers permitted and a desire not to disrupt scenes as they were unfolding. Furthermore, fleeting encounters, for example, a five minute exchange across the plumbers' counter or at a trade show would have been ruined by intercepting with a formal consent sheet. Instead, in these situations I would be clear about my aims, and seek verbal consent. Any potential harm to participants has been minimised by keeping all data confidential and anonymised. Within this thesis, all individuals, organisations and brand names are identified by pseudonyms and the project is registered under UCL Data Protection (reference number: Z6364106/2012/03/05).

Particular consideration was given to my safety and that of my participants when conducting research in the field, and a full risk assessment was completed. Initially, I approached engineers via known contacts and organisations; this had the benefit of ensuring that my whereabouts would be known to more than just the participant (as might be the case with directly targeting a self-employed individual). When I became reliant on my participants to determine the venues for observation and interviews, particularly when I would travel to sites in engineers' private vehicles, I established a 'call buddy' procedure. However, this was revised after a particularly fruitful interview over-ran, causing some concern for those awaiting my communication. Jack and I had arranged to meet at a station near to his work and visit a local café one evening after he had finished for the day. Our interview was flowing well, with Jack readily offering detailed insights into his practices, so when the café closed we decided to retreat to a local pub to continue our conversation. Although I had checked in with my call buddies once, not wanting to disrupt this successful data collection opportunity, I failed to contact them again to let them know that the interview was on-going. Unbeknown to me, this caused some distress for my call buddies, who were communicating with one another in an attempt to establish my whereabouts. After this event, I had to reassess my safety procedure, strengthening the 'call buddy' protocol for when I was in the field (this procedure is detailed in Appendix IX). Revising my risk assessment as I navigated different spaces with heating engineers was an essential aspect in the evolving nature of this investigation, and remained an important consideration until the end of my fieldwork, which I now discuss.

4.5.4 The fragility of my fieldwork and 'leaving the field'

Given the challenges I faced in initially accessing the field (as detailed in Section 4.4.), it is perhaps unsurprising that my fieldwork could, at times, be quite unpredictable. My field visits were subject to last minute confirmation, potential cancellation and being abandoned early. In one diary entry, I note that I had only completed two of the five potential fieldwork opportunities I had lined up for that week. One of these cancellations was on account of the engineer running over time and being 'up to [his] eyeballs' in work. Another was an interview session arranged in collaboration with a merchant, this was cancelled owing to the engineers being 'non-committal due to pressing workloads' and a double room booking (merchant, email comm., 2013.11.25). The third session, a visit to an installation in a loft, was cancelled because the customer had requested to delay the work. Not only does this represent the nature of the heating engineer's job, it clearly demonstrates the fragility of my fieldwork. The difficulty of organising fieldwork in accordance with engineers' schedules, and the reticence of the industry to be involved (particularly in shadowing) meant that there were very few participants with whom I had more than a handful of interactions.

This fragility, coupled with initial delays in gaining access meant that my time to 'leave the field' was largely dictated by the time pressures of this research project (Hammersley & Atkinson 2007). Given the difficulties in deploying the ethnographic approach within this context, and the dearth of existing information on installation practices, it is perhaps unsurprising that I did not feel I had reached 'saturation' by the end of my fieldwork. Indeed, further data may have shed more light on the topic under investigation. Despite feeling that I would have liked to spend more time with heating engineers, particularly whilst I was experiencing success in my snowballing strategy, I had however identified recurring themes and patterns in what my participants were telling me and how they approached central heating installation. As I moved away from data collection and more fully focused on the process of analysis, I found a wealth of material with which to develop accounts of several distinct aspects of the engineer's work. I now turn to this phase of the investigation, detailing what emerged from an iterative process of considering my data alongside relevant social theory. In this, I detail my data analysis procedure, in particular the role that social theory has played and how this has been used in structuring the empirical material that follows.

4.6 Theory, analysis and writing up

"It is almost always a mistake to try to make a whole ethnography conform to just one theoretical framework" (Hammersley & Atkinson 2007: 159). Being wedded to a single theory would leave me unable to take advantage of the iterative benefits of the ethnographic approach, and as such, this thesis does not rely on a single body of theory to inform discussion. The exploratory strategy used here has revealed a series of distinct interactions that shape the installation of domestic heating systems. These are presented as individual empirical chapters, each drawing on a different theory as appropriate to "help make sense of the data" (Hammersley & Atkinson 2007: 166). This application of a variety of theories is not intended to suggest that they can be integrated at a theoretical level. Rather, with a sensitivity to their differences, they are being used to highlight distinct interactions that shape the central heating systems installed in homes. This application of different perspectives can be particularly valuable at a policy level when trying to understand, and impact on, energy related behaviours (Chatterton 2011). Beyond its suitability for the research strategy and value in understanding complex energy related phenomena, this adoption of theory also resonates with my own research 'upbringing' (Van Maanen et al. 2007). Having a background in chemistry meant that I approached this research with little prior knowledge of social theory. In 'resocialising' (Guba & Lincoln 1994) myself I have explored a range of theories used by scholars in related studies, helping me to identify those that seemed insightful for interpreting my own data. In particular, I investigated ideas from both sociology and STS during the early stages of this project, and considered these as I proceeded with the analytical process (detailed below). It is also vital to 'self-consciously' consider the dialogue between theory and practice within the ethnographic process (Pink et al. 2010: 649). In keeping with Blumer's call to recognise social theory for its provision of 'sensitising' rather than 'definitive' concepts, I have used theory to provide a "sense of reference and guidance in approaching empirical instances" (1954: 7). In this iterative analytical process, I moved back and forth between theories that seemed relevant and the data and ideas that were emerging from my fieldwork.

4.6.1 Analysis

Rather than forming a distinct research stage, analysis has been an informal iterative process, weaving between data and theory. As Marshall and Rossman note:

> "The process of bringing order, structure, and interpretation to a mass of collected data is messy, ambiguous, time-consuming, creative, and fascinating. It does not proceed in a linear fashion; it is not neat."
>
> (2006: 154)

This 'messy' process started in the field, and included incremental reviews of data as it was collected (Hammersley & Atkinson 2007). This has included formal coding, but also thoughts, notes and memos made throughout the data collection and writing phases (Hammersley & Atkinson 2007). Early analysis and a constant process of reviewing data fed into my subsequent data collection. This is comparable to the 'grounded theory' approach promoted by Glaser and Strauss (1965). However, this iterative process is common within the ethnographic approach, and instead of culminating in the generation of theory, can also produce descriptions and explanations as research products (Hammersley & Atkinson 2007).

My process of generating descriptions included repeated and detailed readings of the data (both incremental items as they were collected and the whole corpus after leaving the field). From this I identified a series of emergent themes, including the 'installation network', 'installer decision making' and the 'physicality of the heating system' amongst others. These initial themes informed additional fieldwork, including the development of the interview schedule (discussed in Section 4.5). With this additional fieldwork, time and theoretical reading, these were refined to four broad themes that each feed into an empirical chapter: the craftsman, supply chains, physicality, and constructions of customers. All data was stored, coded and analysed within maxQDA, selected for this work because of its ability to manage multiple types of data (text, audio and images) and accessible user interface. Coding, or placing segments of data into these baskets (Marshall & Rossman 2006: 159), is just one stage in bringing meaning to the data collected.

The process of writing is recognised for its contribution to producing an ethnography. Indeed, for Humphreys and Watson "as much or more of the analysis or the interpretation of the fieldwork experience occurs in the process of writing as occurs in the preparation for writing" (2009: 41). However, "the world does not arrange itself into chapters and subheadings for our convenience" (Hammersley & Atkinson 2007: 191). Finding the structure and words to present this material has been as much a part of the interpretive act of ethnography as the identification of salient themes and theories (Marshall & Rossman 2006: 162). For this work, writing has been an invaluable analytical tool, advancing the refinement of ideas and the logic of arguments. It is the written account of this empirical material that I now address.

4.6.2 Turning to the empirical material

I have interpreted the wealth of data collected during my time in the field using four distinct concepts that are relevant to different aspects of the material collected, each presented as an independent empirical chapter. By applying different perspectives, I have been able to explore several different aspects of engineers' culture in a detailed way. My account commences in ***Chapter 5*** by elaborating on who heating engineers are. In this, I explore the extent to which a Community of Practice (CoP) exists amongst heating engineers. Drawing on ideas of learning, identity creation and membership within this community provides further understanding of how engineers' practices are shaped and how these, in turn, shape the installation of domestic heating systems. Next, ***Chapter 6*** focuses on the supply chains within the heating industry, in particular, the social networks that are inherent in these. For this, I use the concept of social capital, exploring the benefits that different actors in the supply chain yield through both strong and weak ties to others, and how these may shape the central heating systems installed in homes. In ***Chapter 7***, I turn to the materiality of the installation process, in particular using Actor-Network Theory to look at the negotiations that take place between heterogeneous actors in the installation scene. Specifically, I explore the way in which new system components are jostled into position and encouraged to play the roles proposed for them. Finally, ***Chapter 8*** applies the concept of scripted users to explore the ways in which engineers, and the wider heating industry, construct the end users of central heating systems. In particular, I look at the engineer's intermediary role in scripting users and reconciling the differences between imagined and actual users.

It is only through the interpretivist, iterative approach to data collection and analysis detailed in this chapter that these insights could be compiled. Not only is the ethnographic approach described here the most suitable to answer my research question, it also adds to a growing body of qualitative research within the field of energy and buildings, in particular, applying a cultural approach to study the role of building intermediaries in shaping energy consuming practices. Having detailed the conduct of this investigation, including; my scoping studies, my route to accessing participants, and my data collection strategies and identity during my time in the field, all that is left is to present the ethnographic insights gleaned. The following four chapters are each structured in the same way, starting with an introduction to the theoretical concept being applied, before presenting the relevant empirical material and concluding with a discussion of the findings. Together, these chapters present a detailed account the multi-faceted nature of central heating installation, and the ways in which this can shape the energy consumed through domestic space heating.

5 A community of craftsmen

The heating industry is one 'where everyone knows everyone' (fieldnotes, PHEX, 2013.11.13). People may remain in this industry for many years, sharing stories, and reinforcing similar practices and accepted ways of working. In November 2013, during the Plumbing and Heating Exhibition (PHEX), an industry event at which manufacturers display their latest products, I was talking to Mark, a plumbers' merchant, about the industry. He pointed to a group of engineers stood at the bar, noting:

> 'That group of guys have all been doing this since they were fifteen - they all know each other. It's an industry where people stick around, it's not as fluid as some other industries where people move around and move on'
>
> (Fieldnotes, PHEX, 2013.11.13)

Indeed, the individuals that Mark was talking about shared the comfort and familiarity of people that had known each other for a long time. Despite the variation in training and specialisation amongst those practising in this industry (detailed in Chapter 3), it has enduring memberships, with people treading a similar course and developing shared understandings and stories as they do so. During three consecutive days of fieldwork, I conducted an interview, attended a manufacturer training session and conducted a second interview, all accessed through seemingly unconnected routes. Without prompting, the participant of the first interview mentioned that he had been considering the exact training session I would be attending the next day. It was during this training session that Burt, the course instructor, told a story where he likened connecting a new boiler to an existing central heating system to putting dirty oil into a new car engine (fieldnotes, VM training, WGC, 2013.08.21). This story was then repeated to me almost verbatim the following day as I interviewed a sales representative that had previously worked with Burt. Although I had accessed each of these individuals through independent routes, they had something in common: their paths crossed through industry events, previous work and shared stories. In this respect, they could be said to belong to the same 'community of practice'. This concept, introduced by Lave and Wenger (1991), will be applied to the empirical material detailed in this Chapter, which is presented in three sections, exploring engineers' identities, learning processes and community membership, in turn. Before I discuss these, I begin with an introduction to communities of practice, followed by a description of the three concepts from this body of work that will be used throughout the remainder of this chapter: learning, identity and varied membership within the community.

5.1 Introducing communities of practice

The term 'community of practice' is intended to imply:

> "Participation in an activity system about which participants share understandings concerning what they are doing and what that means in their lives and for their communities"
>
> (Lave & Wenger 1991: 98)

This concept arose from an idea of learning as social participation, wherein learning is a process of being an active participant "in the *practices* of social communities and constructing *identities* in relation to these communities" (Wenger 1998: 4, emphasis in original). In this way, participation in a community of practice "shapes not only what we do, but also who we are and how we interpret what we do" (Wenger 1998: 4). A community of practice does not form on the basis of formally defined structures, instead it is:

> "A form of traverse self-organization which does not correspond either to the formal structuring of the organization (the work group) or to its informal structure (friendship groups)"
>
> (Gherardi & Nicolini 2002: 196).

Thus, it is an "intuitive notion" (Lave & Wenger 1991: 42), one which has a fluid, emergent and informal structure (Brown & Duguid 1991; Wenger 1998). Despite their informality, communities of practice are identifiable by their common traits. In particular, members share a collective understanding of what the community is about, they are mutually engaged in the practices of that community, and they have a shared repertoire of communal resources, such as language, routines, tools and stories, developed within that community (Wenger 1998; Wenger 2000). There are three particular aspects of communities of practice that I found to be valuable in illuminating the empirical material that follows: learning, the construction of identities, and varied degrees of membership in the community. In the sections that follow, I elaborate on each of these in turn, before describing how these concepts are applied throughout the remainder of this chapter.

5.1.1 Learning in the community

Learning to be a member of a particular community of practice is achieved through a process of 'legitimate peripheral participation'. This term is intended to capture the social dimension of knowledge, suggesting that learning is situated in, and an integral part of, social practice (Lave & Wenger 1991: 35). The composite term 'legitimate peripheral participation' is to be taken as a whole, but its individual components are intended to capture different aspects which are essential to the social learning process: legitimacy relates to accepted ways of belonging, whilst peripherality suggests that there are multiple, more or less engaged, ways of being located in the community (Lave & Wenger 1991: pp.35-6). I will elaborate on this in Section 5.1.3, when I discuss degrees of membership. This composite concept has been used to understand the process of becoming a practitioner within a community (see for example, Lave & Wenger 1991; Gherardi & Nicolini 2002), as well as the on-going learning work of community members (see for example, Brown & Duguid 1991; Schenkel & Teigland 2008; Koch & Theusen 2013). I now elaborate on learning as on-going work, which is the application that I am most concerned with in this investigation of heating engineers' installation practices.

Brown and Duguid (1991: 41) note the importance of 'learning-in-working', suggesting that work practice, and the learning inherent in it, is very different to work as outlined in abstract representations that feature in formal descriptions of it (in the case of heating engineers, these formal descriptions include the regulations and guides detailed in Chapter 3). For example, Orr (1986) noted the significance of 'war stories' in the work of photocopier repair technicians; these are anecdotal re-tellings of problem machines and solutions. Despite these technicians primarily working alone, and sharing ad hoc, informal interactions, these stories were shared amongst community members. Further, because they were situated in the practices of the community (i.e. the lived realities of repairing photocopiers), these war stories could become embedded in the 'community memory' and used as a diagnostic tool for future work (Orr 1986: 67). Similarly, Schenkel and Teigland (2008) highlight the importance of spontaneous, face-to-face communications, particularly storytelling, for learning within and between communities of practice on a large-scale construction project. In the construction context, Bresnen et al. (2003) also highlight the capture of learning within a project environment, which is:

> "Dependent on the identification of comparable problems/ opportunities that the project team's experiences could be applied to, the representation of those experiences as stories of success or failure, and the incorporation of learning into new routines which can be applied elsewhere."
>
> (Bresnen et al. 2003: 165)

Furthermore, Lave and Wenger (1991: 109) identify the ability to talk both within (i.e. exchanging information) and about (through stories, lore) the community as important elements of membership. These ideas of social learning practices and story telling are applied in the first section of the following empirical analysis which explores learning amongst heating engineers. Beyond being a vehicle for sharing and using information, these stories and informal communications might be used to 'claim status as a member of the community' (Orr 1986: 68), and in the construction of identity within the community (Brown & Duguid 1991: 47). The identity of community members is the second key concept that I found helpful in exploring the existence of a community of practice amongst heating engineers, and is elaborated in the following section.

5.1.2 Identity in the community

As an inherently social undertaking, learning and operating within a community is more than participating in a certain set of activities; it implies becoming 'a kind of person', or assuming a particular identity (Lave & Wenger 1991: 53). As Duguid notes, it is membership within the community of practice that:

> "Offers form and context as well as content to aspiring practitioners, who need not just acquire the explicit knowledge of the community but also the identity of a community member."
>
> (2005: 113)

Thus, the community of practice provides a context for an individual to develop not only their practice, but also their identity. Wenger notes that identity is "not merely a category, a personality trait, a role, or a label" (1998: 163); instead, its construction is an ongoing, complex process, only achieved through engaging with the practice of the community. Further, Brown and Duguid highlight that those who develop noncanonical practices (i.e. diverging from those stipulated in official work guidance) are continuously reconceptualising both "their own and their community's identity in their own terms so that they can break out of the restrictive hold of the formal descriptions of practice" (1991: 52). This idea of identity construction is applied in the second section of the following empirical analysis to understand how heating engineers might conceptualise both their own and their community's identity. In particular, I explore how this might impact on the way heating systems are installed. Wenger (1998) suggests that, although identity construction occurs through engagement in the social practice of the community, it may also be shaped by trajectories of both previous and concurrent memberships in other communities of practice. In this way there can be differing degrees of membership within a particular community. This is the final concept that I will use to explore heating engineers' community, and is discussed in the following section.

5.1.3 Degrees of membership in the community

The term legitimate peripheral participation is intended to "create a landscape - shapes, degrees, textures" that reflect the variation in community membership (Lave & Wenger 1991: 35). This captures a lack of centrality amongst a community; it is not necessarily the case that an individual undertakes a linear learning trajectory in moving from a newcomer to a centrally located 'old timer'. Furthermore, Handley et al. reject the idea that a community of practice is a homogeneous 'social object', instead suggesting that the socio-technical context within which communities are situated "generates a fluidity and heterogeneity within communities" (2006: 645). In their selection of the term 'community', Lave and Wenger note that they intended to capture this heterogeneity:

> "We assume that members have different interests, make diverse contributions to activity, and hold varied viewpoints. In our view, participation at multiple levels is entailed in membership in a community of practice. Nor does the term community imply necessarily co-presence, a well-defined, identifiable group, or socially visible boundaries."
>
> (1991: 98)

Despite this emphasis that a community of practice is more nuanced than a co-located, well-defined group, Duguid (2005) argues that studies using this theory tend to focus on the 'community', rather than the practice. In doing so, many studies applying this approach have been based in environments where a recognisable 'community' is co-located, that is, where the individuals under scrutiny are situated in the same place. This is understandable given that the prevalence of tacit knowledge within communities of practice means that they are likely to involve face-to-face interaction (Duguid 2005). Studies of communities of practice amongst building professionals are of particular interest to this investigation; however, in keeping with this focus on co-location, many of these have taken place on construction sites (Gherardi & Nicolini 2002; Schenkel & Teigland 2008; Koch & Thuesen 2013; Tutt et al. 2013). Despite it being "difficult to apply" (Pink et al. 2010: 653) the idea of locality amongst construction professionals, who move between different construction sites, it is still possible whilst these individuals are temporarily co-located. Heating engineers present a particularly interesting case in this regard. This varied and disparate workforce (the composition of which is detailed in Chapter 3) often practice alone in private properties. Consequently, the final section of analysis presented in this chapter explores just how membership might vary amongst these different individuals, and what this means for the 'community' and the ways in which central heating systems are installed. Having introduced the three aspects of communities of practice most salient to the following empirical material, I now detail the suitability of this theory for the approach used, and outline the remainder of this chapter.

5.1.4 Scrutinising learning, identities and membership

It was through spending time with engineers, particularly in group contexts, that I began to see the ways in which the practices within this community are maintained, organised and modified. The dynamic nature of communities of practice means that the practices and knowledge within them are not fixed, and cannot be acquired in a straightforward way (Lave & Wenger 1991). Wenger suggests that: "it is a mistake to assume that practice is inherently a conservative force, and it is also a mistake to assume that practice is erratic or can be modified by decree" (1998: 98), noting that, as a result, 'close scrutiny' is required to understand the reasons for practice to be the way it is. Similarly, Brown and Duguid suggest that studies of work need to be grounded in the "concrete circumstances of actual practice" in order to reveal the complexity of their undertaking (1991: 42). Arguably then, the ethnographic approach adopted here is ideal for exploring the existence of a community of practice amongst heating engineers, and the learning, identities and membership inherent in this community. Within studies of the built environment, the application of ethnographic methods on construction sites and projects has provided insights on the situated nature of learning safety (Gherardi & Nicolini 2002), the creation of new languages amongst construction workers (Tutt et al. 2013), and knowledge sharing processes amongst overlapping communities of practice on large construction projects (Bresnen et al. 2003; Koch & Thuesen 2013).

The following empirical material is presented in three sections. Firstly, I look at engineers' learning processes, in particular, how they share information, discuss new ideas, learn, and adapt their practices as a community. Secondly, I use the idea of engineers' identity within a community to explore how their portrayal to outsiders, and interactions with customers, are shaped. Finally, I turn to engineers' degrees of membership within this community, particularly looking at those with different training trajectories and backgrounds, and how these variations shape both the installation and use of domestic central heating systems. The closing discussion will consider the application of concepts from communities of practice theory for understanding installation practices, and detail the implications of the insights revealed for how the energy consumed through central heating systems is shaped.

5.2 Learning in the community

5.2.1 Testing: 'more exams than actual work!'

Learning is inherent in the work of heating engineers. The competence required to practice as a heating engineer is re-assessed every five years through a formal examination process (which is introduced in Chapter 3). These assessments, intended to ensure that engineers remain abreast of the changing requirements of their job, are a combination of written and practical examination, for which the pass mark is 100% (Logic 2012). This was described to me several times as an 'open-book' type multiple choice exam, with the engineer required to answer questions, and to refer to specific regulations and information available in the literature provided.

Many of my participants recognised the benefits of these assessments. They were regarded as an opportunity to 'refresh' their knowledge and skills. Indeed, one participant noted that the rigorous testing procedure reassures him that 'he's doing a good enough job to keep doing the work' (fieldnotes, manufacturer training, 2013.12.02). However, this is an abstract learning process, whereby engineers are situated in a testing centre and they have to complete a written assessment. This is quite different to the engineer's day-to-day work, particularly their physical engagement with the technology. For some engineers, this testing procedure, and the requirement to make their expertise explicit, is difficult. For example, Jack noted that the examination process "scrambles your brain" (Jack, SE, interview, 2013.09.11). One of my older participants, George, found this particularly 'traumatic':

> "A couple of times I thought I've got learning difficulties or something y'know and I, I felt like an imbecile, y'know I really did and it was err, and I thought, whenever he asked me sort of once I'd gone beyond about half way I was like, I just lost it, y'know I could've quite easily walked out and I'm sort of like thinking, should I do this…?"
>
> (George, SE, interview, 2013.10.15)

Although George had been operating in the industry for over fifty years, and appeared to be an incredibly knowledgeable and intelligent individual, the assessment procedure made him feel 'like an imbecile'. George was not alone in his dislike of the examination process. Whilst this is one of the only formally recognised notions of continued learning within the industry, it is by no means the only way that engineers learn. In fact, this learning and assessment via 'intentional instruction' is quite distinct from informal, often social means of learning (Lave & Wenger 1991). Although they were rarely recognised as such, it is these often unthinking forms of learning that I found to dominate heating engineers' everyday work. The remainder of this section therefore explores some of the more informal means through which engineers learn.

5.2.2 Informal learning

In their everyday work, heating engineers manipulate a complicated array of components, and have to satisfy a variety of guidelines and regulations (these are outlined in Chapter 3). All of these are subject to change as they are updated and modified in line with changing policy and industry expectations. As such, the learning work of the engineer is never done:

> "If anyone says 'I don't need to learn anything else, I've learnt all I need', that's bullshit, you'll always learn, 'till the day you die, if you're not learning then you're doin' something wrong…"
>
> (Carl, SE, interview, 2013.12.16)

Given the changing nature of heating engineers' work, it is perhaps unsurprising that Carl saw learning as a fundamental and on-going aspect of his job. Carl is a self-confessed 'gadget freak' who, at the time of our interview, had imported some computer controlled thermostatic radiator valves from Germany, and installed them in his own home to "see what happens" before recommending them to his customers (Carl, SE, interview, 2013.12.16). Carl was not alone; several of my participants had a strong personal interest in maintaining their knowledge of central heating technologies and keeping abreast of changes in the industry. They would 'keep an eye on' new products by attending industry events, such as EcoBuild and the PHEX (fieldnotes, manufacturer training, 2013.08.), and reading trade journals and magazines. Jack referred to these as his 'gentleman's mags', suggesting that he keeps them 'by the bed', or reads them in a coffee shop ahead of starting his day at work (Jack, SE, interview, 2013.09.11). Meanwhile, Amir suggested that these magazines were useful for information about "new products and changes in the industry, new directorships, movers and shifters, details of illegal installations, changes in the law" (Amir, independent merchant, interview, 2013.08.12). In particular, *Registered Gas Engineer*[24], a supplement published by Gas Safe Register, was often cited as a source of information. This magazine includes Technical Bulletins and Industry Standard Updates, which detail changes in the regulations and guidance surrounding the installation of central heating systems. This analysis shows that, with new information being disseminated through these different avenues on a regular basis, learning is an inescapable part of the engineer's work. However, whilst the

[24] This is a monthly supplement sent to all Gas Safe registered engineers. It contains stories of gas installations, updates to industry regulations and guidelines, along with more general news about the industry and new products.

acquisition of information via magazines, and attendance at industry events represent accepted avenues of learning within this community, these are not the only informal means through which engineers learn. A fundamental part of heating engineers' work is problem solving, which is in itself a learning process. Engineers' strategies for managing problem solving begin to point to their preferences for more social learning strategies, and, as such, they provide the focus of the following section.

5.2.3 Learning through problem solving

Problem solving includes determining the most suitable products for a particular property, negotiating these around any existing socio-technical arrangements (which provide the focus of Chapter 7), and 'fault finding' – the process of identifying what is wrong if a central heating system is not working as it should. Problem solving can be a valuable and very rewarding learning process for the engineer:

> "I think if you've got a, a job that is hard work, it means you're actually tryin' to solve the problem, that's what I enjoy. I don't want easy days, 'cos if you have easy days then you learn something else, you 'ave to, you need to learn something else."
>
> (Martin, SE, interview, 2013.09.10)

Martin enjoys the challenge of solving problems so much that he does not want 'easy days' in his work. Of particular import for this discussion is who, or what, engineers turn to in solving these problems. While the engineer could turn to the instruction manual, according to one course tutor, this is 'against blokes' religion' (fieldnotes, manufacturer training, 2012.10.10). During one training session, the course leader implored the attendees to look at manufacturer's instruction manuals when fault finding:

> [Burt] asked the installers 'what do you do if you've got a fault', Eric made the symbol of a phone with his hand, put it to his ear and said 'hello, manufacturer'. Burt replied, 'yeh there's that, or RTFB' – he asked what RTFB meant and explained to me that was 'another one you should write down', and it meant 'Read The Fucking Book'.

(fieldnotes, manufacturer training, 2013.08)

Burt's use of profanity here emphasises his frustration at engineers not referring to the manual. Rather than engineers being too proud or lazy to seek guidance from an instruction manual, it can be suggested that they do not learn effectively through these means. In fact, one of my participants, Dale, noted that it was harder for him 'to take things in' by reading than through being shown, or told, about them (Dale, sales rep, interview, 2013.08.22). Helping engineers to 'get hands on' with products is one of the key strategies adopted at manufacturer training sessions because engineers 'learn by taking things to pieces' (fieldnotes, manufacturer training, 2013.12.02). The success of this strategy was highlighted by one attendee, who commented that he had 'been [wiring controls] for years by looking at manuals and guides but it had never been as clear as this' (fieldnotes, manufacturer training, 2012.10.10). Furthermore, during these sessions, heating engineers demonstrated their preference to speak to, and thus learn from, others. I found that when engineers were in a communal environment, they would share stories and anecdotes that seemed to act as valuable learning tools. Understanding this social aspect to engineers' learning is particularly important considering that, unlike many communities of practice, they do not work in a co-located environment. It is because of this that I now explore how this social learning activity is important for this group.

5.2.4 Banter: the sharing of stories

According to Wenger, "local lore, shared stories, inside jokes, knowing laughter", are indicative that a community of practice has formed (1998: 125). As Seb, the manager at a plumbers' merchant, explained, 'that's what you get in the plumbing industry - a lot of banter, friendly people' (fieldnotes, Plumb Shop, 2013.06.17). When heating engineers come together, it is these exchanges that prevail; discussions, coffee breaks and lunchtimes are filled with the sharing of anecdotes and stories. These might be personal tales, stories of recent work, problem solving successes, and customer interactions (this final type of anecdote, and the constructions of customers portrayed through it, provide the focus of Chapter 8). In the following two sections, I look at how these exchanges are opportunities for engineers to learn about diagnostic processes, changes in the industry, and to discuss how to, or how not to, perform their work.

Conversations for learning

During one manufacturer training day, Burt, the course instructor, was emphasising the importance of ensuring that existing central heating systems are clean before adding a new boiler. He elaborated by telling a story of when he was called out to a job where they were having problems with a newly installed boiler, explaining his process for identifying the problem as he did so:

> He said he took a look and the secondary heat exchanger and it was blocked up with stuff, so he took it out and replaced it. He said that as soon as he got to the property he knew what the problem would be … the radiators had '50 layers of peeling paint' and they were rusting on the bottom, they were just poisoning the whole system. Burt told the installer that he needed to swap the radiators [because] there was… too much rubbish in the system and it was blocking up the boiler.
>
> (Burt, fieldnotes, manufacturer training, 2013.08.21)

Burt's problem solving process included identifying the blocked heat exchanger, and looking at the condition of the radiators which revealed that the blockage was likely to be caused by debris from the rusting system. As with Orr's (1986) photocopier repair technicians, through repeating this story, the problem solving methods applied can become embedded into the heating engineers' community memory. In this way, engineers and industry representatives create a stock of information that they can utilise in future, should similar scenarios arise.

These interactions can also be valuable learning mechanisms for finding out about new requirements of the job. Brian suggested that his predominant way of finding out about "new bloody rule[s]" is through "word of mouth", via his peers (Brian, SE, interview, 2013.09.16). Amir, the owner of an independent installing organisation and merchant, uses this strategy to ensure that his employees remain informed about upcoming changes, in particular during conversations in the pub (Amir, independent merchant, interview, 2013.08.12). A discussion that dominated many conversations during my fieldwork was a change to the flue gas analysis procedure during the commissioning of a boiler. This had recently been announced in Technical Bulletin 143, and was published in *Registered Gas Engineer* (a copy of this is included in Appendix XII). This process involves using an Electronic Combustion Gas Analyser (ECGA) to measure the ratio of CO_2/ CO being emitted from the flue, this ratio has to be less than, or equal to, 0.004 for the boiler to be considered safe. The reading from the ECGA should be noted on the Commissioning Checklist. The break times during manufacturers' training sessions provided engineers with an opportunity to discuss this upcoming change, and how they would accommodate it within their existing practices:

> Dan had talked about taking a reading and getting a print off to provide evidence for the commissioning sheet. One of the engineers commented 'that's all well and good, but I don't have a printer on mine because it doesn't prove anything', you could be holding the probe anywhere and taking a print out. …Carl said that he thought that the printer was a good way to provide evidence that you've done the testing.
>
> (fieldnotes, manufacturer training, 2013.12.02)

The analyser can provide a print out of the reading, much like a receipt. This can be attached to the Commissioning Checklist as evidence of the CO/CO_2 ratio at the time of testing. However, as engineers discussed this particular piece of equipment, they revealed different concerns about the printing function, in particular, whether it provided an accurate representation of what the probe was measuring. Exchanging these concerns can be a way for engineers to share their understandings of this new requirement, and how they may accommodate this into their practices in different ways. Through the sharing of these stories, engineers can situate the abstract information provided in the Technical Bulletin within the intricacies of their actual practice (Brown & Duguid 1991). Whilst the informal discussions and 'war stories' (Orr 1986) presented so far have both previously been recognised for their role in social learning (Bresnen et al. 2003; Schenkel & Teigland 2008), a third type of story that prevailed amongst heating engineers, the 'bad practice story', which I have not found to be explicitly identified in existing accounts of communities of practice. This type of story is a tool used by heating engineers for perpetuating what is *not* right amongst community members, and is detailed more in the following section.

Bad practice stories

Industry magazines have regular 'bad practice stories', or, as one of my participants named them, 'naughty pages' (Gerry, SE, interview, 2013.08.20). These are examples of poor workmanship of varying severity, from messy pipes, poor finishes and incorrect locations to unsafe, illegal installations that readers (the majority of whom are registered heating engineers) have sent in (see Figure 5.1).

Figure 5.1 "The good, the bad + the ugly": an example of the bad practice stories published in industry magazines, source: (GSR 2013a).

A Gas Safe representative told me that the organisation were trying to change the 'dobbing in' culture, and make it more acceptable to report unsafe gas works (fieldnotes, Gas Safe meeting, 2013.11.28). However, I found the exchange of bad practice stories to be an important part of engineers' culture, one which extended beyond magazine articles into their conversations with one another. In these exchanges, engineers might relay what they have read, but also their own experiences of bad practice. Exemplars of what not to do may be used to reinforce the correct course of action, for example, where room thermostats should be located:

> "Don't put it on the radiator, you'll be surprised how many calls we get where the room thermostat's been turning off at room temperature. Not behind curtains, not behind clothes we've had an engineer who's been asked by a tenant if they can put it in the cupboard because it didn't match the wallpaper. Not in the loft, not in the garage and not in the shed. Ok? All places that we've found room thermostats situated and then the tenants complaining that the system doesn't work as they expected."
>
> (Phil, manufacturer training, audio, 2012.10.10)

Phil uses stories of incorrectly located thermostats to demonstrate to engineers where they should not place these devices. Brown and Duguid highlight that such stories can act as repositories of 'accumulated wisdom', which might be quite different to those embedded in documentations of work practice that privilege "the decontextualized over the situated [and] sweep away the clutter of practice" (1991: 45). In this case, the British Standard guidance to install heating controls in a "position readily accessible to the user" (BSi 2013b: 46), fails to account for the curtains, cupboards, wallpaper and building occupants that engineers may encounter in their everyday practice; indeed, these proved to be so important that they provide the focus of Chapter 7. Instead, it is in Phil's descriptions of bad practice that these are introduced, acting as a learning tool for engineers.

During my fieldwork, I came across my own bad practice story, a 'botch job' that a self-employed engineer, Chez, was rectifying. The previous engineer had installed two-port valves to manage the flow of water around the heating and hot water circuits (the design of central heating systems is detailed in Chapter 3), but failed to connect them, leaving the electrical wires hanging lose and rendering the valves useless. Chez showed me this, commenting that "the person that did this had no idea about central heating" (fieldnotes, SE install, 2013.03.04). Although this is an example of negligent central heating work, this case proved to be beneficial for my research. The story became my own token of bad practice, and was one that I, often unthinkingly, used to contribute to bad practice discussions between engineers during training sessions. The telling of this story was a demonstration of my own peripheral membership to this community of practice, and elicited further conversations with engineers. Furthermore, as in my own example, anecdotes can also be used "as a claim to status as a member of the community" (Orr 1986: 68), making them an important aspect of the engineer's identity. The identifiers that engineers share are a second indication that community of practice exists amongst these individuals. Engineers' demonstration and maintenance of their identity plays an important role in shaping the installation of central heating systems, and this provides the focus of the following section.

5.3 The engineer's identity

5.3.1 Heating engineers, not 'hairy arsed plumbers'

In operating and learning as members of this community, heating engineers assume a particular identity. Throughout this thesis, the participants of this research have been intentionally labelled as gas or heating engineers. During a meeting with representatives of Gas Safe Register, I was told that this vocabulary is used for 'positive reinforcement', and to distinguish those doing the job legally from those that are not. Furthermore, the use of this term allows heating engineers to 'say they are qualified in something' (fieldnotes, Gas Safe meeting, 2013.11.28). In *Registered Gas Engineer* magazine, this term denotes a competent, registered member, whilst an 'illegal gas fitter' indicates someone who has installed an appliance without being registered with Gas Safe (fieldnotes, Gas Safe meeting, 2013.11.28) (see Chapter 3 for the formal qualifications and registration procedures that heating engineers are required to complete to be deemed competent). Gas Safe Register are central to the existence and development of this community of practice:

> "Gas Safe is like the erm, all you've got if you've got the, the premier league, you, you pass the exam, but, then you've got to apply to join the governing body, basically the club, all, all Gas Safe is, is a club, once you've applied to the club, you, then you get this card come through and that, that gives you the right to work on gas."
>
> (Eddie, organisation, interview, 2013.07.04)

Becoming a legitimate member of the Gas Safe club is verified through examination, followed by certification and the receipt of a photo licence card, which was introduced in Chapter 3. However, during my fieldwork, heating engineers and surveyors were rarely asked by customers to produce these cards[25], with one of my participants noting: "I bet I don't take my ID and show it to someone more than about three times a year" (Jack, SE, interview, 2013.09.11). This echoes Wenger's finding that membership cards are rarely actually a signifier of membership in a community of practice (1998: 7). Instead, a heating engineer may be recognisable to those outside of the community through their 'uniform', usually comprised of combat-style trousers, a polo shirt, and a fleece jacket in the winter, along with the badges, labels and logos that adorn their clothing, vans, and the documentation they use. However, these are relatively facile representations of legitimate membership in this community. Instead, it is engineers' characteristics, ways of working and representations to non-members that demonstrate their identities and membership. One way in which engineers define their identity within this community of practice is by distinguishing themselves from traditionally comparable trades.

[25] This is a recognised problem, and one of Gas Safe's aims is to raise consumer awareness of gas safety, to this end, they run campaigns actively encouraging the general public to check engineer's gas cards, and consequently seeking to stress the import of the membership card within this community (GSR 2014a).

Ahead of my visit to the PHEX, I discussed the potential to talk to heating engineers at the event with one of my informants, Eric. He cautioned me, suggesting that I would have to avoid all of the 'hairy arsed plumbers' to get to the heating engineers (survey-organisation, fieldnotes, 2013.11.12). Eric was certainly not the only one to make this distinction:

> "There's still that boundary, or the band where the heating engineers can become plumbers, but plumbers can't be heating engineers, they're quite the borderline, they haven't got that technical, bit more technical, erm and I'm not knocking any of 'em because I know people that will be proud, I'd be proud to be called a plumber, the old boys that I've worked with, they've got more knowledge on their little finger than I'll 'ave when I die…"
>
> (Carl, SE, interview, 2013.12.16)

This quote from Carl highlights the technical skills of the engineer, which mean that while they are able to carry out the work of a plumber, the reverse is not possible. Beyond encompassing the skills of a plumber, James suggested that he also performs the work of an "electrician […] a carpenter, […] a plasterer, or bricklayer, or anythink like that" (James, organisation, interview, 2013.07.04). Thus, the multi-skilled heating engineer's, training, qualifications and abilities might be considered to incorporate and surpass those of traditionally comparable trades. This additional expertise allows the engineer to charge a premium for their work; for example, Gerry noted that he charges £200 per day for gas work, but only £150 for more general plumbing work (Gerry, SE, interview,2013.08.20). In fact, the range and complexity of the engineer's skills are such that my participants compared themselves with some quite different professions:

> "It's like, it's a bit like being a doctor, 'cos when you go to parties you can imagine being a doctor, tell you what doc, I get this really long 'ere … but when I go to parties, they go 'what do you do?', I go 'oh, I'm a heating engineer, I do plumbing and heating', they go 'why does my boiler always bang in the morning and why do I get all this tapping noise in the morning and the evening?' "

(Jack, SE, interview, 2013.09.11)

For Jack, it is the diagnostic element of the heating engineer's work that makes his job comparable to that of a doctor (this analogy is extended to consider the 'human' characteristics of central heating systems in Chapter 7). Participation in the community of heating engineers is a constituent of Jack's identity; as such, it is not something he can 'turn off' when he is not actively engaged in the task of installing a central heating system (Wenger 1998: 57). Instead, Jack negotiates his identity as a 'doctor' of central heating systems even when he is in a party setting. Other participants suggested that the level of qualification required to be a heating engineer actually exceeds that of a doctor or a pilot (fieldnotes, survey-organisation, 2013.02.14). Thus, the engineer's identity is established by more than the formal training and qualifications they receive, and it is not contained explicitly in the work they perform. Instead it is, at least in part, defined in relation to their skill-set and that of other professions. In this way, it is only through engaging in the practices of the community, including installing, manipulating and diagnosing central heating systems, that an engineer can be identified as a community member.

Furthermore, their identity is defined in the way they differentiate themselves from, and present themselves to, outsiders. Although community members readily discuss bad practice amongst themselves (as introduced in Section 5.2), they are particularly wary of revealing this to outsiders, because it might have a detrimental impact on the reputation of all community members. In fact, Tom noted that he would "never slag off someone else's work" in front of a customer, no matter how bad it is (Tom, SE, interview, 2013.07.17). Similarly, Doug pointed out that to "name a few cowboys" did not do the industry "any favours whatsoever" (Doug, SE, interview, 2013.12.03). The negative impact that television programmes like Rogue Traders and Watchdog[26] have had on the industry's reputation was mentioned several times by my

[26] This is a second UK television programme mentioned by heating engineers for its role in exposing bad practices amongst tradespeople. The first was Rogue Traders, introduced in Chapter 4. The role of these programmes is also discussed in Section 4.5.1.

participants. Indeed, the undercover work that is used to produce these programmes evoked suspicion about my motives as a researcher; this proved to be an association that I had to try to shake off during my fieldwork (these concerns presented a particular challenge in gaining access to heating engineers, as elaborated in Chapter 4). These programmes were also noted for providing too much publicity and exposing the secrets of the community to outsiders. It is not desirable for customers to know too much about engineers' practices, as Giovanni noted, with the information presented in these "the customer thinks he knows everything, [but] he knows nothing" (SE install, fieldnotes, 2012.04.25). This is largely owing to engineers' need to protect their reputation and skills, but also to be perceived as experts by those outside their community. Demonstrating the identity of an expert is an important signifier of membership in, and on-going maintenance of, the community. Heating engineers' strategies for demonstrating expertise are now discussed.

5.3.2 Demonstrating expertise

There are certain ways in which an engineer's expertise is demonstrable to outsiders, for example: being able to solve customers' problems; recommend particular products; perform tidy work; create a high quality finish to the pipework; and complete the documentation and registration associated with a central heating installation (this was introduced in Chapter 3). It was also suggested that an expert is someone for whom the task becomes unthinking, being able to "do it off the top of their 'eds, without even thinkin' about it" is a sign of an experienced engineer (James, organisation, interview, 2013.07.04). The engineer's work becomes tacit through experience, but also familiarity with the tools and products they are expected to manipulate. During one training session, the course instructor demonstrated how to remove the boiler casing, suggesting that it was 'one of the main things to get right because the customer doesn't want you to turn up and not know how to take the front cover off the boiler' (fieldnotes, manufacturer training, 2013.08.21). There are variations in the case and boiler design from each manufacturer; thus, in order to demonstrate expertise, engineers may limit their choice of technologies, ensuring that they are able to manipulate these devices without thought (this may also shape their brand loyalties, see Chapter 6 for other factors influencing these). For Rodney, “there’s nothing worse than turning up at a customer’s house and having to get the manual out to look at how to install it because then it looks like you don’t know what you are doing” (fieldnotes, PHEX, 2013.11.13). It is for this reason that Rodney exclusively installs Ocipura boilers, the brand that he learnt to use as an apprentice (this is discussed more in Section 5.4). Indeed, on the one occasion I did witness an engineer referring to the manual whilst installing a boiler, he justified this to me by explaining that he had been servicing, rather than installing, recently and ‘it wasn’t that he had forgotten what do to it just wasn’t fresh in his head and he had to think about it more’ (install-organisation, fieldnotes, 2013.03.19).

Moreover, the expert engineer should be able to “talk the talk”; that is, provide details about the products being installed and be “persuasive” about why these are a good option (Jack, SE, interview, 2013.09.11). During one manufacturer training day, an engineer queried whether, when replacing individual system components, he would have to modify the central heating system controls by adding zoning (this is a best practice requirement outlined in the Building Regulations, discussed in Chapter 3). The course instructor, Harry, suggested that it was best to provide two quotes to the customer, one with zoning and the other without, but explained to the engineers in the room that it was ultimately their decision. He elaborated:

> “I pretty much guarantee most people would say 'well actually, that's fair, you as a plumbing and heating engineer have come in as an expert and explained it all to them, but you've left it in their court to make that decision…At the end of the day guys, you are the industry experts, you're the installers [incomprehensible] ok, so they're relying on you to get this information to them.”
>
> (Harry, manufacturer training, audio, 2013.06.04)

Here, a manufacturer representative positions heating engineers as the industry experts, whom customers are reliant on for their information. Indeed, expertise might be demonstrated by the way in which the engineer interacts with the customer. In one instance, I spent over 90 minutes travelling across London with Sam, a surveyor, to reach a job. There was no shortage of conversation during our journey, Sam readily shared insights about his work and was highly personable. However:

> I noticed a change in Sam's persona when we entered the property - he was more business-like, he went straight to the corner with the boiler in it and started listing what would be removed. He was quickly reeling off the changes that would be made, listing 'we'll take this, this and this out' whilst pointing to the different parts of the system, he said 'we'll put the new boiler in the kitchen'.
>
> (survey, organisation, fieldnotes, 2013.02.14)

In front of the customer, Sam quickly asserted his position as an expert. Our time in the property was brief and the conversation focussed on where the new boiler would be located (locating the components of a central heating system is elaborated in Chapter 7). As we were leaving, Sam commented that a thermostat would be fitted in the hall, but no other controls were mentioned. It was only after we had left the property that Sam clarified for me that a wireless thermostat would be used, with a programmer fitted near the boiler (survey-organisation, fieldnotes, 2013.02.14). Sam only briefly discussed what would be installed and where it would be fitted, whilst hastily demonstrating this expertise, he failed to communicate with the customer about the controls. Thus, being able to "talk the talk" might result in a limited exchange of information with customers about the products being fitted in their homes. In this case, it is the controls that were overlooked; this provides one explanation for why end users have limited understandings or awareness of the heating controls fitted in their homes (as identified by Rathouse & Young 2004; Revell & Stanton 2014). These limited explanations and their implications will be discussed in more detail in Chapter 8; however, in the following Section I explore how householders' involvement in decision making may be restricted by the engineer's desire to demonstrate their expertise.

5.3.3 Identities shaping product decisions

In their role as experts, heating engineers may expect customers to heed their advice:

> "There are customers that tell you what they want and there, there are customers that don't listen to, I, I mean, they're employing me as the heating engineer to put a new boiler in, to do what I need to do with the heating, but they know better, some customers know better."
>
> (Martin, SE, interview, 2013.09.10)

As the qualified heating engineer, Martin finds it frustrating when some customers do not listen to his advice. Similarly, Keith expressed his frustration with customers who questioned his recommendations, because he is 'qualified in what [he does]' (interestingly, Keith is not actually formally qualified in what he does, this will be returned to in section 5.4) (Keith, organisation, interview, 2013.09.05). For some engineers, a lack of compliance from customers might lead them to reject a particular job. Carl highlighted that he will not fit a particular product if he knows "it's not gonna do the job", instead he might turn down the work, telling the customer "you're not listening to what I'm sayin' to you, you won't be happy at the end result" (Carl, SE, interview, 2013.12.16). He went on to suggest "they don't choose me, I choose them"; it is the engineer that has the final say in whether the work goes ahead (Carl, SE, interview, 2013.12.16). Similarly, Eric suggested that he would rather "walk away" from a job than end up on "Watchdog at eight thirty", if the customer requests something "completely stupid" (Eric, SE, interview, 2013.09.09). Indeed, the engineer's own preferences, and desire to use products that they are familiar with may be so dominant that they refuse to install an alternative:

> Faye: ok, and do, erm...customers, do they kind of ask for specific things, relating to the boiler?
> Brian: they sometimes will ask for specific boilers, we try to change their mind
> Faye: do you (laughing)? Just to what you prefer to fit?
> Brian: Just don't the boiler, don't like Ocipuras, don't like specific boilers, don't like manufacturers, so...yes, 'why do you specifically want that?', 'oh, 'cos my mate Dave's got one, it's bin all good', 'this one'll be good too'. Again, there are times when obviously if you want an Ocipura, you get someone else to fit it.
> Faye: yeh?

Brian: Because I don't like them, err, it's changed a bit now, but, no we don't source specific boilers, so, yeh.

(Brian, SE, interview, 2013.09.06)

Brian's dislike of a particular brand leads him to 'try to change' his customers' minds, and if this is unsuccessful, he will decline work where the customer specifies that product. Similarly, the engineer may adopt an approach to gently 'educate' the customer to accept their recommendations. Amir owns a medium sized installing organisation, whose strategy is to 'fact blast' the customer in order to 'educate them to how [they] would suggest' (Amir, organisation, interview, 2013.08.12). The obstacle here is trust, there is a perception that outsiders, in this instance the customer, assume that the engineer is 'tryin' to sell' something, and if the customer gets this impression there is a risk that the engineer, or organisation, will lose this work to a cheaper competitor. The problem of being undercut by engineers (or perhaps the cowboys discussed in Section 5.4) not fitting all of the required controls, or installing cheaper brands, was cited as a key issue by my participants and may lead them to have to justify their recommendations to customers. For example, during one of the surveys I observed, Jack, a self-employed engineer, recommended TRVs on the radiators, and quickly justified this to the customer by commenting that 'a lot of people think that heating installers just add them on for a bit of extra money, but they are recommended by the government now' (survey, SE, fieldnotes, 2013.10.30). However, as Dale noted "installers are tradesmen at the end of the day and some are really good at putting their point across and some are not so much" (Dale, sales rep, interview, 2013.08.22). Thus, the 'sales' role that engineers may need to adopt in justifying their product recommendations does not always sit comfortably alongside their characteristics, or their role as experts.

In this section I have highlighted the identity work that goes into being a heating engineer. In particular, the way that their demonstration of expertise is essential not only for shaping the way that they are received by outsiders, but also for maintaining the identity of the community. Thus far, I have demonstrated a series of similarities that suggest that, whilst it is multifaceted, a community of practice exists amongst heating engineers. Membership is demonstrated by the overlapping learning processes, shared stories and similarities in the characteristics of group members. However, as Dale noted, different engineers may adopt their expert roles in different ways. Indeed, this disparate, heterogeneous workforce (as detailed in Chapter 3) may create opportunities for the divergence of practice. The following section explores the ways in which this variety plays out within the community.

5.4 Degrees of membership

Different types of member can be quite recognisable, even notorious, amongst community members, for example new entrants and 'cowboys', whilst other variations may be more subtle. In the final section of this chapter I consider the 'landscape' of community membership (Lave & Wenger 1991), first detailing the features that define new entrants and cowboys, before exploring the ways in which different aspects of installation, surveying and wiring controls, can be performed in quite different ways.

5.4.1 New entrants and 'cowboys'

A new entrant is someone who is undergoing, or has recently completed, the formal training required to be a heating engineer (see Chapter 3). At the end of this process, qualifications are gained and certificates administered. However, these individuals are not yet classed as complete participants in the community, as James highlighted: "you can come along with all the certificates under the sun, right, but you still know jack shit" (James, organisation, interview, 2013.07.04). The new entrant can only become a full member through legitimate peripheral participation in the day-to-day working practices of the community, and a formal apprenticeship constitutes only part of this process. This essential, formative time has an enduring impact on heating engineers' practices. Some of my participants noted the legacy of the products they were initially exposed to as new entrants, for example, Rodney highlighted that he only fits Ocipura boilers, because 'it's what he was taught on when he was an apprentice' (fieldnotes, PHEX, 2013.11.13). Meanwhile, Malc explained to me that he was currently 'brainwashing' his apprentice to fit Bedlington boilers (fieldnotes, PHEX, 2013.11.13). This reflects Banks' (2000b) suggestion that brand loyalties are cultivated during the initial apprenticeship. Furthermore, both the volume of paperwork and cost, are factors that might prevent an experienced engineer from taking on an apprentice newcomer, this is particularly true for self-employed engineers. It was suggested that, because of this, new entrants are more likely to spend time with employees working for larger organisations, where specialist expertise might be distributed amongst individuals (see Chapter 3 for the specialisation strategy that organisations might adopt). This could limit the potentially valuable exposure of apprentices to the multi-skilled expertise of self-employed, long-term operatives (fieldnotes, manufacturer training, 2013.06.01). Thus, not only could entrants' initial learning limit the products that they later fit in homes, but who they learn from might restrict the expertise they are exposed to and consequently use in their own practice.

Indeed, with a multitude of routes to entry (see Appendix IV) it is perhaps unsurprising that there is a wide variation in the expertise, training and experience that individual heating engineers possess. At the lowest end of this range are the 'illegal gas fitters' introduced in Chapter 3. These are often regarded as performing the poorest quality or lowest standard of work, and are known amongst industry members as 'cowboys' or rogues. These individuals are particularly recognisable to industry members. Whilst there was a suggestion that Polish or Romanian migrants were typically rogues, the 'cowboy' is arguably more recognisable by his traits in comparison to legitimate community members. Key signifiers might include a poor finish to the work, an unsafe installation, broken parts, an incomplete, unsigned Commissioning Checklist, or no documentation at all. Furthermore, these individuals are recognisable by their inability to exhibit expertise:

> [Seb] said that it was obvious, the cowboys don't know what they want, they come in and expect him to be able to tell them what product to put in, they'll just ask for a boiler and he'll have to ask what size and they will tell him the number of rooms in the house and ask what size should go in. He said he'll say something like 'maybe a 30, but

> you need to size up properly', and the installer will just say 'I'll take one of them then'…
>
> (fieldnotes, merchant-chain, 2013.07.22)

Seb is a plumbers' merchant, who, although not a heating engineer himself, is aware of the signifiers and traits of legitimate community members. Whilst Seb may advise and assist community members, sometimes helping with technical aspects like the sizing of central heating systems (this is elaborated in more detail in Chapter 6), he is wary of advising those that are unable to demonstrate their own ability. Thus, while considered outsiders by the community (and those closely associated with it), 'cowboys' still operate within it. Presumably, they can only do this because they are incorrectly recognised by non-members, such as customers, as qualified heating engineers. In order to protect the identity of the community, and the individuals operating within it, the heating industry seeks to eschew these outsiders. Community members do this through actively distinguishing themselves from these 'cowboys', for example, cowboys' work is often the subject of the bad practice stories discussed in Section 5.2, and features on the television programmes discussed in Section 5.3 that give the industry a bad name.

Thus, there are a variety of individuals operating within the heating industry. Whilst new entrants may still have work to do to fully establish their identity as community members, they are accepted as legitimate peripheral participants. However, it is important to consider their learning trajectory, including who and what these new members are exposed to, and how this subsequently influences the central heating systems installed in homes. Meanwhile, 'cowboys' might be classed as 'non-members', or, at the very least, undesirable ones. They are regarded as having a detrimental impact on the community and are not welcome by its members. However, there are also more subtle variations in community membership that, although less immediately recognisable, are insightful for understanding how differences in installation practices may emerge within this community. It is to these more nuanced memberships that I now turn.

5.4.2 Surveying

I begin by investigating the practice of sizing a central heating system, performed by two different operatives. The first is a self-employed heating engineer, Tim, who performs all stages of the installation. The second is a surveyor for an organisation, Keith, who primarily performs surveys, but does not physically install central heating systems.

Tim is a Gas Safe registered engineer who has been operating in the industry for over 25 years. I joined Tim in a privately owned, three-bedroom, mid-terraced Victorian house that was undergoing refurbishment. Tim explained that he had spent "about an hour and a half"[27] working through a series of sizing calculations in pencil, and that he would type them up if the customer requested (Tim, SE, interview, 2013.12.10). In line with sizing methods detailed in industry standards (these are discussed in Chapter 3 and Appendix II), Tim systematically calculated the heat loss for every room in the property. He calculated the ventilation heat loss (that lost via ventilation through the building fabric) and transmission heat loss (that lost via thermal conduction through the building fabric) separately and summed these to reach the room's overall heat loss value, which is equivalent to the required output of the new radiator (see Figure 5.2).

[27] The self-employed engineers I spoke to suggested that they might spend between one and three hours on a survey (e.g. Rodney, fieldnotes, PHEX 2013.11.13; Doug, SE, interview, 2013.12.03; Jack, survey, SE, fieldnotes, 2013.10.30; Roy, SE, interview, 2013.08.08) often in the evening, after they have completed their other tasks for the day.

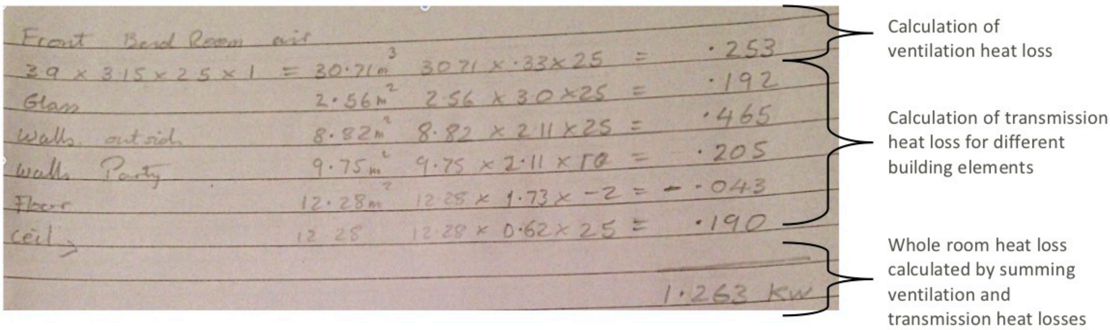
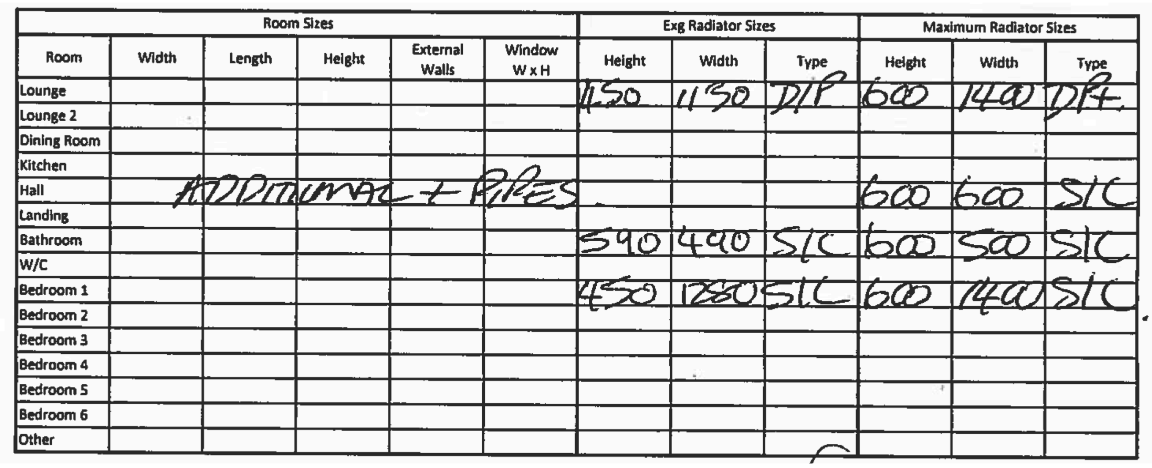


Figure 5.2 Tim's calculation for the front bedroom of the property, annotated to identify his distinct treatment of ventilation and transmission heat losses. These calculations were repeated for every room; a full copy of these is included in Appendix XIII.

Tim explained that he carried out his sizing calculations according to the CIBSE Domestic Heating Design Guide (field diary, post-interview, 2013.12.10); he also used his knowledge of building construction to assign appropriate U-values to the building elements. Furthermore, given the precision of the dimensions used for each building element (noted to two decimal places), he had presumably physically measured the spaces. Tim then summed the heat loss for each individual room to arrive at a value for the whole house heat loss of 12.51kW (Tim's full calculations are included in Appendix XIII). Based on this, he suggested an Ocipura 12kW system boiler to his client (Tim, SE, interview, 2013.12.10). The calculations Tim performed accounted for space heating only, as the hot water demand in this property was to be managed by a separate water cylinder.

My second example is Keith, a surveyor who visited several properties each day, performing a brief central heating system design process in each one. In one instance, I shadowed Keith as he performed eleven surveys in a single day, all following a similar, almost standardised, procedure (survey-organisation, fieldnotes, 2013.07.26). For Keith, the survey is "literally a visual inspection", for this, he suggested he did not need to be Gas Safe registered because "you'll never ever be goin' in even doin' gas checks" (Keith, organisation, interview, 2013.09.05). The brands, and some of the products, that Keith specified were determined by a council contract written under the Decent Homes[28] programme; however, he still conducted a brief survey in each property to determine the work carried out and size the system. Keith's procedure included a 'visual inspection' of the boiler to determine whether it needed to be replaced (this is, quite literally, looking at the boiler, but not interacting with it), and measurement of any new radiators. To size each radiator, Keith would measure the available space for a new radiator, and specify the largest length that he could fit in the space (survey-organisation, fieldnotes, 2013.07.26). Following this, Keith would complete a survey sheet (one of Keith's completed survey sheets is included in Appendix XIV and Figure 5.3 provides an excerpt from this) detailing the new boiler (a '30si combi'), and the dimensions of the new radiators to be installed.



Room Sizes						Exg Radiator Sizes			Maximum Radiator Sizes		
Room	Width	Length	Height	External Walls	Window W x H	Height	Width	Type	Height	Width	Type
Lounge						1150	1150	D/P	600	1400	DP+
Lounge 2											
Dining Room											
Kitchen											
Hall	ADDITIONAL + PIPES								600	600	S/C
Landing											
Bathroom						590	490	S/C	600	500	S/C
W/C											
Bedroom 1						450	1280	S/C	600	1400	S/C
Bedroom 2											
Bedroom 3											
Bedroom 4											
Bedroom 5											
Bedroom 6											
Other											

Figure 5.3 Excerpt from Keith's survey sheet, showing the existing ('Exg Radiator Sizes') and replacement ('Maximum Radiator Sizes') radiator dimensions.

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[28] Decent Homes is a government-led regeneration programme, specifically targeting social housing. The definition of a Decent Home requires that:

> "a) it meets the current statutory minimum standard for housing
> b) it is in a reasonable state of repair
> c) it has reasonably modern facilities and services
> d) it provides a reasonable degree of thermal comfort"
>
> (DCLG 2006: pp.11-2)

For this, central heating upgrades are performed simultaneously with kitchen and bathroom upgrades. Keith works in a team of four people, the other members of which are dedicated to the kitchen and bathroom work.

In this example, every replacement radiator was larger than its predecessor, and its consequent output increased. Furthermore, in the lounge, a double panel radiator with fins ('DP+') was to replace the existing double panel radiator ('DP') (see Appendix II for detail on types of radiator). This change in radiator type, along with the increase in dimensions will approximately double the output of this radiator (Stelrad n.d). When I asked why he was specifying different sizes, Keith explained that:

> He always puts them in a bit bigger than is really needed because 'you need to protect your back', he said that 'come winter, if it's cold in the property then the council could get back to us and ask us to fit bigger rads'.
>
> (survey, organisation, fieldnotes, 2013.07.26)

Keith was knowingly specifying larger radiators than necessary for the space (in this case, a one-bedroom, mid-floor flat) to ensure that the property was warm enough and to prevent any repercussions from the council. He also noted that 'you want it nice and cosy' in the living room (hence the DP+), and 'a bit cooler' in the bedrooms (survey, organisation, fieldnotes, 2013.07.26).

Both Tim and Keith are designing central heating systems; however, they do this in very different ways, and arrive at very different solutions. While Tim suggested a 12kW (heat-only system boiler) for a three-bedroom Victorian house, Keith specified a 30kW (combination boiler) in a one-bedroom mid-level flat. Whilst Keith's sizing also accounted for the water load on the property, it was likely that both the boiler and radiators in his example were significantly oversized for the space, having a potentially detrimental impact on subsequent energy consumption. Here, we see the lived reality of diverse membership within this community. Tim is a self-employed all-rounder who has undertaken the formal training and qualifications required to become a registered gas engineer. Meanwhile, in his progression from general builder to surveyor, Keith has bypassed the formal training and qualification routes outlined in Chapter 3, and is not Gas Safe registered. Furthermore, Tim is perhaps afforded more autonomy in his decision making within privately owned properties, whilst Keith's decisions have to satisfy the specification stipulated by a local council and a national regeneration programme. Thus, there are quite distinct working practices at play in this community. There is a separation amongst the individuals operating; this can be geographic, but also related to the different training trajectories, types of customer and properties being catered for. Furthermore, within this dispersed community, it may be difficult to align and manage these quite distinct trajectories. Indeed, this variation becomes even more extreme when individuals with quite distinct competencies operate within the community, as I found in the case of installing heating controls.

5.4.3 Wiring controls

As introduced in Chapter 3, the requirements surrounding the installation of controls are ambiguous, and the task does not have to be performed by a Gas Safe registered engineer. Instead, it can be performed by a variety of individuals, who can include heating engineers, but also electricians, as summarised by Martin:

> "It's not for everyone, […] I know very good heating engineers that haven't got a clue about wiring, they just don't wanna touch it and y'know, they're not interested in it at all. They get an electrician in who does it. Although a lot of electricians are special, erm specialising in heating and wiring and some are, don't wanna know. So it really does depend on the individual."
>
> (Martin, SE, interview, 2013.09.10)

During my fieldwork, it was suggested that 'they don't teach a huge amount of wiring and electric' during college courses (manufacturer training, fieldnotes, 2012.10.10), so heating engineers might not receive formal training on the installation of controls during their initial learning trajectory. Instead, they can gain electrical training through other means, for example attending manufacturer training sessions, or learning on the job. Alternatively, a self-employed engineer or organisation might sub-contract an electrician to perform this work. Within organisations that adopt a specialisation strategy, there may only be a few individuals who possess the skills to wire in controls, as Eddie noted "a lot of [his employer's] guys, when it comes down to wiring they ain't got a clue, so I gotta go out and wire the system" (James & Eddie, organisation, interview, 2017.07.04). Thus, there is a wide variation in the skills and expertise of the individuals performing this task, to the extent that some of them are classed as electricians rather than heating engineers.

Some of my participants had originally qualified as electricians, and later re-trained as gas engineers (Carl, SE, interview, 2013.12.16; John, manufacturer training, fieldnotes, 2013.11.26), while others had originally trained as heating engineers and gained additional qualifications in electrical work (Jack, SE, interview, 2013.09.11). I also met electricians who had chosen to specialise in central heating specific electrical work, but they had not received any formal training in central heating (Gary, install, organisation, fieldnotes, 2013.02.22). Amongst this varied landscape, individuals with different training backgrounds and identities might adhere to different guidance. For example, Gary, an electrician, explained that his 'bible' was the NICEIC book of regulations, and he also read a monthly magazine provided to electricians registered with this organisation (install, organisation, fieldnotes, 2013.11.16). This is not included in the heating industry literature introduced in Chapter 3 and consulting this distinct literature may be a source of conflict for the different actors operating in this community:

> [Gary] said that, as an electrician, he has to follow the Part P regulations, but Eric, his manager follows the Gas regs and this can cause arguments between the two of them. Gary gave the example of a local isolation switch for the boiler, he said that according to the Gas regs a local isolation switch was required for the boiler, where a fuse has to be removed to cut power to the boiler, whilst according to the Part P regulations you only need an on/ off switch with the boiler.
>
> (install, organisation, fieldnotes, 2013.11.16)

Therefore, while Gary followed Part P of the Building Regulations, his manager, Eric, a Gas Safe registered engineer, followed the gas regulations. In doing so, these colleagues arrived at different conclusions about whether you need a local isolation switch for a boiler, or just a standard on/ off switch. Considering an alternative scenario, a fully qualified heating engineer installing heating controls with little knowledge of electrical wiring may result in them being incorrectly wired. This was identified as a common problem by the instructors at a training day provided by a large controls manufacturer:

> [They] emphasised that '70% of valves are not faulty when returned, it's actually a wiring problem' – they were explaining that they often get products returned when they aren't actually faulty, rather they have just been wired in incorrectly.
>
> (manufacturer training, fieldnotes, 2013.06.04)

These differences, and the impact they have on the installation of heating controls, may also have consequences for the use and subsequent energy consumed through these systems. In one instance, I observed Gary as he removed an existing programmer from the kitchen, adjacent to the cooker, and fitted its replacement in the airing cupboard, which was located in the bathroom (see Figure 5.4).

Figure 5.4 Hiding controls to satisfy electrical regulations.

When I asked Gary why he was re-positioning the programmer in this way, he explained that 'the regulations suggest that the timer shouldn't be that close to the cooker…but because most UK kitchens were too small this wasn't possible and so there was some leeway in the regulations' (install, organisation, fieldnotes, 2013.11.16). Gary's priority was to comply with the electrical regulations and, to accommodate these, Gary positioned the programmer out of sight in the airing cupboard. This might be considered contrary to the 'readily accessible' location cited by the British Standards outlined in Chapter 3. For Gary, the electrical regulations take precedent over any of the heating industry's guidance on siting controls. This 'hiding' of central heating controls may have a detrimental impact on the way they are used (as discussed in Chapter 2), and is more fully addressed in Chapter 7.

Gary's identification and training as an electrician might also shape the way in which he explains the operation of the controls to the tenants. In this example, Gary advised the occupants to set the programmer to constant (i.e. permanently 'on') and that way 'they had full control of the heating through the thermostat in the living room' (install, organisation, fieldnotes, 2013.11.16). He suggested that the occupants set the thermostat to between 20-22°C, but turn it down to '15°C or something at night' (install, organisation, fieldnotes, 2013.11.16). On an earlier occasion, I had shadowed Gary whilst he provided the same advice to a different occupant. In making these recommendations, Gary relied on his own experience rather than any formal training or advice, noting that "we got used to it when my boys were babies, we still do it now" (install, organisation, fieldnotes, 2013.02.22). Further, during a conversation between Gary and I, he described how 'some people just don't get that a thermostat switches on and off and that you go this way for on and this way for off' (install, organisation, fieldnotes, 2013.11.16). In this, Gary revealed his own misunderstanding that the thermostat operates as a switch. If the person installing the controls does not fully understand their operation, it is perhaps unsurprising that end users possess the incorrect theories of home heat control identified in Chapter 2.

These findings suggest that neither an electrician with limited knowledge of heating, nor a heating engineer with limited electrical knowledge is the ideal person to install central heating controls. In this no man's land, which borders the boundary between the electronic and mechanical aspects of the central heating system, individuals with knowledge of both are participating. In Chapter 3, I described how the installation of heating controls is not governed by the GSIUR – the regulations outlining the responsibilities placed on competent gas engineers. It seems that, whilst this guidance is open to interpretation, the engineers' community of practice, or at least an aspect of this, is open to diverse memberships. Furthermore, the industry's attempts to ensure that heating engineers operate to particular standards (for example through the qualification and registration procedure outlined in Chapter 3) may be challenged by the variety of actors operating. In this Section, I have demonstrated that this variation can lead to recognisable differences in practice, for example in the cases of the new entrants and 'cowboys' that operate, but also more subtle ones, for example with the different surveying and installation processes at play. With this in mind, I now turn to discussing the data presented in this chapter, commencing with an overview of the chapter and outline of how this discussion will proceed.

5.5 Discussion: the implications of the engineers' community

This chapter has demonstrated the existence of a community of practice amongst heating engineers. Within this community, engineers partake in informal, social learning processes and they exhibit a shared identity. However, their community is also heterogeneous and dispersed, and the range of different individuals operating results in a variety of installation practices. The ways in which heating engineers learn, form their identity and practice as members of this varied community has never previously been identified. It is through applying a detailed, ethnographic approach that I have been able to observe heating engineers both at work and in more social settings. Not only has this approach revealed the existence of a community amongst engineers, it has created an understanding of the intricacies of its operation, without which "the practice itself cannot be well understood, engendered (through training), or enhanced (through innovation)" (Brown & Duguid 1991: 40). Indeed, it is with this information that I make a series of suggestions for further research, policy and industry in Chapter 9. However, before proceeding, the following discussion considers some of the limitations of the communities of practice approach applied, followed by the implications of this material in relation to existing research and policy strategies aimed at reducing the energy consumed through domestic space heating.

5.5.1 The difficulties of drawing boundaries around the community

Heating engineers display some of the characteristics that indicate that a community of practice has formed, for example, their social learning processes and shared identity, which are discussed in the following sections. However, this group also includes a significant degree of heterogeneity, with people of different backgrounds and expertise partaking in different aspects of central heating installation. Consequently, one challenge in applying communities of practice theory to this group is identifying where the boundaries of the community lie. As Wenger notes:

> "The very notion of community of practice implies the existence of a boundary…[yet]… the boundaries of communities of practice are usually rather fluid"
>
> (2000: 232)

The fluidity of these boundaries can be beneficial in allowing for the introduction of new elements to a practice (Wenger 2000). However, as Handley et al. (2006) note, these variations in membership can also result in nuanced differences in practice and identity structures, creating the potential for tension and conflict within the community. Indeed, in this chapter I have demonstrated the conflict that can occur when an electrician and Gas Safe qualified engineer might apply their understandings gained from different guidance to the same practice of installing heating controls. This may result in heating controls not being fitted in line with the guidance provided by the heating industry, or in positions which are not conducive to their future use.

Furthermore, the current capacity of communities of practice theory to define these heterogeneities is limited. It might be suggested that electricians are partial members within the engineers' community; they engage in one aspect of installation, but do not necessarily share the same identity as an engineer. Alternatively, if the installation of heating controls is a no man's land, in which neither the heating engineer (without electrical training) nor the electrician (without heating knowledge) are fully equipped to fit controls, this process might be better defined as a new boundary practice (Wenger 1998, 2000). In this way, it would perhaps be effective to consider the installation of these devices as a stand-alone entity, with specialist installers. Indeed, the continued development of heating controls within the electrical domain (see Peffer et al. 2011), with increasingly complex functionality, could necessitate an entirely different skill set amongst these individuals. To add further complexity to defining this community, its heterogeneous members are not co-located. This is a second limitation in applying the concept of a community of practice to this group.

5.5.2 The limitations of a dispersed community of practice

Although Lave and Wenger (1991) highlight that communities of practice do not necessarily need to be co-located, this is often taken to be a prerequisite to community formation (for example, in the construction site studies of Gherardi & Nicolini 2002; Schenkel & Teigland 2008; Koch & Thuesen 2013; Tutt et al. 2013). Heating engineers present a particularly interesting case in that they are rarely co-located, and they primarily work as self-employed individuals (this is discussed in Chapter 3). Whilst I have identified that a community of practice can exist amongst a group that comes together relatively infrequently, the dispersed nature of engineers' work can open up the potential for the emergence of variation in practices. Bresnen et al. highlight that "the creation, diffusion and application of knowledge is situated and thus heavily influenced by the context of practice" (2003: 159). This is particularly true of the heating industry, where every property presents a different installation context. For example, in contrasting the survey procedures of two heating engineers, I found quite distinct practices taking place. These individuals had taken different routes into the heating industry, but they were also operating in different contexts. In particular, Keith's work in social housing was shaped by the contractual obligations of the Registered Social Landlord and national upgrade scheme that he was working under. Thus, the individually situated nature of each job, accompanied by the fact that these individuals are often dispersed allows for the emergence of varied installation practices within this community. However, as Pink et al. highlight for the construction industry, despite the fragmented work of heating engineers, "there are simultaneously continuities in knowing across workers, sites and time" (2010: 653). It is these continuities that demonstrate the existence of a community of practice.

5.5.3 Learning through talking

Heating engineers work against a backdrop of changing technologies, regulations and guidelines, making learning a significant part of their practice. Although my participants recognised the importance of the formalisation of this learning, they expressed their discomfort in completing the exams and assessments stipulated by the heating industry (these are detailed in Chapter 3). Indeed, through applying ideas of situated learning, I have revealed that engineers undertake a process of social learning. When heating engineers are together, much of their conversation consists of anecdotes about their own work, how they adopt changes and new requirements into this, and the work of others. It is primarily the non-routine that engineers discuss, that is when things change, when there are particularly perplexing problems to tackle, or when they come across an example of bad practice. These stories may be a "communal response to an unmet need" (Orr 1986: 69); in other words, they provide the situated information and problem solving strategies that cannot be portrayed through industry guidelines or manuals. Further, if, as this analysis demonstrates, engineers learn through multifaceted, informal routes it is a gross over-simplification to assume that practice within this community can be modified by decree (Wenger 1998). For example, a change in the requirements stipulated in the Building Regulations, discussed in Chapters 2 and 3, is not linearly transposed onto engineers' practice. Instead it undergoes a process of dissemination, interpretation and discussion, exposing it to multiple interpretations and potentially resulting in some very different lived realities of practice (as in the case of engineers' varied adoption of the flue gas analysis procedure in section 5.2.3).

5.5.4 Harnessing expert engineers

The heating engineer's identity is a deeply embedded facet of community membership. Through particular terminology and traits, a fully qualified, competent heating engineer is distinguished from other professions and those that do not share the same suite of skills. Furthermore, the definition and reinforcement of this identity is encouraged by an organisation central to the development of this community: Gas Safe. Importantly, identities are:

> "Key to deciding what matters and what does not, with whom we identify and whom we trust, and with whom we must share what we understand"
>
> (Wenger 2000: 239)

For heating engineers, this identity leads them to present themselves as experts to outsiders, particularly customers. To demonstrate this expertise it is important that engineers can seamlessly select and install products. To achieve this, engineers may restrict the products they install to those that they are most familiar with, meaning that they can skillfully interact with the device without having to consult manuals and user guides. Thus, it is this preservation of an expert identity that leads heating engineers to display risk averse tendencies that limit their acceptance of new technologies (as identified by Banks 2000b and Killip 2011). In turn, this reluctance to adopt new devices may limit the success of technologies (and the strategies that encourage their adoption, as discussed in Chapter 2) that aim to reduce the energy consumed through central heating systems.

Furthermore, this expertise can be demonstrated by being able to 'talk-the-talk', for example through being an assertive decision maker, and providing brief explanations to customers. This finding goes some way to explaining why Rathouse and Young's (2004) focus group participants felt that engineers did not have the time to explain heating controls, and suggested that this may be better if it was allocated to someone else. Furthermore, Janda and Parag (2013) highlight that whilst middle actors in the construction industry may be in a position to contribute to energy efficiency aims, it is not always within their remit to do so. The engineer's brief interactions are unlikely to facilitate discussions about energy efficiency, or the consideration of energy efficient products. Moreover, these issues may be regarded as tangential to the heating engineer's, and heating industry's, priorities (for example safety, as discussed in Chapter 3). Thus, in moving towards the more sustainable construction and use of buildings, the energy community may look to establish the best strategies for heating engineers to 'reorient' themselves (Rohracher 2001: 138), so that their professional goals include energy efficiency (Janda & Parag 2013), or consider who else might be best positioned to play this role. However, achieving change in this community is unlikely to be straightforward considering the varied degrees of membership within and the existing complexities of heating engineer's work.

5.5.5 Considering broader networks

To conclude, this chapter has demonstrated the existence of a community of practice amongst heating engineers, but also detailed the idiosyncrasies of how this presents itself. Whilst engineers take part in social learning processes and have shared identities, there is also heterogeneity amongst those practicing within this community. However, whilst there may be a fluid boundary around engineers' community of practice, their interactions are not confined to the community. In the following chapter, I explore engineers' links beyond the community. In particular, I look at the relations amongst supply chains and how these can shape the energy consumed through domestic central heating systems.

6 Supply chains and social networks

6.1 Introducing social networks and social capital

> "I like to be on first name terms with people, so I like to go into my plumbing shop, 'hello Andy, Dave, George' whatever, I like to chat [...] I don't like going into shops where you're a bit of an alien, y'know what I mean? [...] I think blokes are creatures of habit, y'know they like...so of course, they don't like to go into different suppliers all the time, they like goin' to the same suppliers, talk..."
>
> (Jack, SE, interview, 2013.09.11)

The familiarity that Jack highlights is common within heating engineers' supply chains. The majority of engineers that I spoke to expressed a preference for a single merchant, or a small selection of local ones. These preferences exist in relationships ranging from the informal interaction between a self-employed engineer and independent merchant, to the formal agreements between large contracting organisations and national chains. Furthermore, manufacturers have a presence within this network through their sales representatives, who interact with both merchants and heating engineers. Within the heating industry, these relationships develop because of the benefits they yield for all parties. Engineers, merchants and sales representatives "establish relations purposefully and continue them when they continue to provide benefits" (Coleman 1988: S105). These benefits could be understood as the product of social capital, which is used to describe "the types of resources that accrue to persons by virtue of social ties" (Portes 2000: 2). The concept of social capital is used within this chapter to explore the nature of, and benefits accrued from, interactions within the supply chains that heating engineers are a part of. Exploring these relationships reveals a series of ways in which they shape the actions of engineers, and potentially, the energy consumed through central heating systems once they are situated in homes.

Social capital is subject to some controversy within the academic literature, with a variety of definitions being used by different authors (see Nahapiet & Ghoshal 1998; Lin 1999; Portes 2000; Adler & Kwon 2002 for reviews). These definitions vary according to their focus on the sources or effects of social capital, and whether this is an individual or network property (Adler & Kwon 2002). Nahapiet and Ghoshal capture these complexities with their definition of social capital as:

> "The sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit. Social capital thus comprises both the network and the assets that may be mobilized through that network."
>
> (1998: 243).

However, in order to understand the relations at play in engineers' supply chains, I use an intentionally narrow definition: that social capital is the resources accrued to individuals by virtue of their social ties. As Coleman notes:

> "Social capital is defined by its function. It is not a single entity but a variety of different entities, with two elements in common: they all consist of some aspect of social structures, and they facilitate certain actions of actors…within the structure."
>
> (1998: S98)

Thus, social capital can be considered as "the resource available to actors as a function of…their social relations" (Adler & Kwon 2002: 18). The exact nature of these resources within engineers' supply chains will be explored in the remainder of this chapter, but examples include loyalty, reciprocity and trust. Due to it being a property of relations, social capital is not a tangible commodity that can easily be traded, since relationships cannot be passed readily from one person to another (Nahapiet & Ghoshal 1998: 244). There are two dimensions of social capital that will be used to explore the empirical material contained in this chapter: relational and structural. The relational aspect focuses on the content and influences of peoples' relations, whilst the structural aspect considers the overall pattern of network connections, for example, who you might turn to for information (Nahapiet & Ghoshal 1998). In the next section, I look at how each of these aspects, in turn, can contribute to understanding the empirical material that follows, before outlining the remainder of the chapter.

6.1.1 The relational and structural dimensions of social capital

In discussing the need to study supply chains from a social network perspective, Galaskiewicz notes the importance of understanding the relationships at play, highlighting that:

> "What gives networks a dynamic quality and what makes networks "work" are the underlying social meanings of the relationships to those who are party to the network. That is, the underlying expectations shared among those in social relationships make networks trustworthy and ensure that they deliver on their promise."
>
> (2011: 7)

In this quote, he highlights the significance of acknowledging the social meanings of relationships, and in particular the trust and expectations inherent in these relationships, for understanding what it is that makes supply chain networks "work". I will first elaborate on the nature of trust, before discussing the expectations at play within relationships. Trust can be defined as a willingness to be vulnerable to another party (Mishira 1996). Through literature review, Nahapiet and Ghoshal identify four aspects of belief in another that lead to trust: belief in their good intent; belief in their competence and capability; belief in their reliability; and, belief in their perceived openness (1998: 254). Trust within relationships might help in ensuring efficient, timely interactions, bypassing the need for more formal measures of honesty (for example, written contracts) (Galaskiewicz 2011). Meanwhile, expectations or social obligations "represent a commitment or duty to undertake some activity in the future" (Nahapiet & Ghoshal 1998: 255). In explaining obligations, Coleman notes that "in some social structures, it is said that "people are always doing things for each other"" (1988: S102). He compares obligation to a credit slip, when one person does something for another, the recipient has a debt to the donor, which is then recovered through future reciprocation (Coleman 1988). This reciprocity is a key feature of the engineer's supply chain that can shape the products installed in homes, and is elaborated in the following empirical material.

In addition to unpicking the social meanings of engineers' relationships, it is important to look at the patterns of linkages in place (Nahapiet & Ghoshal 1998). Here, my focus turns to the structural dimension of social capital, in particular, the information channels that network ties provide access to. The strength of tie is defined by Granovetter as a "combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie" (1973: 1361). Network ties have generally been categorised as either strong or weak; it has been argued that successful networks have a collection of both (Uzzi 1997). Strong ties are valuable for 'preserving or maintaining resources' (Lin 1999: 34) i.e. maintaining the status quo and for the transfer of complex, or tacit knowledge, particularly where trust is required (Krackhardt 1992; Levin & Cross 2004). However, strong ties are not the only way to gain useful resources. The benefits of weak ties, characterised by distant and infrequent interaction (Levin & Cross 2004), have also been highlighted. Weak ties are particularly valuable in the delivery of non-redundant information (i.e. new knowledge) (Granovetter 1973; Levin & Cross 2004; Hansen 1999). Within a closed network, or one with just strong ties, it stands to reason that actors are well known to one another, thus the only way that new information enters the group is through a weak tie to someone primarily operating in another group (Granovetter 1985). The relationships between merchants, sales representatives and heating engineers consist of both strong and weak ties, each delivering different types of valuable information.

Bresnen et al. (2005) identify the interaction effects between the different dimensions of social capital, that is to say, the relational and structural dimensions outlined above co-exist within social networks. For example, the authors note that where strong norms of trust and reciprocity have developed, strong social linkages are likely to be at play within a social network (ibid: 241). Consequently, these relational and structural aspects are considered together in interpreting the empirical material that follows. The use of these concepts to understand engineers' supply chains is elaborated in the following section, before outlining the remainder of the chapter.

6.1.2 Studying social capital in supply chains

As discussed in Chapter 2, although identified as potentially important (Killip 2013; Owen et al. 2014; Janda & Parag 2013), the day-to-day interactions of those in supply chains have not previously been studied in detail with regard to their potential impacts on energy consuming practices in buildings. Research conducted by Bowden et al. (2012) included ethnographic observation of both plumbers and plumbers' merchants with a view to understanding their role as water efficiency intermediaries. However, whilst the authors acknowledged the role of plumbers' merchants in the delivery of information to plumbers, they did not explicitly look at the content of their relationships and how these act as conduits for this information. Within the construction context, Bresnen et al. (2005) have combined the concept of social capital with in-depth interviews to explore knowledge sharing and creation in construction project based firms. The authors highlight that 'there is much to be gained' from exploring social capital within the construction industry, in particular noting the distinct nature of social capital in this setting compared with other organisational environments on account of the discontinuous and dispersed nature of construction work (Bresnen et al. 2005: 243). As discussed in Chapter 3, similar specificities apply to the heating industry, which primarily consists of self employed engineers and small organisations.

The following material explores the role of social capital in heating engineers' supply chains, using this concept as a tool to identify the ways in which these networks operate. In particular, I reveal the impact that these social networks have on heating engineers' practices and influencing the technologies that are fitted in domestic properties. As the most prominent actors in the everyday work of the engineer, it is the relationships between the engineer, merchant and sales representative that provide the focus of this discussion. Amongst these actors I reveal the use of both strong and weak ties for information transfer. I also detail how the relational elements of trust, loyalty and reciprocity amongst these actors deliver benefits. Through revealing the nature of the engineer's supply chain, I will identify why we need to include a wider array of actors in policy that aims to reduce the energy consumed through space heating, and the information channels that could be utilised in modifying current installation practices. The chapter closes with a reflection on the use of social capital as a means to explore the findings presented, and their relevance to the energy consumed through the central heating technologies installed in homes.

6.2 The plumbers' merchant

The process of installing a central heating system is complex (see Chapter 3 for more detail on the different stages involved in this). The task requires numerous tools and consumables, and many of the components of a central heating system are intricate, particularly the boiler which contains a huge number of small parts that are easily misplaced. For all of these tools, consumables and parts, the engineer is reliant on the merchant on a daily basis, even visiting multiple times per day (merchant–chain, fieldnotes, 2013.07.22); this makes the merchant one of the most prevalent actors in the engineer's network. In the course of my fieldwork I found myself searching for a specialised washer between floorboards and having a field visit called short on account of a missing clip for a flue joint (a 'nightmare' that meant the engineer could not fire up the boiler and may have had to source the part from his merchant (SE install, fieldnotes, 2013.11.20)). The majority of customers at a plumbers' merchant hold a branch specific account, managed primarily by an individual member of staff. The inception of these interactions was described to me as an "arbitrary" thing, with an engineer making initial contact because "a mate goes in there" or it's "where you're gonna get the stuff the cheapest" (Gary, sales rep, interview, 2013.08.22). Despite the arbitrary nature of its establishment, the engineer and merchant might begin to build a relationship (Asad, merchant-chain, fieldnotes, 2013.07.25), facilitated by regular informal communication. These strong ties are demonstrated by the friendly, informal interactions that dominate in the plumbers' merchant:

> These personal exchanges happened throughout the day, both on the phone and in person with the installers that visited the store, they would chat about quite mundane things at times, but it was clear that many of the customers were very familiar with the people that worked in the branch. It was a very friendly atmosphere.
>
> (merchant-chain, fieldnotes, 2013.06.17)

The discussions between engineer and merchant include both personal and work-related elements. Engineers may even extend their visits for this informal conversation, something which proved to be particularly beneficial for my own research. For example, during a day at Plumb Shop, Brian, a regular customer, arrived. The branch manager, Seb, explained that Brian had 'an opinion about everything' and would be good for me to talk to (see Chapter 4 for the gatekeeper role that Seb played in this research). Seb introduced me to Brian, and made us both a cup of tea. At Seb's request, Brian readily agreed to chat to me, resulting in a 30 minute informal interview (merchant-chain, fieldnotes, 2013.06.17). The relationship between engineer and merchant is supplemented by regular remote communication, via phone or email. Phone calls between the two are frequent and short lived; something that is facilitated by familiarity:

> "Phone up 'Andy, it's Jack', I could be any Jack couldn't I? He goes 'alright Jack, how you goin'?', he knows you straight away, 'give us a price on a so-and-so boiler can you' or 'can you do this for us?', y'know and of course he will and that's half of it."
>
> (Jack, SE, interview, 2013.09.11)

Here, Jack recognises that he does not need to go beyond a first name in identifying himself on the phone, meaning that he can immediately get to the business of ordering a boiler. Jack's account reflects the majority of phone calls that I witnessed during my fieldwork. Both engineer and merchant are familiar with the information exchanged, and do not need to elaborate beyond the essential details; in this instance, specifying the boiler model. The efficiency of this mode of communication was further highlighted by Asad, a member of staff in the merchants, who noted that 'they could get someone on the desk that spends £300 and takes hours to deal with', whilst another customer might spend '£3,000 on the phone in 5 minutes' (merchant-chain, fieldnotes, 2013.07.25). Thus, the social capital yielded through these frequent interactions is the speed and efficiency with which the two actors can do business. These valuable information channels are particularly important where multiple contact is required between merchant and engineer, for example in relaying back and forth between requests, costing information and purchase confirmations. The frequency of these calls was made apparent when Seb was able to recite Brian's mobile phone number from memory (merchant-chain, fieldnotes, 2013.07.25).

In contrast to this, one of my participants, George, travels across the UK for his work (his list of locations included Leeds, Derby, West Midlands, Cambridge, Colchester, Bournemouth, Croydon, Reading, Guildford, Woking and Central London). George is a self employed engineer, who prefers to buy his products at one of three local branches and take them to his destination. However, because of his variable location, and the sometimes unpredictable nature of his job, George occasionally uses merchants where he is relatively unknown.

> George: I mean, be prepared to wait, if your face isn't known and you walk in you're interrupting their day.
>
> Faye: I suppose yeh that's...'cos with some of the installers I've seen they will use the same supplier and they will know each other well.
>
> George: yeh, exactly, yeh, and that that erm that is a bone of contention in, in a lot of merchants in the building trade, if your, if your face is known expect good service, if your face isn't, expect to wait. You're treated like an imbecile. (laughing)
>
> (George, SE, interview, 2013.10.15)

In George's experience, he is either ignored or 'treated like an imbecile' if he is not familiar to the staff in the merchant. This is a sharp removal from the relaxed interactions I previously outlined, but it is an important one. George's comments demonstrate that without a relationship, the engineer may not have access to the same social capital benefits as those with ties to the merchant, in this case a fast and friendly service. Thus, although strong ties and familiarity are common between merchant and engineer, this is not always the case. Through convenience and necessity an engineer may visit merchants where he is less well known. Regardless of tie strength, in moments of interaction between these two actors, the job of the merchant extends far beyond that of mere supplier. The merchant is a key information channel for the engineer, acting as advisor, expert and, at times, taking decisions about the technology out of the engineer's hands. The examples in the following section demonstrate these varied roles, and investigate the role of tie strength in the extent of the merchant's reach.

6.2.1 Strong ties for loyalty

One of the benefits of strong personal ties between merchants and engineers is loyalty. Seb, the branch manager at Plumb Shop, noted 'if I left and went to work for Plumb Parts or something, then Calshrift [an installation company] would join me' (Seb, merchant-chain, fieldnotes, 2013.06.17). Calshrift is a major customer, they order 'about 100 boilers a month' (Seb, merchant-chain, fieldnotes, 2013.07.22). A shift such as the one Seb proposes could have huge implications for the profitability of his branch of Plumb Shop. Seb's claim that clients are more loyal to individuals than an organisation was enforced by the case of another of my participants, Jack. At the beginning of this chapter Jack outlined how he likes to be on first name terms with his merchant, Andy. After spending some time with Jack (I met him on five occasions), I established that Andy had in fact recently changed the national organisation he works for, and, in keeping with the comments above, Jack (and apparently several other clients) had moved with him.

> "Now, I do a bit of work now with Parts Merchant, I do a bit of business with Parts Merchant 'cos Andy used to work for Installer Spares in Launston and of course Andy moved to Parts Merchant, and then 'cos I got on really well with Andy and he's the

> manager, he always looked after me so it stands to reason that you're gonna do a little bit of work with 'im…"
>
> (Jack, SE, interview, 2013.09.11)

Here, Jack has highlighted that his relationship with Andy is one of the reasons he has moved some of his business from Parts Merchant to a different national chain, Installer Spares. Jack continued to describe the person taking Andy's position as 'a complete idiot', alluding to the importance of the engineer's perceptions of the merchants' expertise in developing a strong tie. Loyalty is one of the vital social capital resources yielded through these relationships. With loyalty, the merchant can retain his customer base, even if he moves. This is demonstrative of a key feature of social capital: that it is not easily traded (Nahapiet & Ghoshal 1998). These friendships and loyalties take time to build and are not automatically exchanged when there is a change in staff at the merchants. Further, by being loyal, the engineer is guaranteed to retain a good service, and be 'looked after'.

On another occasion, Jack told me how his loyalty to Andy can extend to reciprocity. If Andy did Jack a favour, Jack would 'do the same in return'. He gave the example of Andy being short on reaching his target for boiler sales, and Jack buying a couple of boilers to 'help him out'. Through this exchange, Andy can achieve his monthly target and get a bonus, whilst Jack knows that Andy would 'go out of his way' to reciprocate in the future (PHEX-industry event, fieldnotes, 2013.11.13). Strong ties, familiarity and reciprocity were common amongst the heating engineers and merchants I spent time with. This might extend beyond the professional and into the personal sphere, for example exchanging copper pipe for a recommendation for who could repair an oak sideboard damaged by a leaking fish tank (merchant-chain, fieldnotes, 2013.06.17). However, engineers will not necessarily demonstrate loyalty to a single individual, sometimes alternating between a number of merchants for financial reasons and for convenience. In his interview, Tom listed three suppliers, but did not preferentially use one because his priority was ensuring that he was getting the lowest price for his customer.

> "I would phone them, yeh, if you can make. To be honest, if you didn't, you'd be a fool because you could, there's no set prices for a lot of these things, you could phone up one supplier and get a shower or a little product like that for twenty quid less when they're buying two thousand, three thousand pounds worth of products, you can save 'em sort of two hundred, three hundred pounds, just by goin' on your phone for five minutes."
>
> (Tom, SE, interview, 2013.07.12)

Tom contacts different merchants to maximise his economic efficiency. Despite this, Tom still limited his supplier to one of three, meaning that he retained a certain degree of familiarity with those merchants. As previously outlined, the five minute phone calls that Tom mentions are no doubt facilitated by this familiarity. Tom was not alone; other engineers told me that they would use a range of suppliers, with their selections driven by price and convenience (merchant-chain, fieldnotes, 2013.06.17). These priorities reflect Killip's (2013: 527) assertion that it is probably 'more normal' for builders to use more than one supplier, being driven largely by price and the availability of materials, but also by service. However, it is less likely that these individuals will benefit from the same loyalty and reciprocity that those with stronger ties enjoy. Whether or not strong ties and loyalty exist between the merchant and engineer, the merchant can act as a key information channel, disseminating product knowledge and expertise.

6.2.2 Trusted ties shaping product decisions

George was earlier introduced as a self-employed engineer who travels across the country for his work. George's preference was to use the nationwide chain, Plumb Parts, because they tend to have somebody with 'product knowledge'. He highlighted the importance of this because of the variations in products. Giving the example of a particular boiler having two potential types of valve, he suggested: "when you talk to somebody with product knowledge, they can say 'well, this is better, you can use this', or y'know, you can get more sort of input" (George, SE, interview, 2013.10.15). Given his frequent travel and his earlier recognition that he experiences a poorer quality of service amongst those he does not know, George's ties to individuals within different branches of Plumb Parts are likely to be weak, suggesting that a strong tie to the merchant is not always required for the engineer to be comfortable seeking information from them. Coleman (1988: S117) suggests that those serving as a source of information for others acquire information for their own benefit, not for those who make use of them. With this product knowledge, the merchant is better able to assist the engineer and, perhaps more importantly, gain return custom.

The merchant's knowledge is particularly beneficial to heating engineers for problem solving, a task so common to both actors' everyday work that these queries appear as routine procedure (Suchman & Wynn 1984). In some cases engineers visit the merchant equipped with a picture of the problem part on their phone, or the part itself. The experienced staff I spent time with were able to identify these problems and recommend solutions in an incredibly short space of time with very little explanation from the engineer. One merchant described this process to me as 'a game of charades', because engineers sometimes cannot identify or articulate what they need and he has to deduce a solution from the little evidence given (Seb, merchant-chain, fieldnotes, 2013.06.17). In this case, Seb's experience at 'charades' means that he can identify the information the engineer needs, even if the engineer does not know how to ask the right questions. The engineer arriving at the merchant's with queries and problems to be solved sits in stark contrast with the expert engineer portrayed in Chapter 5. Whilst engineers are highly protective of their expert status in front of their customers, this appears not to be the case with the merchant. This is indicative of a key resource delivered by social capital: trust. In these moments, the engineer is willing to reveal what he does not know, safe in the knowledge that exposure to the merchant will not have a detrimental impact on his professional standing. Furthermore, the engineer demonstrates a belief in the competence and capability of the merchant.

However, merchants do not act without their own agenda. The solutions that they suggest and the knowledge that they share are likely to be shaped by their own product preferences. My fieldwork demonstrated that if the engineer does not make a specific request, then the merchant will direct them towards their own preferred brands. For example, Amir, an independent merchant, noted that '60%' of his customers do not ask for a specific brand; as a result, his customers are given his preferred Stockman device (merchant-independent, fieldnotes, 2013.07.16). Similarly, Seb explained, "if someone asks for a thermostat, I'll naturally pick up a Humes, if someone asks for a Marshon thermostat, they get a Marshon" (Seb, merchant-chain, fieldnotes, 2013.06.17). Humes is the organisation's own brand of controls, which Seb is incentivised to sell, and so it is this product that he automatically provides for his customers. As the "middle man", during these exchanges the merchant might be proactive in trying to promote products that "they've actually got a chance to make money on as well" (Dale & Gary, sales reps, interview, 2013.08.22). The merchant's priorities and preferences are likely to be shaped by contractual obligations, informal rewards, profitability and their relationships with sales representatives (which are elaborated in Section 6.3). Furthermore, merchants, particularly those operating independently, are likely to stock preferred products to protect their reputation. For example, Amir stocks only two types of control; a market leading brand and one cheaper alternative. If a customer requests a product outside of his chosen range, Amir suggests that he "try Joe Bloggs down the road" because they "wanna stay with reputable companies" (Amir, merchant-independent, interview, 2013.08.12). This was specific to controls, which he suggested are more likely than larger items to be returned to the merchant if there is a problem. Amir was less concerned about boilers, for which he suggested customers are more likely to turn directly to the manufacturer's warrantee. Without the responsibility of returns, Amir was comfortable stocking a wider range of products. The potential liability placed on the merchant was emphasised in another case, when I was visiting the branch of a national chain. The manager relayed a story to me about the risks of being too specific about which products to install:

> He said that there was a case a couple of years ago with Kintyre, where they had recommended a boiler and something had gone wrong and it had caused a fire. Kintyre got into trouble over it because they had recommended it.
>
> (merchant-chain, fieldnotes, 2013.06.17)

The manager noted that within his organisation, whilst they will suggest particular brands, they 'try to avoid recommending specific models' because it could make them liable, like in the Kintyre case that he detailed (merchant-chain, fieldnotes, 2013.06.17). Thus, the degree of specificity may vary depending on which element of the heating system the merchant is recommending. In this case, the boiler may carry a higher risk because of the potential health and safety implications if it goes wrong. Despite the merchant's apparent caution in being too forceful in shaping some product decisions, suggesting favoured brands and parts no doubt influences the products that get fitted in homes. With regard to heating controls, it appears that these are determined based on the affiliations and preferences of the merchant, rather than their suitability for particular customers (see Chapter 2 for the implications of this, and Chapter 8 for more on customers and controls). Further, if the engineer trusts in the merchant's expertise, they may not question these suggestions. Indeed, with regard to the sizing of central heating systems, I found that the merchant's reach can be greater than just recommending particular brands. This is discussed in the next section.

6.2.3 Sharing expertise and sizing systems

Phil: [Inaudible - coughing] What do you use? How do you size a whole system?

Attendee: Whatever the deal is in the plumbers' merchant

All: [Laughter]

(Manufacturer training, audio, 2012.10.10)

When the topic of conversation turned to the sizing of central heating systems during one training day, an engineer wryly remarked that he sizes based on 'whatever the deal is in the plumbers' merchant'. This was met with laughter, but my experience in plumbers' merchants suggests that they can, in fact, play a role in shaping the sizing of central heating systems.

During my time in Plumb Shop, an engineer, Roy, requested two '7 by 9 DP' radiators, that is two double panel radiators that are 700mm high by 900mm wide (see Appendix II for more information on the type and sizing of radiators). After checking stock availability, the merchant identified that the only two in stock were a '7 by 9 DP+' and a '7 by 10 DP+'. Roy considered the pricing of these products, checking availability with a competing merchant, but concluded that he was happy to purchase a different size and type of radiator than he had originally requested (merchant-chain, fieldnotes, 2013.07.22). It is the shift in type that is important here, moving from a double panel (DP) to a double panel with fins (DP+) significantly increases the output of the radiator. Oversizing may help to achieve lower return temperatures, potentially increasing the efficiency of system operation; however, this example demonstrates that the formal sizing procedures discussed in Chapter 3 are not necessarily being followed (see also Appendix II). Instead, product choices, including the sizing and output of components, are shaped by 'whatever the deal is in the plumbers' merchant'. This significant role of transactions taking place in the plumbers' merchant is a key insight into the way that central heating systems are selected in homes, and potentially their energy consumption.

The reach of the merchant with regard to sizing was further highlighted by George, who suggested that they may actually perform the calculations on behalf of engineers.

> "Well if you give them the room size, wall content, window size, erm, whether it's been insulated with stuff, just the basic facts and they'll come back to you and say, y'know, you need about this size, or you need this capacity…"
>
> (George, SE, interview, 2013.09.16)

George suggested that "if it's critical or close", you can provide the merchant with information about the property, he lists room size, wall content, window size, and they will "deal with it for you" and "tell you what radiators you need" (George, SE, interview, 2013.09.16). In this, the expertise traditionally reserved for the competent heating engineer (introduced in Chapter 3 and discussed more in Chapter 5) is transferred to the merchant. This example is demonstrative of the engineer placing trust in the merchant's ability to size the central heating system. Whilst spending time in an independent merchant, a member of staff, Nasir, received an email from an end user asking him to size up for a series of radiators in her property. The email detailed the dimensions of each room and the height of the windows. It also stated that the property had no cavity walls and requested TRVs on all radiators. Nasir explained to me that he would now perform the heat loss calculations in order to determine the required output for the radiators.

> He explained that he would use the dimensions and information given but he would have to make 'a certain number of assumptions' – for example about the level of insulation and he would use standard heat losses to size for the customer.
>
> (Nasir, merchant-independent, fieldnotes, 2013.08.12)

In this example, the merchant is communicating directly with the customer, completely bypassing the expertise of the competent, Gas Safe qualified engineer called for in the regulations and guidance shaping this process (see Chapters 3 and 5). Furthermore, since Nasir's only knowledge of the property is that received through this email communication, he has to perform his calculations based on 'a certain number of assumptions'. This practice was carried out across the organisation, with Nasir's colleague, Ryan, also performing sizing calculations. Ryan showed me the Mear's calculator[29] he uses for this, in which he enters the dimensions of each room to reveal the required output for the radiators (merchant-independent, fieldnotes, 2013.08.12). Ryan also highlighted the 'prompt sheets' that he uses to know what to offer customers when they ask for central heating systems, these included the different controls that might be required, chemicals and filters. Neither

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[29] This is a circular slide rule, consisting of two plastic disks with a series of measurements written on them. The engineer rotates the top disk according to the dimensions and physical properties of the space, along with target room temperature. With these parameters in place, the bottom disk will reveal the heat requirements of the space.

Ryan nor Nasir have any formal training or qualifications related to the installation of central heating systems. Instead, both have a background in construction and followed a career trajectory into desk-based work in a plumbers' merchant (merchant-independent, fieldnotes, 2013.08.12). Despite this, they are contributing significantly to the sizing and design of the central heating systems installed in homes, bypassing the expertise of qualified heating engineers. This example is drawn from an independent merchant, and this practice may not be as prevalent in national chains (particularly considering the liability risks highlighted in Section 6.2.2.). Further, during the course of my fieldwork, I documented examples of engineers performing detailed sizing calculations (some examples of this are discussed in Chapter 5) and visiting the merchant with specific product requirements. However, it is important to emphasise the potential reach of the merchant in shaping product decisions and sizing central heating systems. Arguably, it is owing to the trust inherent in the relationship between merchant and engineer (and sometimes the end user), that the merchant can be allocated the task of sizing central heating systems. This may be supported by strong ties between the two actors (see Section 6.2), but it may also be the case that the merchant's expertise is recognised regardless of tie strength. The value of ties of different strengths is further demonstrated by the sales representative, who uses both in navigating amongst merchants and engineers.

6.3 The sales representative

The sales representative, or rep, is a transient actor, who operates within a particular geographical area. In their 'patch' they are the 'middle man', moving between merchants and engineers and performing a range of tasks. Within the merchants, a sales rep is distinguishable by their clothing and demeanour. In contrast to the casual attire of engineers and merchants, the rep will be smartly dressed, usually wearing a shirt and smart trousers, or a dress and high heels if they are female. I found them to be confident and vocal. In their dual role, acting between both merchant and engineer, the sales rep again relies on relationships and ties.

Faye: ok, and as erm sales rep what's your role in- inbetween the merchant and the installer, where does the sales rep come in (incomprehensible)?

Dale: it's relationship innit, it's a personal...

Gary: yeh it's, it's huge relationships, y'know. If you've got the relationship with the merchant and you can make them money, they're gonna back you and promote you, and then you rely on the relationship with the installer t-, to [...] you want the relationship because you want them to use your product…

(Gary & Dale, sales reps, interview, 2013.08.22)

Gary and Dale are sales reps and – as they highlight above – an important part of their job is to establish relationships with both the merchant, who sells their product, and the engineer, who buys and installs their product. These relationships are variable, whilst some engineers and merchants will seek the available benefits from strong ties with the sales rep, others will not. The role of the sales rep, as allocated by the manufacturer, might also differ between companies. For example, Dale noted that a big brand, like Bedlington Boilers, might use their sales reps to "tick boxes, drop leaflets off", and rely more on their "phenomenal" marketing and after sales team. Conversely, a "lesser brand" would rely more heavily on their rep to provide technical advice and solve problems with boilers in situ (Gary & Dale, sales reps, interview, 2013.08.22). Engineers might use sales reps in different ways, depending on the nature of their relationship. At interview, whilst some talked extensively about their relationship with the sales rep, others only mentioned this actor in passing. As James pointed out, "what you got to appreciate wi' reps is, some are arseholes, some are useful" (James, organisation, interview, 2013.07.04). For example, some sales reps might be valuable for gaining information about upcoming training days, and providing free access to these, or to learn about changes with products (Ibrahim, organisation, interview, 2013.07.06; Tom, SE, interview, 2013.07.13; Martin, SE, interview, 2013.09.10). Alternatively, where stronger relationships exist, the sales rep might act as more of an informant, able to provide expertise to the engineer in times of need (James & Eddie, organisation, interview, 2013.07.04). Beyond offering advice, I now turn to the sales rep's relationship and rapport with both merchant and engineer, which can shape the products that are sold and installed (Amir, merchant-independent, interview, 2013.08.12; Jack, SE, interview, 2013.09.11).

The rep simultaneously seeks relationships with merchants, and uses them to access engineers, in particular, through visits to the branch. A rep may come and go from a merchants following brief, quite formal exchanges taking place across the counter; if they do not have an appointment to see the manager, they may be turned away (merchant-independent, fieldnotes, 2013.08.12). Alternatively, the visits can be extended and informal, with cups of tea and friendly conversation fostering valuable information exchanges. Without a defined place of work, it is the merchant that provides the physical space for interaction between sales reps and engineers to take place. In all of this, the key to the role of the sales rep is having "that personal contact", with both merchant and engineer, which "makes a massive difference" (Gary & Dale, sales reps, interview, 2013.08.22). In the following discussion, I look at the way that sales reps operate within the central heating industry, how they adapt to the culture and practices of engineers, and how their actions might shape the central heating technologies fitted in homes.

6.3.1 Imparting information and fostering loyalties

Sales reps (and the manufacturers they work for) have identified engineers' frequent visits to the merchant as an opportunity for interaction.

> [Dennis] said that when the installers are in the merchant they have a bit of time on their hands, it was a great opportunity to talk to them because they will be stood waiting for an order to be run through or something, so you can have a chat to them then.
>
> (Dennis, sales rep, fieldnotes, industry event, 2013.09.23)

Here, Dennis, a sales rep, identifies the plumbers' merchant as a space where engineers will be located, but also where they have the time to talk. In the same way that I was able to conduct informal interviews in this space (an example of this is included in Section 6.2.), sales reps similarly use the merchant to interact with engineers. The reps' strategy extends beyond my opportunistic meetings, with them creating scenarios to engage the engineer. One such approach is the 'breakfast morning', where the sales rep will schedule an early visit to the merchant's, during which they prepare bacon sandwiches for engineers, simultaneously informing them about new products. The timing of these is important, the merchant is busiest first thing in the morning (many branches open from 07:30), when engineers visit to collect the equipment they need to perform their work that day. Breakfast mornings are popular, they were mentioned to me several times and I unexpectedly witnessed one whilst shadowing a sales rep, who explained 'every rep has a George Forman grill in their car' (sales rep, fieldnotes, 2013.07.16). These sessions are a key opportunity for reps to deliver new information to engineers. Indeed, the potential of these 'technical mornings' for the promotion of water-saving products to plumbers has recently been recognised by Bowden et al. (2012).

It is in these moments that 'most [engineers] will come over and have a chat', the remainder will, at the very least, take a leaflet (Dennis, sales rep, fieldnotes, industry event, 2013.09.23). A similar strategy was exemplified by one manufacturer conducting a 'roadshow'. This involved sales reps travelling to merchants across the country in a van which had a series of demonstration products on display, for engineers to interact with. The jam doughnuts available at the van presented a tempting incentive for engineers to detour from their day (merchant-chain, fieldnotes, 2013.07.25). For Amir, it is "when [the reps] come in" that they "impart any information that they have", it is through these informal means that he "gain[s] the knowledge" about new products and changes in the industry (Amir, merchant-independent, interview, 2013.08.12). The reps' ability to impart information about new products might even lead engineers to seek them out. A couple of my participants noted their enjoyment at visiting industry events, like the Plumbing and Heating Exhibition (PHEX) because it gave them the opportunity to communicate with reps. For example, Brian highlighted that "you get to talk directly to the people that are standing there, you'll 'ave three or four reps and you get to the stage 'well, what about, why haven't you done this…?'" (Brian, SE, interview, 2013.09.16).

Given the brief and temporary nature of these meetings, it may be suggested that the tie between sales rep, engineer and potentially merchant, in these moments, is weak. However, as illustrated by Amir, these weak ties can still yield social capital, in particular the diffusion of information (Granovetter 1973). More specifically, these ties provide *useful* information, that is new information or novel insights less likely to come from close ties (Levin & Cross 2004). In this case, this is information regarding products that engineers and merchants may not previously have been aware of. Furthermore, for the rep, this can help to ensure product sales and may encourage the development of stronger ties and loyalties from engineers.

Beyond products, the rep can also use these interactions as an opportunity to recruit engineers to manufacturer training days. The rep might provide supplementary incentives including a curry, a couple of beers (manufacturer training, fieldnotes, 2013.08.21), or a go-karting trip (Jack, SE, interview, 2013.09.11). Further, the rep might use the merchant's knowledge here, for example, asking them to identify engineers eligible for the training session. This might be "guys that buy a lot of boilers […] or just folks you've known a long time that are good lads" (Jack, SE, interview, 2013.09.11). Following initial recruitment, the engineer can then begin to be introduced to installing that manufacturer's product.

> Jez explained that it takes an ASM [Area Sales Manager] approximately 6 months to make 'one of you guys' buy a boiler, and they judge you as a loyal customer once you've installed 4 boilers. Jez said that his job was all about changing the mindset of the installers.
>
> (manufacturer training, fieldnotes, 2013.11.26)

Jez, a course instructor, highlighted that following initial recruitment by the ASM (sales rep), it is up to him, during training sessions, to 'change the mindset' of the engineers. This is a process of explaining and selling the product to the engineers. In this, we see that weak ties between sales rep and engineer are beneficial, yielding social capital resources to both parties. With rewards like food, drinks and activity days, the engineer is open to gaining new knowledge. Meanwhile, the sales rep, sometimes with the help of the merchant, can work to gain sales. Furthermore, it is through this initially 'forced' reciprocity that product loyalties and longer-term interactions can begin to develop. Demonstrating loyalty to a particular manufacturer can be beneficial to the engineer; it is here that the benefits of stronger ties become apparent, as I elaborate in the following section.

6.3.2 Strong ties for specialist support

Engineers may demonstrate product loyalties for a variety of reasons, for example, to maintain their expert appearance (which is discussed in Chapter 5), or because of the cost and quality of the product. Furthermore, as one participant noted, installers are "far more incentivised by the manufacturers than they ever were" (Gary & Dale, sales reps, interview, 2013.08.22). For example, installers might be rewarded with gifts, promotional materials and discounts for fitting certain products. However, there are also "a lot of relationships going on" (Gary & Dale, sales reps, interview, 2013.08.22), through these, product loyalties can be encouraged. If an engineer "jump[s] from boiler manufacturer to boiler manufacturer", then they may miss out on the backup support (for example, technical assistance) that loyal customers receive (Eddie, organisation, interview, 2013.07.04). Conversely, if there is a stronger tie between the engineer and the sales rep, the engineers might gain access to specialist assistance for problems.

> James: It's what you get brought in to, what they advise you and y'know, sometimes because you are with Ocipura, instead of ringin' the helpline to get the technician out we got a number which can get a bloke out now to change that part...
>
> Eddie: I got the reps number, the rep, I seen him the other day
>
> (James & Eddie, organisation, interview, 2013.07.04)

Through building up a rapport with the Ocipura rep, James and Eddie are able to bypass the organisation's central technical helpline. Instead, they can directly contact the rep if they need assistance. The sales rep becomes a comrade in trying to solve problems that arise with the technology. Where a strong tie exists between engineer and sales rep, the engineer might turn to this actor as the 'first port of call' (manufacturer training, fieldnotes, 2013.08.21) if he has any problems with a product. The engineer knows that the sales rep will be able to 'sort it out for him', even if this is by 'ringing technical' on his behalf (manufacturer training, fieldnotes, 2013.08.21). Alternatively, they might bypass technical support altogether; this can be particularly beneficial because these official lines of advice are "not always as good as you would want them to be" (Ibrahim, organisation, interview, 2013.07.06). In some cases, it was noted that they are just "looking at the computer and a flow chart" (Ibrahim, organisation, interview, 2013.07.06), which is the same troubleshooting chart that is available in some manufacturer's installation manuals. If the engineer is able to refer to this themselves, then they do not gain any new information from someone looking at this from a call centre. Instead, what can be beneficial is the engineer's ability to contact a sales rep, who either has installing experience, or can "recommend somebody" who is more able to help (Ibrahim, organisation, interview, 2013.07.06). Thus, through remaining loyal, and developing strong ties with particular sales reps, the engineers can gain a valuable social capital resource in the form of an efficient, specialised technical service.

The quality of support available through the rep can also shape the product preferences of the merchant. Amir cited three boiler brands that his company predominantly sells and installs, their product preference is based on three things, the quality of the boiler, reliability and, "last but not least", the support.

> "We get a lot more support out of them in terms of err, how they back customers up in terms of warranties, we have a bit more clout with their reps, erm we have erm a better sort of rapport with err the whole company overall, so when something doesn't go our way we get a bit more support out of 'em in sorting things out without having to go through loads of red tape."
>
> (Amir, merchant-independent, interview, 2013.08.12)

Not only does Amir have "more clout" with their reps, he has a better rapport with the whole company. With this support, he is able to bypass "loads of red tape" in order to solve problems with boilers. Amir also noted a previously unsuccessful experience where he had tried to "strike up a relationship" with a different company, which would perhaps have fared more preferably "if the rep was a bit better" (Amir, merchant-independent, interview, 2013.08.12). However, without that relationship, he had been unable to "break through" the red tape and consequently did not pursue sales of that particular brand of boiler. In keeping with this, a breakdown in a relationship with a sales representative might also result in a shift in product loyalty. For example, the 'rubbish' replacement for a rep who had recently changed role had led Jack to use an alternative brand (industry event-PHEX, fieldnotes, 2013.11.13). In this, we see that building strong ties is beneficial for both engineer and sales rep. The social capital resources available here include access to a priority service and a high level of technical support for the engineer. This might be particularly beneficial in maintaining their expert appearance (the importance of this is discussed in Chapter 5). Meanwhile, the sales rep develops a loyal customer, helping to ensure future product sales. For the sales representative, it is not only relationships with engineers that are important, but also merchants. I now turn to exploring the development of strong ties with the merchant, this can be particularly beneficial in helping the sales representative to maintain an awareness of who is buying and selling their products.

6.3.3 Strong ties for insider information

With ties in place, the rep is able to encourage the merchant to sell their product. Personalised incentives can encourage reciprocity, for example, football shirts if the branch staff meet their sales target (the suitability of these incentives are established through personal ties), or visiting to provide product training (sales rep, fieldnotes, 2013.07.16). Promotions are so dependent on personal relationships that they may vary between branches of the same national chain (Seb, merchant-chain, fieldnotes, 2013.06.17). For Amir, having a personal relationship with the Stockman sales rep means that "you aren't ashamed" of asking for something, or seeking more information if "you've heard something along the grapevine" (Amir, merchant-independent, interview, 2013.08.12). Whilst it may be personal relationships that influence what happens at branch level, national chains and large manufacturers often have agreements that govern what is sold. For example, a 'deal' between Plumb Parts and Stockman means that Plumb Parts branches are required to 'have 4 rows of Stockman controls on display' and sell a certain number of Stockman products (Phil, sales rep, fieldnotes, 2013.07.16). Conversely, a breakdown in these organisational level relationships might result in a national merchant not stocking certain products. One engineer suggested that Installer Spares the plumbers' merchant would not stock Sableton products because "their relationship is terrible" (Doug, SE, interview transcript, 2013.12.03), although I do not have first hand information from these organisations to support Doug's comment.

However, if strong ties exist between the sales rep and the merchant, the rep might extend their visit to the merchant, staying for an informal chat over a hot drink. In one instance, a sales rep for Ocipura arrived at the Plumb Shop branch I was spending time in. He spent an hour with the branch manager, Seb, chatting over a cup of tea. During this time the two men discussed their families, recent holidays, a caravan renovation and a recent fishing competition. It was only towards the end of the conversation that the topic shifted.

> Brian asked 'who's fitting Bedlington's?'. Seb mentioned to Brian that he had recently got a big new client that he might be interested in. He said that they were called First Class and that they'd spent £60,000 in a week and a half. I think Seb said that they were installing Bedlington's. Brian said he'd like their name and number; Seb went to look it up and wrote it down for him. After this Brian left.
>
> (merchant-chain, fieldnotes, 2013.06.17)

Through this five minute diversion in the conversation, the sales rep has gained details of a potentially lucrative customer. It was after Brian's visit that Seb explained that he was the sales rep for Ocipura, but they had known each other for years and he was 'more of a friend, really' (Seb, merchant-chain, fieldnotes, 2013.06.17). The strong tie between Seb and Brian yields some useful social capital resources. With a certain degree of loyalty in place, Seb is willing to divulge the details of his customers to Brian who is then able to target those customers for future sales.

Alternatively, the sales representative might directly target the customer for information, and then look to the merchant to shift their buying practices. On one occasion, Phil, a sales rep for Stockman, had organised to take one of his customers, Kelly, for lunch. Kelly is the 'buyer' for a large contractor for social housing companies, it is her job to decide what products will be used on the company's servicing contracts. This is a relatively large organisation that had recently won a contract for servicing 30,000 social housing properties over the next 5-10 years. Phil and Kelly knew each other well; they were teasing one another throughout lunch with tongue-in-cheek comments, there was only one brief interval that was explicitly dedicated to work. In this exchange, Phil enquired about Kelly's new contracts, and Kelly divulged that there was one new contract that would be having Ouseman instead of Stockman products fitted. Phil was interested in where Kelly would source the products from: the Birley Park branch of Plumb Parts, or Urban Supplies? Kelly noted that she would not use Birley Park, citing the poor parking and bad service (sales rep, fieldnotes, 2013.07.16). This initially inconsequential exchange lasted no more than five minutes. However, when Phil and I were back in the car he went to work rectifying the situation.

> Phil rang Aaron [Key Accounts Manager for Plumb Parts, London], he said that he had just met with Kelly and that she was specifying Ouseman TRVs. Phil suggested that Aaron ring Kelly this afternoon and quote Stockman TRVs, because 'she's hot, she's got a belly full of food, and she wants to sleep, so she might do it just to shut you up'…
>
> (sales rep, fieldnotes, 2013.07.16)

Phil suggested that Aaron, who manages accounts for Plumb Parts, contact Kelly whilst 'she's hot' and 'she's got a belly full of food' to quote for the Stockman product, rather than the Ouseman one. Following this we visited the Birley Park branch of Plumb Parts that Kelly had previously stated she was not using. Phil relayed her reasoning back to Scott, the branch manager, and the two men resolved that they would have to show her 'what it was really like'. For this, Phil would set up a meeting, whilst the branch was quiet, and make sure they had 'all hands on deck' to make a good impression (sales rep, fieldnotes, 2013.07.16). Phil later explained to me that it was beneficial for him to encourage buyers to use Plumb Parts because Stockman have a deal with Plumb Parts, to sell a particular number of their products (sales rep, fieldnotes, 2013.07.16). Thus, the sales representative can use his strong ties with both customers and merchants in order to influence product sales. A strong tie provides a valuable information channel, which the sales rep can harness, ultimately shaping the central heating technologies installed in homes.

6.4 Discussion: the impacts of supply chains and social capital

This chapter has revealed that the job of the heating engineer is a collaborative one. Heating engineers, whether self-employed or working for an organisation, rely on and communicate with a wider network of actors in order to perform their work. As discussed in Chapter 2, the potentially influential role of supply chains on intermediaries in the built environment has been recognised; however, the interactions amongst heating engineers and their networks have never before been captured in detail. The in-depth data collected through observation of, and interviews with, heating engineers has revealed the significance of these relationships. In particular, I have identified the plumbers' merchant and sales representative as two prominent actors, who can strongly influence the engineer's installation practices. It is the concept of social capital, which describes the types of resources that actors gain through social relations, that has been used to reveal the consequences of these relations, particularly their benefits. The following discussion commences with a brief reflection on the application of social capital as a tool to explore these relationships, before proceeding to detail some of the implications of them for the installation of central heating systems.

6.4.1 Reflecting on the utility of social capital

Social capital is not an equivalent resource for all of the individuals operating within supply chains, nor does it have consistent benefits across the industry. The central heating industry is made up of a diverse and distributed workforce (which was introduced in Chapter 3), and operates on a variety of scales, with multi-national organisations functioning alongside independent engineers and suppliers, for example. Both of these are factors that might present specific variations in the nature of social capital across this network that have not been captured through the current analysis. For example, social capital may not be an important resource for some of the individuals and organisations operating. Instead, these may prioritise economic efficiency, or formalised contractual requirements. However, within my analysis of this phenomenon, I have sought to explore the role that social capital plays and so prioritised those relations where it was apparent. Moreover, social capital is nuanced and specific to the individuals acting within these relationships. It is these 'intangible and ephemeral' qualities that make it difficult to quantify, measure and use as a resource (Bresnen et al. 2005: 237). So, whilst I have identified its existence and potential role in shaping the central heating technologies installed in homes, it is the very characteristic of social capital as embedded in relations that makes it difficult to appropriate. This introduces a potential limitation in utilising the concept of social capital for fostering change within the central heating industry; although this does not prevent the possibility of intervention from policy makers and industry representatives, which will be discussed in Chapter 9.

Furthermore, my analysis has focused on only two actors within the engineer's supply chain, the merchant and the sales representative. The significance of these actors emerged during my fieldwork through conversations with, and observations of, heating engineers; they are present in the engineer's everyday work. However, it is worth noting that in Banks' (2000b) early analysis, he identified other actors that are implicated in the specification of heating equipment, including housing associations, local authorities and housing developers. Indeed, all of these were mentioned during the course of my fieldwork; however, I was not witness to these relationships and interactions as they played out, and so have been unable to document the exact nature of their role. Galaskiewicz (2011) highlights the vast scale and complexity of supply chain networks (for example, noting that they often extend across international borders). With particular reference to the construction industry, Bresnen et al. (2005: 243) note widespread interorganisational working, subcontracting and outsourcing, which can all present challenges in the development and use of social capital. The role of social networks and relationships with customers is another aspect that has not been elaborated here. The significance of these relationships has been noted for other SMEs in the construction industry (Killip 2013), as has a reliance on reputation, and the trust implicit in this (Banks 2000b). However, I was unable to capture detailed information on the nature of these relationships, and their potential implications (although I do have data on engineers' constructions of their customers, which provides the focus of Chapter 8).

Throughout this discussion, I have explored social capital as the resources that accrue to individuals. However, this is not the only way that social capital has been conceptualised. In particular, Portes (2000) notes the transition of social capital from its original guise as the benefits yielded to individuals through community ties (as it has been used here), to an attribute of the community itself. Indeed, Lin notes that "scholars agree that it is both collective and individual goods; that is, institutionalized social relations with embedded resources are expected to be beneficial to both the collective and individuals in the collective" (Lin 1999: 33). Within this chapter, my focus has been on the benefits accruing to the individuals within relations; however, it is also true to say that these relations may yield, and be driven by, benefits for the wider network. For example, Banks (2000b) previously highlighted that manufacturers may employ a range of techniques to foster brand loyalties, including points schemes, websites, helplines and promotions, suggesting that there is a broader range of factors that feed into heating engineers' product choices. Like these strategies, the relations discussed in this chapter may be, in part, associated with motivations of profitability from manufacturers and suppliers; however, whilst they have been considered, they have not provided the focus of my analysis. Despite these potential wider emphases, focusing on micro-level interactions, and constraining the definition of social capital to just those benefits that accrue to individuals has helped to reveal the implications of these relations for the central heating technologies installed in homes. It is to these findings that I now turn, first discussing the role of social capital in the provision of information, before elaborating on the role of merchants and sales representatives in shaping the central heating technologies installed in homes.

6.4.2 Social capital for information

One of the key direct benefits facilitated by social capital is timely access to relevant information (Adler & Kwon 2002). Within the engineer's supply chain, this is true of strong and weak ties to both merchants and sales representatives. Strong ties are useful in providing access to complex, tacit information (Krackhardt 1992; Levin & Cross 2004). For the heating engineer, these ties are particularly important for problem solving and supporting their expertise. Indeed, I highlighted that heating engineers might turn to the merchant to help identify parts and solutions to problems, exposing limitations in their own expertise in doing so. This is quite distinct to their presentation as experts to outsiders and customers (which is detailed in Chapter 5), and supports the suggestion that builders' or plumbers' merchants present an "opportunity to acquire and share knowledge in a non-competitive way" (Owen et al. 2014: 172). This is in keeping with Killip's (2011) suggestion that these networks of middle actors might act as useful and reliable sources of information, in particular identifying suppliers and merchants as valuable 'allies' for SMEs in the construction industry.

Meanwhile, through exhibiting loyalty to a particular manufacturer, and developing strong ties to a sales representative, heating engineers secure an ally to help in their work and support their expertise. In particular, relationships with sales representatives can provide specialist support and a priority service when they need help in problem solving. The existence of brand loyalties amongst SMEs and heating engineers has previously been identified (Banks 2000a; Killip 2011). This research contributes to our understanding of these brand loyalties by revealing the significance of the social capital resources available through individual relationships with sales representatives. Although, as noted by Banks (2000a), brand loyalties might develop at an early stage (for example, during apprenticeships – as discussed in Chapter 5), the evidence presented in this chapter has demonstrated that these may shift depending on the relationships that engineers have with sales representatives, and the quality of service and technical assistance they subsequently receive. Additionally, weak ties can be beneficial for the delivery of non-redundant information (Granovetter 1973), particularly in a cost effective way (Hansen 1999).

In their transient role, the sales representative can act as a valuable information channel, introducing useful information, for example, providing details about new products during breakfast mornings and fostering future brand loyalties in the process. The information available through both merchants and sales representatives is important in shaping the products that come to be installed in homes. However, the reach of these actors, and the social capital inherent in their relationships, extends far beyond the provision of information.

6.4.3 The role of supply chains in shaping central heating technologies

Contrary to Banks' conclusion that plumbers' merchants "simply act as a counter and distribution system for the manufacturers" (2000a: 8.8), I found them to be integral to heating engineers' everyday practices. Some engineers may prioritise cost and convenience over building strong relationships, reflecting Killip's (2013: 527) suggestion that for builders it is 'more normal' for them to use more than one supplier. However, through repeated informal communication others will develop strong ties to their merchant. The plumbers' merchant can be very influential in the sizing of central heating systems. In this, trust is the social capital resource that leads the engineer to, at times, rely on the merchant's expertise. However, the merchant does not necessarily have training specific to the installation of central heating systems, meaning that the industry guidance written to ensure the accurate sizing of central heating systems is not always followed. Furthermore, the merchant is unlikely to have visited the property in which the system is installed, meaning that central heating systems might not be sized to reflect the thermal properties of the dwelling, as they should be. The importance of sizing central heating systems, with consideration of the thermal characteristics of a property is discussed in Chapter 3. This supports Orr et al.'s (2009: 41) suggestion that guidance on boiler sizing is not being followed, but reveals a necessary extension to their conclusion that this is simply based on "decisions by the boiler installer", to include the merchant as well.

Moreover, in all of this, merchants do not act without their own agenda. Again, in contrast with Banks' (2000a: 8.8) original conclusion that merchants exhibit "no great brand loyalty", I found that merchants' own affiliations and preferences, along with their contractual obligations and informal rewards, can play a strong role in shaping the central heating technologies installed in homes. The merchant's affiliations might, in turn, be shaped by their relationships with sales representatives. Thus, the role of plumbers' merchants and sales representatives in shaping heating engineers' day-to-day work, and the central heating technologies installed in homes can be great.

Furthermore, social capital is not easily transferred or traded (Nahapiet & Ghoshal 1998). I have demonstrated the enduring loyalties at play between merchants, engineers and sales representatives, and the benefits associated with these. For example, where ties develop between engineer and merchant, social capital resources might include a fast, friendly service and short-lived exchanges (for example, over the phone) as a means of performing efficient transactions. Loyalty and reciprocity are inherent in these ties; with these features, the engineer is 'looked after' by the merchant, whilst the merchant can guarantee repeat business. Meanwhile, the sales representative might foster strong ties to the merchant, using these as a rapid route to learn about and subsequently influence who is installing their products. These strong ties can be fostered through repeated interactions, but also the personalised incentives, meals, and favours that have featured throughout this discussion. These data provide key insight into how product decisions and preferences might be shaped by factors extending far beyond the person physically installing the central heating system. Further, the concept of social capital provides a potential explanation for the reticence amongst heating engineers to fit alternative products (for example, the slow uptake of the condensing boiler discussed in Chapter 2). Closed social networks, consisting primarily of strong ties like those outlined above, can lead to exclusion, and reduce the flow of new ideas into the group (Adler & Kwon 2002). For example, the rejection of new sources of knowledge and information from those outside of the existing network being deemed irrelevant (Bresnen et al. 2005). In this way, heating engineers, and their supply chains may simply perpetuate the use of tried and tested products, and enduring (mis)understandings.

To conclude, this chapter has presented evidence that supply chains are extremely important in shaping the central heating technologies installed in homes. Through applying ideas of social capital, in particular its conceptualisation as resources that accrue to individuals through virtue of their social ties, this chapter has revealed the purpose of the relationships that heating engineers, sales representatives and plumbers' merchants maintain. The impact of these relationships on the central heating technologies installed in homes and their potential energy efficiency has been demonstrated. These relationships are of such significance that they warrant further investigation, but also the attention of policy makers and industry representatives concerned with impacting the practices of heating engineers and the energy consumed through space heating. It is with these stakeholders in mind that I return to the implications of these findings, outlining their impact, and using them to make a series of suggestions, in Chapter 9.

6.4.4 Turning to the technology

Before proceeding, there are two empirical chapters remaining in this thesis. In both Chapters 5 and 6 I have applied broadly sociological theories, investigating how the relationships and interactions between social actors shape the central heating technologies installed in homes, and the subsequent energy consumed through these systems. However, central heating installation is not a purely social endeavour, indeed, this process centres on the addition of new technologies to a property. It is because of this that for the empirical material that follows in Chapters 7 and 8, I take a more socio-technical stance, investigating the role of the central heating system itself, and the way that social actors interact with this. Although quite distinct, these aspects are of equal import in shaping the energy consumed through space heating systems.

7 Negotiating non-humans

> "A central heating system is no different to our body, our heart pumps out, arteries out, veins back, so we send out oxygenated blood and we send out hot water and it returns cooler or comes back as y'know with less oxygen in in the veins, back to the pump which is like the boiler and back out again, it's the same thing, and it feeds vital organs and in the, in a house situation the radiators are the vital organs."
>
> (Jack, SE, interview, 2013.09.11)

In comparing the central heating system to the human body, Jack identifies its role as an active member of the home. Although Jack previously compared his job to that of a doctor performing diagnostic work on this complex body (this is elaborated in Chapter 5), he was not alone in giving life to the central heating system. Another of my participants, Roy, noted that boilers have "got their own little brains…they can tell you what's wrong" by displaying fault codes, which indicate the specific nature of a problem, on their electronic screens (Roy, SE, interview, 2013.08.08). Meanwhile, Eddie highlighted heating controls' ability to have a conversation, suggesting that when programming a particular device, it "is asking you a question…it's got a question mark at the end of the text, so it's a question, you just got to answer the question and press the relevant button" (Eddie, organisation, interview, 2013.07.04). In his call to consider the missing masses, Bruno Latour highlights our tendency to anthropomorphise the non-human. In doing so, he suggests, we are recognising that a particular non-human either *has* human shape or *gives shape to* humans (Latour 1992). Indeed, the central heating system is far from an inanimate object that is manipulated during installation. Instead, it is endowed with a character; it is an actor, defined through its participation in a series of performances (Akrich & Latour 1992: 259). The system, and the individual components that constitute this, vie for position alongside the existing socio-technical arrangement of the property, within engineers' work and ultimately as part of occupants' space heating practices. Given its prominent and active role in the installation process, and subsequent space heating practices, it is essential to investigate just how this technology takes its place within the home. This chapter applies the concept of Actor-Network Theory (ANT), looking at how this can illuminate the non-human aspects of the installation process, and how these are relevant in shaping the energy consumed through space heating. I first introduce this theory in more detail, before outlining how it will be used in the remainder of this chapter.

7.1 Introducing Actor-Network Theory

Actor-Network Theory stems from a rejection of technological determinism, which views technology "as an external, autonomous force exerting an influence on society" (Wajcman 2002: 351). Instead, the proponents of ANT attempt to eliminate *a priori* distinctions between the social and the technical, suggesting a 'generalised symmetry', where different elements of society (for example, the social, the technical, and the natural) are all described with a single repertoire (Callon 1986a). Indeed, with this concept we may even challenge the idea of 'society'. For example, Latour suggests that the social is not a "thing amongst other things", instead it is a "type of connection", and a study of the social should be considered as the "tracing of associations" (2005: 5). These associations are between both human and non-human actors, named as such in order to disrupt our familiar ways of characterising things, and consequently be more able to see how aspects of everyday life are structured. It is their position within these networks that affords non-humans agency, that is, they can shape, and are shaped by, the patterned networks that constitute social life. The use of homogenous terms, 'actors' in this case, is thus intended to recognise the relational nature of the seamless webs in which heterogeneous elements (such as people, technologies, buildings and energy) interact (Hughes 1986). Through recognising that actors are defined by their connectivity, relations and interactions with other actors, ANT presents a 'general attitude' to remain open to a range of insights for understanding the complex structuring of social life (Hitchings 2003: 100).

We cannot therefore, if we follow this logic, take the installation of a central heating system to be a given 'social' entity; instead, this practice both shapes, and is very much shaped by, the technologies and physical things that form a part of it. As Law notes:

> "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. And, just as human beings have their preferences - they prefer to interact in certain ways rather than others - so too do the other materials that make up the heterogeneous networks of the social."
>
> (Law 1992: 382)

The key here is that it is not only the preferences of humans that need to be accommodated, but those of materials too. For example, just as an electric vehicle cannot operate without the cooperation from electrons, fuel cells and electrodes (Callon 1986b), a boiler cannot operate without cooperation from the water that flows through it, and the network of pipes and radiators that contain this. In asserting their preferred ways of interacting, the technical and material entities at play in the installation process have a hand in shaping the final configuration of the system, and its use. With such great reliance on the interconnections and relations between these actors, it is important to consider their fragility in association. In this, I am particularly interested in the enrolment of different actors in the installation scene, that is, the way that they are 'seduced, manipulated, or induced' (Latour 1999: 194) into position within the socio-technical network of a property. This existing arrangement includes the aesthetics of the home, the technical configurations in place and social practices that are already established. The installation of a central heating system consequently presents a scene where a network is undergoing change, this may involve persuading different actors to play the roles proposed for them (Akrich 1992), negotiating them into position and encouraging them to mingle with these existing arrangements. In the following section, I elaborate on my use of ANT to understand the events taking place during installation, before outlining the remainder of this empirical chapter.

7.1.1 Navigating negotiation

It is during installation that the individual components constituting these networks are revealed and that their priorities and preferences come into play. As Law notes, "…for the healthy person, most of the workings of the body are concealed, even from them" (1992: 384). It is only in moments of change, when someone is ill, or a central heating system is replaced, that these otherwise single, coherent objects are opened up to expose the complex networks of vital organs, arteries and pumps that constitute them. Akrich highlights that to study how actor-networks are stabilised, we have to "find circumstances in which the inside and the outside of objects are not well matched. We need to find disagreement, negotiation, and the potential for breakdown" (1992: 207). Thus, in order to understand how the central heating system and its associated practices come to be, it is valuable to look at it during the installation process, whilst it is exposed. In particular, the ethnographic approach applied for this investigation affords the perfect opportunity to 'follow the actors' whilst this negotiation takes place and explicitly avoid pre-defined categories and conceptions of how they interact before witnessing it first-hand (Latour 2005: 12). Indeed, its value in tracing the influence between people and other actors has led ANT to be used to propose the network of actors implicated in the specification of domestic heating equipment (Banks 2000a; Banks 2000b), and to analyse the 'products, practices and processes' of SMEs in the UK construction industry (Killip 2013). Although both studies identify the role of heterogeneous actors in shaping design decisions, and domestic socio-technical arrangements, they rely on interviews away from the scenes of these negotiations and do not capture the active role of the non-human in these decisions. Arguably, studies situated with both the humans and non-humans under investigation are more fruitful in revealing their negotiated performances. For example, Watkins' multi-sited ethnography of the refrigerator followed the device through scrutinising its associated manuals, texts, and advertising literature and through householder interviews in the home itself (Watkins 2008). Here, she notes householders' active engagement with the refrigerator as they provided refreshments during the interview (ibid). Likewise, when Hitchings set out to understand the materiality of the private garden, he conducted some of his interviews within participants' actual gardens, thus ensuring that both he and his participants were "constantly reminded of the material presence of the plants" (Hitchings 2003: 103).

It is through my similarly co-located approach that the situationally specific negotiations taking place during the installation of a central heating system are revealed. In the remainder of this chapter, I explore how human and non-human actors collaborate in creating the central heating system and the understandings that may surround this. In this discussion, the process of different system components, the boiler, pipework, radiators and controls, establishing their position and coming together to form an operational central heating system is explored. Accommodating this system within existing domestic networks is not always a comfortable process; indeed it may lead to the exclusion of existing technologies. Alternatively, central heating components may be squeezed in, boxed away, and hidden, in order to accommodate the requirements of the socio-technical systems they become a part of. Throughout, I link back to the aims of this thesis by considering how the installation process might influence the end use of the central heating system, and the energy it consumes. In particular, I explore the different boundaries in place for the engineer installing the system and the occupant using it. This chapter closes with a discussion of the way in which central heating systems come to be in homes, identifying the insights afforded through the application of the Actor-Network lens and the limitations of this approach.

7.2 The boiler

My exploration begins by scrutinising the most complex organ in the system, the boiler. For a boiler to operate successfully, it is reliant on the alignment of a huge number of heterogeneous actors, chemical, electrical and mechanical. Each of these have their own properties and requirements to be fulfilled, and the role they play in the successful operation of a condensing boiler is discussed in Chapter 3, and Appendix I. These components are ordinarily hidden behind the boiler's white case, which constitutes just one of the actors that helps to black box central heating systems. Within ANT, black boxing is a term used to describe when a network of actors becomes stabilised to the extent that it is recognised as a single, coherent entity

(Callon & Law 1997). For example, a 'boiler' is the unit fronted by a white case, within this there is a multitude of heterogeneous actors coordinating, but these are not necessarily considered whilst this unit stands as a coherent whole. However, a boiler cannot operate without cooperation from the gas and water that flow through it, and the networks of mechanical and electrical devices that contain these. As discussed in Chapter 5, it is only the expert engineer that is granted access to the inside of the boiler. As Figure 7.1 shows, it is during installation that these complex innards are exposed.

Figure 7.1 The exposed innards of a boiler.

In opening this white box, we see that the operation of the boiler, and its constituent parts play a significant role in shaping the installation process:

> "Well, it, it can be, it's silly, when you're selectin' a boiler sometimes it comes to do with nothin' to do with the property, to do with the, the physical size of the appliance, erm, one o' the models you can pipe up the boiler from behind the boiler, so

sometimes that has a, has a bearing. Flue distances will have a bearing, erm, if you've got a, err excessive flue runs to the gas erm, gas pipe sizing is a big issue that has sort of raised it's head with the, the greater volumes of gas with kilowatt rating, you can make sure you've got the correct gas and pipe sizin', erm, so they all have a determining factor when you erm, erm, when you're selectin' the boiler…"

(Eric, organisation, interview, 2013.09.09)

As Eric notes, the boiler's associated connectivity is a fundamental consideration; flue runs, pipe sizing and gas volumes all have to be accommodated when determining which products to install. The importance of these appendages was further highlighted by Malc, who noted that when he goes in to a property to perform a survey, he 'looks for three things - flue, condensate and drainage' (Malc, SE, industry event-PHEX, fieldnotes, 2013.11.13). Thus, the boiler is not confined to a white box, its installation and operation relies on cooperation from the actors within the case, but also the extensions beyond it. Variations in the requirements of different boilers, and the individual socio-technical arrangement of each property may mean that engineers have to be flexible in their product choices. Indeed, contrary to the tendency for engineers to exhibit brand loyalties (which is discussed in Chapters 5 and 6), Carl did not "have a particular manufacturer, because some boilers lend themselves to certain circumstances" (Carl, SE, interview, 2013.12.16). However, these are not the only constraints on boiler selection and positioning. Despite its importance as the heart of the central heating system, the visible presence of this device and its associated connections is not necessarily desired.

7.2.1 Hiding the heart

"You go into a place and they want it in the kitchen or they want it to go into a cupboard, they don't wanna see it, y'know, they want their home to be warm, but not see it, erm...so, as far as that is, a lot of people now though want space in their homes, so they'll say 'I want a combi boiler'"

(Carl, SE, interview, 2013.12.16)

Unlike the coal fire, which I suggested in Chapter 1 once acted as a focal point for the family, the boiler is not an attractive item to have on display in the domestic environment. Instead, it is preferable for some of Carl's customers if the boiler is not visible. Similarly, James noted that his customers did not want a "bloody great big white boiler" in a position of prominence in the home (James, organisation, interview, 2013.07.04). Furthermore, the aesthetic and spatial implications of central heating systems may shape product decisions. For example, in the above quote Carl also highlights his customers' preference for combination boilers, which do not require a separate water tank and consequently take up less space than the alternative system boiler. A representative of one manufacturer also noted that 'customers are buying based on looks, because they don't want an unattractive boiler in the kitchen' (Dan, manufacturer training, fieldnotes, 2013.12.02). As Gary highlighted:

> "You don't 'ave a cocktail party and bring your mates down to the basement and say 'look at my boiler', but whereas your, your three quarter of a million pound kitchen that everyone's standin' in with your fancy oven and what not, people see that don't they? But the boiler is just, just as long as it gives me heatin' and hot water."
>
> (Gary, sales representative, interview, 2013.08.22)

Thus, the boiler is not necessarily a feature to be admired and, if it is deemed unattractive, it may be hidden. The kitchen is a key scene of contention during the installation process, a particular consideration is minimising the impact that the boiler might have on the existing socio-technical arrangement in this space. This can be a negotiation between the existing furniture, cupboards and appliances, but also the occupant's and installer's preferences. This is something that proved to be a particular challenge for Doug in one case:

> "I said…you've now had a brand new kitchen fitted, and it's a solid floor, I'm gonna destroy it, I said if we move the boiler to this side of the kitchen, we can run the pipework there, it'll be fine. Oh, so I was relocating the boiler for a few reasons, one, as I say, to stop damage to the kitchen, she'd gain an extra cupboard space, she might

> have to build a cupboard around the boiler if she doesn't like it, mind you I think they're quite pretty anyway."
>
> (Doug, SE, interview, 2013.12.03)

The new boiler should disrupt the existing scene as little as possible; the actors under consideration in this case include the boiler and central heating pipework, but also the existing kitchen and solid floor, and the customer's potential dissatisfaction if these are disrupted. Whilst Doug determined that the boiler's impact could be minimised by placing it in a new location, he also recognised that the customer may not want the device on display at all, potentially building a cupboard around it (even though he thought they were "quite pretty"). Indeed, at one manufacturer training session, the course instructor proudly demonstrated a new boiler, small enough to fit into a standard kitchen cupboard (manufacturer training, fieldnotes, 2013.07.19). Whilst some attendees were quite excited about this product, which could so easily be concealed in the home, Gerry noted the potential challenges that might come with it:

> "You looked at it, and it was crammed weren't it, it really was crammed in, I thought 'how do you work on that?', but they must've designed it to work on."
>
> (Gerry, SE, interview, 2013.08.20)

Here, Gerry identifies the conflict between the customers' desire to have this white box hidden away and as small as possible, and his own ability to actually interact with, and manipulate, the components inside the case. The intricate innards of these units are already compacted into a small space (see Figure 7.1), and these attempts to make them invisible in the home may intrude upon the engineer's working domain.

7.2.2 Negotiated positioning

Conversely, the engineer's ability to interact with the boiler, and comply with the accessibility requirements outlined in Chapter 3, might be a key consideration during installation:

> [Eric] also looked at the positioning of the boiler, which had a kitchen cupboard in front of it. He assessed the size of the space and said that he would have to go with an Ocipura for servicing purposes, because with the Bedlington Boilers you have to take the whole front cover off including the side panels and there wouldn't be space to remove that because of the cupboard, whereas with the Ocipura you just have the front panel to remove.
>
> (Eric, organisation, survey fieldnotes, 2013.11.12)

The front cover of the Ocipura boiler that Eric describes is much shallower than the alternative Bedlington, meaning that less space is required in front of the boiler to remove it. However, to access the boiler controls (the customer's point of interaction with this technology), the Ocipura case includes a fold down cover that, once the boiler was installed, could not be opened because of an encroaching kitchen cupboard (see Figure 7.2). Eric's solution means that whilst the heating engineer can access the boiler's inner workings, the tenant cannot access the boiler controls. Arguably, this solution has created a physical boundary that may have a detrimental impact on the occupant's use of the technology.

Figure 7.2 A user friendly installation?

Eric's preference was to have a boiler that is simultaneously accessible for servicing but out of sight. He further demonstrated this inclination during a survey in a council owned 3-bedroom semi-detached house. The existing heating system was over 30 years old, it had a boiler located in the kitchen, with a water tank stored in an airing cupboard upstairs in one of the bedrooms. Eric suggested installing a combination boiler, this would mean the tenant would lose the water cylinder, but gain space in the airing cupboard that could be used to house the new boiler. This is a significant shift in the existing technical arrangement, which Eric had to justify to the tenant:

> "Well I'll just look at, it's above your drainer, it's next to the sink, you've got your clock, it's not so much the, to be honest it's not so much the boiler, it's the little components around it that I will be more looking at to be honest and I, personally I just think, 'well, if we can put your boiler out of your kitchen, put it in a cupboard, close the doors, you don't see any of the pipes, you don't see any of the bits and pieces that go with it…"
>
> (Eric, audio, survey, organisation, 2013.10.23)

For Eric, it was the "little components" around the boiler that make it better placed out of sight. However, the tenant expressed some dismay when she realised that Eric's proposed new arrangement would mean that she would no longer be able to use the airing cupboard, asking: "where am I gonna put me wet washing?" (audio, survey, 2013.10.23). The replacement and relocation of the boiler was problematic because it had the potential to disrupt the tenant's existing (seemingly unrelated) domestic routines. This shift, combined with the level of disruption that would be involved in replacing the central heating system, including all of the pipework, led the tenant to decline the work at that time. However, sometimes the desires of the building occupant and their existing socio-technical arrangement are disregarded. I joined Sam, a surveyor, as he was specifying a replacement boiler, and its location, in an owner-occupied flat. The existing central heating system used a boiler positioned behind a gas fire in the living room; however, during a brief initial assessment, Sam established that the replacement boiler would be located in the kitchen:

> Sam: erm…a new boiler location, so all your pipework's in there, whereabouts is your gas meter?
>
> Occupant: errrr…it's in the kitchen erm…just…
>
> [*all move through to the kitchen*]
>
> Occupant: bottom there, bottom right
>
> Sam: Okay…right…okay…so you'd be lookin' at losin' a kitchen cupboard […] erm…[pause] and you've got the hot and colds over there that you can connect to.
>
> (survey, organisation, audio, 2013.02.14)

The new boiler could not be located in the living room (where its predecessor had been) because of the need to ensure it was connected to both condensate and overflow pipes which extend beyond the property (these are a requirement of condensing boilers, as detailed in Section 3.2). On entering the kitchen, four new actors joined the discussion, each asserting their own influence. The boiler had to be piped to the gas meter. However, since the boiler was no longer going to be in the living room, any existing gas pipework would have become obsolete, so new pipework would have been required in the kitchen. Furthermore, the new boiler needed to be connected to the 'hot and colds', or, the direct hot water circuit (the connections between the boiler and hot water circuit are detailed in Chapter 3). Finally, the location the surveyor had identified for the boiler was, at that time, occupied by a troublesome kitchen cupboard, which needed to be removed. Following the excerpt above, the occupant (an owner-occupier) protested that he would like to keep his cupboard if possible, and suggested perhaps putting the boiler in the bathroom. However, both his and the existing cupboard's attempts were futile; the requirements of the intruding boiler took precedent (see Figure 7.3).

Figure 7.3 The uncomfortable frame for the new boiler, sitting in the shadow of the forsaken kitchen cupboard.

Thus, choosing and installing the boiler is a fragile negotiation between accommodating its complex connectivity, and the requirements of its different components, whilst simultaneously minimising disruption from this demanding technology and satisfying the desires of building occupants. This might include squeezing it in amongst other domestic technologies and concealing it from view. These awkward positionings can also act to extend the domain reserved for the engineer beyond the innards of the boiler inside the case, with the end user being restricted from any interaction with the device at all. Although the boiler is the heart of the central heating system, it cannot operate without collaboration from the other system components. I now turn to the first of these: pipework.

7.3 Pipework

The essential life forces of the central heating system: water, gas, and air, are contained and transported in a network of pipes. Just like the human respiratory and circulatory systems with their specialised network of pipes to transport air and blood, the central heating system has interconnected networks essential for each of its bodily functions. The pipework assigned the task of transporting hot and cold water around a network of radiators has quite different requirements to that carrying gas from the meter to the boiler. Despite their differences, they all play an essential role for the system, and need to be accommodated. However, this is not always an easy task, instead, the design and installation of a central heating system sees these important actors jostling for position in the home. As Keith noted: "no-one wants pipework running everywhere in their 'ouse" (Keith, organisation, interview, 2013.09.05). Indeed, the first challenge the pipework faces in finding a place is overcoming its undesirability, which is now discussed.

7.3.1 How pipework is made invisible

There are several options to reduce the visibility of pipework. Efforts may be made to minimise the length of pipe in the property. This can mean searching for an 'ideal place' to situate the boiler, for example, locating it near to water outlets (Keith, organisation, interview, 2013.09.05). When hot water is demanded at an outlet, there is a delay whilst the water is heated and travels along the network of pipes to the location where it is needed. During this time, cold water comes out of the tap, which can be wasteful. The length of redundant pipework is known as the dead leg, and it is important to minimise this lifeless part of this otherwise vivacious system. Indeed, in one case, Eric and his colleague Adrian decided that a new boiler would be best located in a bedroom adjacent to the bathroom of a four bedroom Victorian townhouse. With the boiler so close to the bathroom there would not be 'pipes flying in any direction', ensuring that the system was 'less offensive to the eye' (Eric, survey, fieldnotes, 2013.11.12).

Alternatively, new pipework might be hidden by 'boxing in', disguised by being painted white or positioned in spaces less visible, for example, the loft (survey, fieldnotes, 2013.07.26). Roy highlighted why aesthetics are important in the design process:

> "Because no-one wants pipes traipsing from A to B, erm clothes lined along a wall, they've just 'ad a kitchen fitted, they put the carpet…the boiler goes in after, not good, er, and you need on a combination boiler to have quite a large gas supply and the boiler has only got a tiny gas supply…"
>
> (Roy, SE, interview, 2013.08.08)

Roy highlighted the gas pipe as a particularly prominent actor in the installation of a new boiler. Newer condensing boilers often require a higher gas flow rate than older non-condensing models. To achieve this the existing gas pipe, which carries gas from the meter to the boiler, sometimes has to be replaced with a pipe of larger diameter. However, as Roy noted, existing gas pipes are often already hidden underneath carpets and behind kitchen units, making it difficult for heating engineers to know their size without "x-ray eyes" (Roy, SE, interview, 2013.08.08). The disruption that changing a well-rooted gas pipe would cause can be enough to shape the choice of boiler, for example, selecting one that requires a lower gas flow rate (Eric, surveyor, organisation, fieldnotes, 2013.11.12). Conversely, the requirements of the boiler may be disregarded in favour of an existing gas pipe and its established position in the home. For example, when I visited Roger, he explained his decision not to disturb the original gas pipe:

> He explained that…sometimes you have to do certain things to get it to go in and the boiler still operates fine. Roger said that in this case they had piped the boiler up to a 15 mm gas pipe, when really it should be a 22 mill…it was all working fine though because there was a decent amount of gas coming through the meters in these

properties. He said that if there hadn't been enough gas, he would have increased the size of the gas pipe, but that would've increased the cost of the job because they would've had to run the gas pipe all the way back to the meter.

(Installation, organisation, fieldnotes, 2013.10.31)

The cost of installing a new gas pipe from the meter to the boiler proved to be too prohibitive for Roger to replace this component. As Roger notes, this particular boiler should really be attached to a 22mm gas pipe, this is to ensure that it has a high enough gas flow rate to achieve the required gas inlet pressure specified by the boiler manufacturer. This should be tested during commissioning, and is specified on the Commissioning Checklist included in Appendix V. A colleague of Roger's later performed this testing, and found that, in this case, the gas inlet pressure actually failed to comply with the manufacturer's instructions. Consequently, this negotiation, in which the existing gas pipe proved to be too troublesome and expensive to move, has potentially compromised the operation of the newly installed boiler[30].

In other cases, the heating engineer may have to tussle with the property's existing socio-technical arrangement in order to install new pipework. In a one bedroom flat, I joined Shaun and Hasan in the kitchen as they were discussing how to connect the gas meter, at one side of the room, to the new boiler at the other:

Hasan was looking at the route between the gas meter and the cooker, he indicated at low level and said that the gas pipe could go along here and connect up behind the cooker. At this point Shaun pulled the cooker out to have a look behind it. He said yeh, the gas goes behind there, but how would they get round the side of the cooker – the pipework wouldn't fit down the side.

[30] The gas inlet pressure denotes the pressure at which gas enters the boiler. It is important that this is high enough to ensure that sufficient combustion can take place to satisfy demand when the boiler is operating at maximum output. However, the compromise detailed here is not sufficient to make the new boiler unusable, or dangerous.

(Installation, organisation, fieldnotes, 2013.04.17)

In this example, Hasan identified the cooker as a potential collaborator; the gas pipe could be connected to the existing pipework behind it. However, Shaun did not think that the space would accommodate the 22mm pipe. Indeed, it transpired during the installation that the cooker would not yield enough space to accommodate the gas pipe. However, the occupant had expressed a preference for the new pipework to be as discrete as possible, noting that he didn't want it to be 'too in your face, with pipes everywhere' (installation, organisation, fieldnotes, 2013.04.17). Instead, the space above the kitchen cupboards and door provided a suitable home for the new gas pipe (see Figure 7.4).

Figure 7.4 Hiding pipework?

There was a compromise in this case, some elements of the existing kitchen arrangement were resolute in their position, in particular, the cooker. The new actor, the gas pipe, was left exposed rather uncomfortably around the top of the kitchen. The engineers agreed that the compromise 'wasn't too bad, especially because it was above eye level and you didn't really look up there' (installation, organisation, fieldnotes, 2013.04.18). They also reported that the occupant was happy with this compromise.

Accommodating pipework is a key part of the installation process, and it is vital to the operation of the central heating system. However, ensuring that the requirements of these devices are fulfilled has the propensity to disrupt existing socio-technical arrangements in the property. Alternatively, like the boiler, this component of the system might be jostled into position amongst other actors, concealed and hidden away. However, the need for harmony and collaboration across the whole central heating system means that satisfying the existing pipework may take priority, consequently shaping the other components installed. This is particularly true of the radiators, to which I now turn.

7.4 Radiators

As the sources of heat distributed throughout each room of the property, the radiators constitute the central heating system's vital organs. The boiler feeds these devices with hot water, which they utilise and then return in a depleted, colder state. For their successful functioning, it is essential then that these organs be seamlessly connected to the remainder of the central heating system. Achieving this balance requires the radiators to connect in to the system's network of pipes, but also to integrate with the output of the boiler, for example through appropriate sizing, discussed in Chapter 3 and Appendix II. However, as with the other components of the central heating system, radiators must find their place within the complex socio-technical arrangements of domestic properties. In doing so, the installation requirements of these devices, and their subsequent efficient operation may be compromised.

7.4.1 Fitting in with existing arrangements

The need for the radiators to fit within the existing configuration of the property might significantly shape sizing procedures. Radiators are often placed under windows; this 'combats' the cold currents that come from the window (Doug, SE, interview, 2013.12.03), and is in keeping with the industry guidance discussed in Chapter 3. Indeed, the presence of the window may make it unsuitable for a lot of furniture, making this otherwise "dead space" ideal for a radiator (Giovanni, SE, install fieldnotes 2012.04.25; Eric, survey, organisation, fieldnotes, 2013.12.17). As the ideal location, it can be the space available underneath the window that determines the dimensions of a newly installed radiator:

> Eddie: but then you look at the window, what size radiator can you get under the window?
>
> James: yeh, and you think oo, 'she wants it underneath the window', I'm gonna have to go 450.
>
> Eddie: so you go longer, but then if you go double, then you can go shorter"
>
> (James & Eddie, organisation, interview, 2013.07.04)

As Eddie noted, the installation is not as straightforward as fitting the space underneath the window, there are different types of radiator that may be more or less suitable (types of radiator and their output are introduced in Appendix II). For example, if a double panel device is installed, with a higher output than a single panel alternative, then a radiator of shorter dimensions can be used. Thus, the process of determining and installing a new radiator is one of negotiation. The radiators should be of a suitable output to cater for the heat requirements of the room, but also of suitable dimensions to fit into their ideal spaces, and with whatever existing socio-technical arrangement is in place.

One particularly troublesome set of actors is the pipework from any existing central heating system. The network of pipes underpinning a central heating system can be resolute in their position, dramatically shaping the sizing of radiators. During one survey, Eric hesitated as he was measuring an existing bathroom radiator, in order to determine its replacement. As he paused, I asked what the issue was:

> He explained that size is the limiting factor and that the manufacturers have changed over the years and they have set sized radiators – he pointed out that the flow and return pipes for the radiator had been boxed in as well – so it would be difficult to alter those.

Figure 7.5 Radiators 'locked in' by boxes.

(Fieldnotes, survey, organisation, 2013.10.23)

In this property, the flow and return pipes connecting to the radiator had been enclosed, making the existing pipework unwavering in its position. Eric considered this predicament, and rather than disrupt this scene he specified a radiator with dimensions that would fit into the existing arrangement. Although this is contrary to the formal sizing procedures discussed in Chapter 3, it is a practice I witnessed several times. Indeed, it seems the neater, more inconspicuous and integrated the existing central heating system is in the home, the more locked in any new configuration will be. However, this size-for-size replacement may not be optimum for efficient operation of the system, or thermal comfort. It assumes that the original was correctly sized for the space and does not account for any changes in the thermal properties of the building that may have taken place since the original installation (for example, additional insulation). In another case, a tenant explicitly requested that an existing single panel radiator in the living room was exchanged for a double panel device. Although a double panel radiator of equivalent dimensions will not visually alter the existing socio-technical arrangement, it has a much greater heat output than its predecessor, potentially altering the thermal characteristics of the space. Indeed, Eric suggested a single panel alternative, but the tenant's request, combined with the disruption that a single panel radiator (of slightly different dimensions) would cause to the existing laminate flooring, resulted in him specifying the double panel device. As we left the property, Eric highlighted some recently installed External Wall Insulation (EWI), acknowledging that he knew the double panel radiator would be 'kicking out too much heat', but that he had little option because of the existing laminate flooring (Eric, survey, fieldnotes, 2013.10.23). The additional EWI would have increased the building's retention of heat since the original heating system had been fitted. With this reduced thermal load, the additional large radiator will be even more unnecessary. During his interview, Eric elaborated on his procedure for sizing radiators:

> Eric: ...if it's existing, erm, it pains me to say, but err, size for size as long as we're not undersizing erm, we have to match the decoration, erm unfortunately as it's social housing there are other factors that go beyond correctly sizing radiators to room outputs and air temperatures and things like that... but unfortunately just to do with claims and sort of other aspects to do with local authority, we do need to make sure there's no decorational issues.
>
> Faye: ok, so is that something that's actually erm written into a contract or something, it's that serious?
>
> Eric: yes, yep
>
> (Eric, organisation, interview, 2013.09.09)

Here, Eric highlights the disparity between the actors prioritised in industry guidance for the sizing of radiators (for example the room outputs and air temperatures discussed Appendix II) and the 'decorational issues' that take precedent in the home. In another case, accommodating these decorational issues had led Gerry to install a variety of sizes and types of radiators throughout a two bedroom semi-detached house that was undergoing refurbishment. Gerry noted that, when it comes to sizing radiators, he 'works it out in his head'; however, in this case, he had been required to determine radiators that would harmonise with the existing network of pipes in the property, but also to comply with the owner's request that the replacement radiators were shorter than their predecessors. I asked Gerry how he had navigated these requirements:

> He said that he had tried to get them as similar as possible to the previous sized radiators – so they were the same length, but lower and he used extended fittings for ones that were a slightly different length…I asked about calculating the output, had he made any measurements or anything? He said that he works it out in his head, he said 'it's a bit old fashioned, but with the TRVs it don't matter, does it?'
>
> (Gerry, SE, install, fieldnotes, 2013.10.17)

Negotiating the new radiators into position both within the property and amongst the existing central heating pipework requires the recruitment of some new actors. Gerry detailed the use of 'extended fittings', adaptors that can help to accommodate a slightly different sized radiator without disrupting the existing pipework, but also the TRVs. In fact, by delegating the management of the radiator output to the TRVs, Gerry did not believe he had to ensure that the radiator was appropriately sized for the space.

It is clear then, that the sizing and positioning of radiators involves negotiation with a variety of other actors that may already be comfortably positioned in a property. For the radiator to find its position, it may have to enrol the existing pipework, and any associated decoration or flooring that restricts this, as well as fulfilling both the engineer's and the occupant's preferences. Furthermore, sizing is a contestation between what will physically fit in the space without disrupting the existing socio-technical scene, and achieving an appropriate heat output from the device. As Gerry highlighted, this negotiation may be assisted by enrolling TRVs to manage radiator output. These constitute just one component of the controls that provide the final element of the central heating system discussed here. These are no different to the remainder of the central heating system in having to jostle for their position in the home.

7.5 Controls

With their delegated role of managing radiator output and system operation, heating controls, particularly their thermostatic elements, are an important consideration in the design process. In their article exploring the reliance of domestic technologies on the temperature of the air around them, Shove et al. suggest that we might think of "the ambient air as part of the device itself" (Shove et al. 2014: 19). For example, they highlight domestic computer equipment that is designed to operate comfortably at 22°C (Shove et al. 2014). This is especially true for thermostatic central heating controls, which 'call for heat' when they recognise that the surrounding ambient air is not at the required temperature. The ambient air is thus an actor, shaping the position and operation of these devices. For example, whilst performing a survey in a two bedroom flat, Jack had to debate where he would install the room thermostat. This particular property had two radiators in the living room, where Jack thought the customer would want the highest ambient air temperature. In order to moderate the remainder of the system, he determined that it would therefore be best to place the room thermostat in the hallway (SE install, fieldnotes, 2013.11.20). Indeed, in Chapter 3, I highlighted that industry guidance suggests that thermostatic devices are located in positions representative of the systems they control. However, this important interaction between control devices and ambient air does not always take priority in the installation process, instead, their location may be determined by the footprints of any existing central heating system and the dwelling's socio-technical arrangements.

7.5.1 Falling into line with existing footprints

In one case, I joined Gary as he was wiring in the controls for a recently installed replacement boiler. For this, he adopted a 'like-for-like' strategy, installing the new room thermostat in the footprint of the old one. He used an equivalent model, meaning that it fit almost perfectly into the footprint of the previous device (see Figure 7.6 - where the barely disrupted paintwork can be seen down the right hand side of the new thermostat).

Figure 7.6 A well established room thermostat.

However:

> [Gary] commented that the thermostat wasn't really in the best place; that it should be on the wall behind, because at the moment it was attached to an external wall and right next to the door…Gary said that the thermostat had been changed like-for-like except that this one had a neon light on it, he said that customers liked this because they could see when the system was on.
>
> (fieldnotes, install, organisation, 2013.02.22)

With the thermostat positioned on an external wall, next to a door, it would be subject to colder temperatures. This could potentially cause disruption to the operation of the heating system, for example, calling for heat when the remainder of the house is already at the desired temperature. Despite this not being 'the best place', Gary proceeded to locate the thermostat in the position that caused minimal disruption to the existing socio-technical scene, and the customer's established routines. The ability of a new controller to blend in with an existing technological footprint was used by one manufacturer to lock people in to using their product. As one course instructor suggested: "my clock will fit on everyone else's backplate - but no one's will fit on mine" (manufacturer training, fieldnotes, 2012.10.10). The backplate is the part of the device that is attached to the wall, the actual control panel then sits on the backplate. Thus, if the control panel and backplate are compatible, then the backplate does not need to be replaced, and the footprint of the technology can remain the same.

Alternatively, disruption can be minimised through the retention of existing controls. I joined Gerry in a property where he had replaced an existing system boiler with a combination boiler. The combination boiler provided instantaneous hot water, and, as such, the associated programmer only required a 'heating' function (this is known as a single channel programmer). However, the customer had requested that his existing twin channel programmer, with both 'hot water' and 'heating' functions, was retained because it had been recently purchased. This meant that Gerry had to modify the wiring to suit the new heating only function.

> Gerry said that he had wired the programmer into the hot water – he said to 'ignore that though' because actually the hot water controlled the heating. The programmer had two buttons, one for hot water and one for heating and he put his hand over the one for heating and said 'ignore that, that's irrelevant' – he indicated that the heating system was controlled off the hot water button.

Figure 7.7 Heating, or hot water?

(Gerry, SE, install, fieldnotes, 2013.10.17)

In persuading the existing twin channel programmer to play the new single channel role proposed for it, Gerry has re-wired the device so that its original 'hot water' function controlled the heating, whilst the 'heating' function became obsolete. He also noted that the customer was 'more used' to pushing the hot water button and so retaining the use of that would minimise the level of disruption to their existing heating practices. Indeed, during installation, heating controls have to negotiate their position not only within existing practices, but also within the existing socio-technical networks of the dwelling.

7.5.2 Blending in with existing networks

For Jim, the programmer is best positioned next to its companion, the boiler:

> He said that his priority is neatness, he makes it as neat as possible. He said that usually means putting it near the boiler and he indicated at the fuse box and the white plastic tracking that ran between the fuse and the controls and said 'you don't really want that on your wall'.

Figure 7.8 'Neatness' prevails.

(Install, organisation, fieldnotes 2013.03.20)

By keeping these compatriots together, Jim minimised the amount of wiring on display in the property. The wires were contained by plastic tracking and the undesirability of this led Jim to prioritise 'neatness', which was achieved by placing the controls close to the boiler, minimising the length of wiring required. In this way, Jim had positioned the programmer in a prominent location, adjacent to the boiler in the kitchen (see Figure 7.8). However, it is not always the case that these allies are so closely connected. In particular, wireless controls can be left adrift, and unsettled amongst the socio-technical networks of the home. In one case, a customer requested that his new wireless programmable thermostat was permanently attached to the wall, because he'd 'already lost it' (whilst the engineer was still in the property!) (install, organisation, fieldnotes, 2013.10.21). Instead, this device had to find its permanent position amongst other household objects, namely, the picture frames and light switches in the hallway. The programmer was finally negotiated into alignment with a yielding picture frame (see Figure 7.9).

Figure 7.9 The alignment of things.

These alignments and collaborations are not always in keeping with the preferences of heating controls. In the same property, Roger, the installing engineer, highlighted to the customer that he had fitted a new TRV on the radiator.

> He pointed out to the customer that he didn't want his TRV 'cuddled' with the curtains, he demonstrated by moving the curtain away from the TRV – he said that it would think it was warmer than it actually is if the curtain is 'cuddling' it.

Figure 7.10 Too close for comfort?

(Install, organisation, fieldnotes, 2013.10.21)

In this case, the TRV may be uncomfortably close to the curtain. Roger warned against these two actors getting too close, since, if it is in close proximity, the curtain might deceive the TRV into thinking that it is hotter than it actually is, potentially disrupting its ability to manage the operation of that particular radiator. Thus, this desire to make heating controls 'blend in' with the existing configuration of the dwelling may have a detrimental impact on their operation. Beyond getting controls to seamlessly merge with their environment, this positioning may amount to hiding these devices altogether.

7.5.3 Hiding from view

Returning to Gary, after he had fitted a thermostat in the footprint of an existing device (this example was discussed earlier and is shown in Figure 7.6), he consulted the tenant ahead of positioning the new programmer.

> Gary went downstairs to get the householder. When he was down there he asked the householder whether they wanted the controls "hiding", and asked them to come upstairs so he could show them. He positioned the programmer underneath the boiler, on the left hand side – it was very close to the boiler and pipework. There was also a large wardrobe to the left of it. The customer said that the programmer would be great in that position, and that it would be good hidden.

Figure 7.11 'Hidden' controls.

(Install, organisation, fieldnotes, 2013.02.22)

Not only was the programmer positioned by the boiler in a location with access hindered by a large sideboard and a wardrobe, it was also encroached upon by the previous inhabitants of the space (see the pictures and objects in Figure 7.11). As discussed in Chapter 2, the location of programmers can shape the way in which they are used. This hiding of devices, and blending them in with the property's existing networks may have a detrimental impact on their use. However, the controls can fight back, using bright lights and backlit screens to ensure that they are seen. During one manufacturer training session, the course instructor noted that a particular control device has 'got a very very bright screen', along with LEDs that are a 'very very bright green colour' to ensure that it can be seen (manufacturer training, audio, 2012.10.10). The instructor advised engineers to use this feature when negotiating the control's position in the home:

> "My advice would be: if you put these things in an airing cupboard, you have the screen on permanently. The pure reason for that is that whenever the customer opens the door, their eyes will be drawn to it, and if something's gone wrong, someone's pressed a button or etcetera, they'll be able to identify it straight away."

(Manufacturer training, audio, 2012.10.10)

This feature means that all is not lost if the controls are hidden away in cupboards. Endowed with a bright screen, they may still be seen, although this, of course, depends on the cupboard being opened. Indeed, in this section I have demonstrated how the heating control devices heralded for their potential to save energy may be hidden when they are negotiated into position. In this, they are expected to match the footprints of their predecessors, blend in with existing socio-technical arrangements and hidden from view. In particular, the hiding of these devices may further contribute to the creation of boundaries for end users interacting with them. This hiding of different central heating components is further discussed in the following section, where I summarise the findings revealed in this chapter and their implications.

7.6 Discussion: the significance of negotiated installations

The installation of a central heating system is negotiated through the interaction of different actors, both human and non-human. Its outcome is precarious, in that the final system configuration cannot be determined prior to these negotiations taking place. The empirical material presented in this chapter provides another facet to our understanding of the ways in which the installation process might shape the energy consumed through space heating. This is the first time that the negotiation of preferences and jostling of positions as central heating components take their place in the home has been revealed. These insights have been explored through using the actor-network lens as "a productive means of engaging practically with the material presence of things" (Hitchings 2003: 99), and afforded a greater understanding of this process. Further, the ethnographic approach used here has allowed the "task of defining and ordering the social" to be revealed by the actors themselves (Latour 2005: 23). For example, this discussion has demonstrated how the actions of both heating engineers, and end users, are shaped by the central heating system and property as much as anything else. The installed, operating central heating system is reliant on the performance and enrolment of both human and non-human actors during the installation process. The results sometimes suit the priorities and preferences of the devices being installed, whilst in other cases those of existing domestic technologies, the engineer, or the end user command the scene. The nuanced contestations taking place during installation have potentially important implications for the energy consumed through central heating systems, the role that heating engineers play, and the hiding of heat in domestic properties. In the following discussion, I first consider some of the limitations of the ANT approach applied before elaborating on the implications of the data presented in this chapter.

7.6.1 Considering the utility of ANT for exploring installation

With such complex negotiations taking place during central heating installation, it is difficult to distinguish the role that the regulations and guidance designed to shape this process (detailed in Chapter 3) actually play. At times a particular document or rule would prevail, for example, a boiler being installed where it is readily accessible for future servicing, but not for use. However, in other moments, guidance would be overridden in favour of minimising disruption to the socio-technical scene. For example, when a desire not to disrupt an existing gas pipe results in a newly installed boiler operating outside of the manufacturer's instructions, or a programmer is wired incorrectly so that the labels on the buttons do not reflect their actual function. Star (1991) highlights this limitation of ANT in addressing the 'invisible work' of these heterogeneous 'externalities', for example, accepted standards and conventions. In particular, she notes that technologists 'move in communities of practice', drawing on Lave and Wenger's notion (as used in Chapter 5) to highlight that these actors:

> "Have conventions of use about materials, goods, standards, measurements, and so forth. It is expensive to work within a world and practise outside this set of standards; for many disciplines…nearly impossible"
>
> (Star 1991: 41).

Heating engineers' participation in the negotiations taking place during installation is guided by information learnt through guidelines and regulation, but also by their own experiential knowledge (some of this learning is detailed in Chapters 3 and 5). Thus, amongst the messy negotiations taking place during installation, it is difficult to evaluate the success of formal guides and regulations in shaping the installation process. This also brings the ability of ANT to account for the engineer's knowledge and understandings into question, which I now discuss.

In applying their own understandings to central heating installation, engineers clearly have agency within the socio-technical network of which the central heating system is a part. It is the nature of this human agency that presents a second critique in the utility of ANT. This theory advocates the symmetrical treatment of agency amongst humans and non-humans. However, it has been suggested that human intentionality and motives distinguish them from non-humans, making this aspirational symmetry flawed (Pickering 1993). Collins and Yearley (1992) point towards the failure of ANT to incorporate the skills and tacit knowledge that exist amongst human actors. Meanwhile, in his analysis of the design of the bubble chamber, Pickering highlights the intentionality of the physicist that developed it, noting that "he did not assemble bits and pieces of apparatus in the laboratory just for its own sake; he had an end in view" (1993: 557). In the same way, it is unlikely that the heating engineer approaches the installation scene without an idea of the final product. Pickering goes on to suggest that:

> "To get to grips with what is special about human agency, then – to break the perfect human/ nonhuman symmetry of actor-network semiotics – one needs to think about the intentions, goals, purposes, or whatever of human action."
>
> (1993: 577)

Consequently, further analysis might more fully consider the intentions of the heating engineer as the central heating system is negotiated into the home. This leads to another limitation in the application of ANT to this empirical material. Throughout this discussion, the central human actor has been the heating engineer. The perspectives I was afforded were through discussion and observation of the installation process with heating engineers. From this position, end users did not often seem to take a significant role in the negotiations taking place in their home, indeed, much of the time they were not physically present for this process. However, this does not mean that they have no involvement in it. Star highlights that science and technology studies are guilty of privileging particular points of view, especially of those with more power, despite STS scholars agreeing "in principle that all points of view are important" (1991: 33). My route to entry for observing these negotiations was through the heating engineer. In many cases, this meant that I would arrive after initial discussions had taken place, or receive the engineer's account of events, meaning that the householders' perspectives have been neglected. In following this actor, I have presented an account of a 'hero's' network (Law 1991); it is the engineer's perspectives, and my interpretations of these, that are presented here. This is a necessary feature of a thesis that aims to explore the role of heating engineers; however, it has also been suggested that this is characteristic of the ANT approach that "finds heroes to be more interesting than ordinary folk" (Law 1991: 13). This is problematic in that it can result in the neglect of actors that are already systematically excluded from these processes (Murdoch 1997), and it creates a biased perspective of the installation process. It is especially important to consider the implications of these negotiations for householders, particularly because once these systems take their active position in the home they are not always used in the most efficient way. However, in these negotiations, it is also apparent that although he may be more powerful, the heating engineer does not necessarily command the scene, which I now elaborate on.

7.6.2 Intermediary installers are coerced into action

Many of the regulations and guidance discussed in Chapter 3 privilege the expert engineer as the orchestrator of events and the expectation is placed on them to deliver energy efficiency. Furthermore, it is increasingly being recognised that professionals in the built environment may apply their own preferences and priorities in shaping the technologies installed in homes (Banks 2000a; Killip 2011; Janda & Parag 2013; Owen et al. 2014). However, the evidence presented in this chapter suggests that we need to expand our gaze in understanding how technologies are selected and installed, modifying our understanding of the role that intermediaries play. Indeed, the heating engineer is not necessarily afforded the liberty to "suggest more or less what he sees fit" (Banks 2000a: 8.10); instead, the products installed in homes are determined through negotiation between a number of heterogeneous actors. For example, boilers are often selected on account of flue runs, gas pipes and their ability to blend in rather than the engineer's preferred brands, whilst radiators may be selected based on existing system layouts rather than the engineer's sizing procedures. Furthermore, the footprint of an existing device may govern the positioning of a thermostat more than the engineer's understanding of where is appropriate for its accurate operation (for example, away from heat sources, this is discussed in Chapter 3). Thus, the privileged engineer may, in fact, be coerced into action by the preferences and requirements of both the established socio-technical networks in homes, and the components of the new system being negotiated into position. Indeed, the ability of the engineer to be flexible in satisfying these varied requirements is essential to the success of the central heating system. As de Laet & Mol highlight "effective actors need not stand out as solid statues but may fluidly dissolve into whatever it is they help achieve" (2000: 227). With competencies re-distributed amongst the different actors in the installation scene, achieving a functioning central heating system is not dependent solely on the heating engineer. Furthermore, the preferences of these different actors do not always coordinate to result in the most efficiently operating central heating system, which I now discuss.

7.6.3 Negotiations do not always prioritise efficiency

In finding a position for new central heating components in the home, the regulations and guidance outlined in Chapter 3 are not always prioritised. For example, a boiler might be selected based on what will fit in the available space, but also its reliance on the multitude of pipework that extends beyond the case. It is this reliance that makes its compatibility with existing pipework a key consideration of the installation process. Indeed, I have demonstrated that pipework, which is often networked throughout the property and embedded beneath floorboards, or concealed from view, is an actor that can be particularly resolute in its position. The resolve of the flow and return pipework, distributing the system's vital lifeblood, hot water, can have important consequences for the sizing of the radiators that connect to it. In a significant removal from the recommended sizing procedure outlined in Chapter 3, the output of these devices might be determined based on what will fit in the available space, or on a simple 'like-for-like' basis. This is particularly problematic if, as I demonstrated with a case where additional External Wall Insulation had been added to the property, the thermal characteristics of the dwelling have changed since the design and installation of the original central heating system. Thus it is the interactions between the different entities at play in the installation process that shape the final configuration, and consequent energy consumption, of domestic central heating systems. However, these negotiations do not always prioritise energy efficiency, or ensure that the regulations and guidelines introduced in Chapter 3 are adhered to. Finally, in jostling for a position within the home, the components of the central heating system can end up being concealed. To end my discussion of the material presented in this chapter, I now consider the implications of this, particularly what this might mean for the use of the central heating system.

7.6.4 Heat is being hidden

Despite being delegated an "actorial" role, and granted an equivalent status to the human body, the central heating system and its components may be boxed away, hidden and concealed in the home. Just like the human body, where the heart, arteries and vital organs remain unseen as they operate, so too should the boiler, pipework, radiators and controls that make up the central heating system. Attempts are made to ensure that the boiler disrupts the installation scene as little as possible, this device may be expected to blend in with its surroundings, squeezed into kitchen cupboards or boxed away. Meanwhile, it is undesirable for pipework to be on display, radiators are expected to fit beneath windows, and controls may be hidden away. One strategy to minimise disruption is to fit like-for-like, or use the footprints of the existing technology as placement guides for new devices. In fact, a significant amount of work goes into enrolling these new actors to perform in the same way as their existing counterparts. These negotiations take place because of the agency of the installation requirements of each component, but also the initiatives of the installer and the householder. Although I did not witness many householder's requests, Banks (2000b: 3) has investigated the importance of aesthetics in installation decisions. He identified through a survey that 46% of householders would prefer to have the boiler concealed (although he does not provide a sample size or response rate for this). With such effort being expended on ensuring equivalence, it can be suggested that rather than central heating installation being a potential moment to introduce new ideas and more efficient operating modes (as suggested in Chapter 2), it is instead a moment for reproducing and reinforcing existing space heating practices. Thus, although heating engineers and the installation process are both potentially effective points of influence in shaping end users' ideas of comfort (Shove et al. 2008), understandings of heat and use of central heating systems towards more efficient means, maintaining the status quo does not promote this activity.

Furthermore, it is only whilst negotiations take place during installation that many of these components are seen at all. During the process of enrolling and aligning these components into a single, coherent unit, they become black boxed. That is to say, their production, and their original existence as standalone entities becomes 'opaque' (Latour 1999: 183), instead they become a 'central heating system'. It is rare that we see this process taking place or its implications; however, through accessing this momentary opening (Latour 1999), I have demonstrated how this black boxing may be additionally compounded by efforts to hide the system components. Furthermore, this process may contribute to the creation of boundaries (Woolgar 1991), that is, physical and metaphorical restrictions that limit the user's interaction with the central heating system. For example, as part of the expert engineer's territory (discussed in Chapter 5), inaccessible controls and hidden devices may present a borderline that the user is not expected to cross.

This hiding ensures that the central heating system is soon to become invisible in its everyday provision of hot water and heat. In particular, if controls are hidden in homes, it is perhaps unsurprising that their presence seems to be under-reported (Shipworth et al. 2010), and that people do not recognise, or cannot distinguish their controls (Rathouse & Young 2004; Revell & Stanton 2014). Furthermore, the data presented here further adds to the growing body of evidence that heating controls are placed in inaccessible positions (Rathouse & Young 2004; Meier et al. 2011a), and in the footprint of existing devices (Peffer et al. 2011). Not only could inappropriate positioning have a detrimental impact on the use and functionality of central heating controls (Rathouse & Young 2004; Meier et al. 2011b), it is an important consideration in the move to the 'smarter' controls introduced in Chapter 3. For example, it may be fruitful to question how people will interact with the advanced interfaces of these devices if they are concealed from view, and how those devices reliant on occupancy sensors to map occupancy patterns may operate if they are hidden in cupboards. It is with a consideration of how central heating controls might be used that I turn to the final empirical chapter of this thesis.

7.6.5 Shifting to the users

To conclude, this chapter has revealed important insights into the lived dynamics of the installation process. To date, there has been no consideration given to the contestations and negotiations that take place during the installation of central heating systems. This discussion has revealed that a variety of actors are involved in this process, and, in asserting their respective priorities and preferences, the outcomes of installation are not always those that might be desired to maximise the energy efficient operation of these systems. I return to this material in Chapter 9 to make a series of suggestions for future work, policy and research.

However, to complete my current exploration of the installation of central heating systems in homes, my analysis considers a particularly important aspect more fully: the end user. As discussed in Chapter 3, at the end of the installation process, heating engineers must hand the new central heating system over to the building occupants. How they will then use this system is an essential consideration in understanding the energy consumed through central heating. Latour notes that, "…no scene is prepared without a preconceived idea of what sort of actors will come to occupy the prescribed positions" (1992: 161). Indeed, in designing and installing central heating systems, heating engineers apply their own constructions of customers. These can shape product decisions, explanations and the subsequent use of central heating systems, as such, these constructions provide the focus of my final empirical chapter.

8 Scripting end users

During their interview, Gary and Dale highlighted that there are two aspects to consider in the design of a central heating system. Firstly, "the facts and figures", which are "not debatable", but also:

> "The customer preference side of it, y'know, what best suits them and their lifestyle and what they, what they would prefer."
>
> (Gary & Dale, interview, 2013.08.22)

It is this consideration of the customer that provides the focus of my final empirical chapter. Heating engineers interact with customers on a daily basis, entering their homes and disrupting existing socio-technical arrangements as they install new central heating systems. This process is shaped by the requirements of the property and the system (as discussed in Chapter 7), but also those of the customer. During the installation process, engineers consider different aspects that can be used to determine what might suit a customer, for example, their demographic information and their lifestyle, as well as their family and working status. This information may be collected through interaction with the customer and observation whilst in their home, but it may also be based on engineers' historic experiences with customers. Through all of these factors, engineers come to develop constructions of their customers that shape the installation process.

As discussed in Chapters 5 and 7, the majority of the central heating system is reserved as the expert engineer's domain. It is the controls that provide the customer's point of interaction with their central heating system. Thus, engineers' constructions are often based on the customer's assumed understandings of, and interactions with, their heating controls. Consequently, it is customers and heating controls that provide the focus of this final empirical chapter. It is during the selection and installation of heating controls that these constructions of customers are put into practice. In particular engineers may choose devices and explain them in ways they believe to be appropriate for particular customers. In this way, these constructions of customers can shape not only the devices installed, but also the way that they are subsequently used. To explore these constructions and their implications, the idea of 'scripting' is applied to the following empirical material. This concept stems from Actor-Network Theory, and allows us to maintain and develop the focus on the materiality of the installation process introduced in Chapter 7. Beyond the contestations and negotiations that take place during the installation process, the idea of scripting provides a lens through which to understand the ways in which decisions and technology configurations may shape the end users' interaction with central heating systems. In the empirical material that follows, I look at the ways in which system installers can inscribe particular values into artefacts, potentially shaping the user as they do so. In order to do this, I first introduce scripting in more detail.

8.1 Introducing scripting

Woolgar (1991) presents the idea of a technology as text, a metaphor that is intended to portray the interpretive processes at play as a machine undergoes a process of construction (it is written) and use (it is read). The relation between the reader (user) and writer (constructor) is mediated by the technology and interpretations of "what the machine is, what it's for, what it can do" (Woolgar 1991: 60). Thus, the design of a technological artefact includes the writing of a script, in which users are configured. Through scripting, the structural features of an artefact encourage certain user actions whilst constraining others (Jelsma 2003). This is a process of "defining the identity of putative users, and setting constraints upon their likely future actions" (Woolgar 1991: 59). The writing of the script relies on the designer having a construction of the product's intended user, including, for example, their identity and characteristics. These user representations encompass "specific tastes, competences, motives, aspirations, political prejudices, and the rest" (Akrich 1992: 208). This co-construction of users and artefacts has been identified in the development of technologies as varied as computers (Woolgar 1991), photoelectric lighting (Akrich 1992), environmental domestic technologies (Rohracher 2003), photovoltaic panels (Abi Ghanem 2008) and domestic appliances such as the fridge (Silva 2000; Watkins 2006).

Of particular significance to this study is the implication that users are variably constructed amongst the different actors involved in the design and development of the technology. Organisations might use a series of 'explicit techniques' for the development of user representations, namely market surveys, consumer testing and feedback on experience (Akrich 1995). However, through simulating prospective users' behaviour and reactions, presenting "typical" scenarios, and employing actors deemed to be representative of real-life users, these techniques create idealised users (ibid). Furthermore, the use of these techniques is 'surprisingly limited' in bringing new products to market (Akrich 1995; Rohracher 2003: 183). Instead, implicit methods, those relying on personal experience, 'expert' authority and experience with related products, can be more powerful (Akrich 1995). Thus, in the design and development of a technology, knowledge and expertise about 'what the user is like' can be distributed. For example, in Woolgar's (1991) case study organisation, which was designing and developing a new range of microcomputers, he distinguished those working in isolation from users (engineering and design sections), from those working first hand with users (technical support, and those who managed complaints and queries). Arguably, those on the front line, who interact with customers on a daily basis, are better positioned to depict the real user.

For a new technology to be integrated into its intended socio-technical landscape, constructions of users must be reconciled with real users. Akrich (1995) identifies a series of strategies adopted to aid this alignment process, including delegating reconciliation of representations to intermediaries. She notes:

> "Such intermediaries might be "outsiders" regarded as able to provide entry to established socio-technical networks. [...] If such networks are to be able to channel the new system towards its intended users, a mutual rapprochement must be effected between the users and the system. This is the task intermediaries have to perform."
>
> (Akrich 1995: 180)

Thus, outsider intermediaries are tasked with establishing harmonious relations between the artefact and its intended users. In Akrich's (1995: 180) example of a home management computer with applications including house surveillance and programmed heating controls, it was the intermediary 'dealers' who were to 'sound out' the varied user constructions for their individual needs and devise a suitable system configuration accordingly (this included installation, programming and after-sales service). However, Rohracher (2003) notes the 'sometimes conflict-ridden' process between users, producers and other actors. In his study of ventilation systems, he identifies that intermediary installers might try to convince users of their own preferred vision of the technology design and use. Meanwhile, in Abi Ghanem's (2008: 201) case, it was the project managers - "deciding where, how and in what way" photovoltaic panels were to be installed in both social and private housing case studies - who configured users. These intermediaries, charged with the delivery of photovoltaic panels, confined users to "project-friendly", passive, indifferent roles that ensured the smooth completion of installation (ibid: 201). These examples demonstrate how the process of configuring the user is not confined to design and development, but extends into the deployment and installation of technologies.

8.1.1 Identifying scripted users

For the remainder of this chapter, I explore the ways in which heating engineers script users of central heating systems through their selection and installation of heating controls. This is an interesting case in that heating engineers meet end users and enter their homes on a daily basis, making them distinct from some of the designers investigated in the studies detailed above. However, they are also similar in that they construct their customers as particular user types and use these to determine the most appropriate control devices to install. To explore the extent to which scripting applies in this case, I first present the most prevalent user types, before detailing how they are considered in the selection and explanation of heating controls throughout the remainder of the empirical material. In particular, I distinguish mechanical, digital and smart control devices, and the types of customers engineers identify they are suitable for. The installation of these technologies may be accompanied by an explanation of how to use them, including the provision of suggested settings and control strategies. Through this provision of advice, the engineer portrays particular images of thermal comfort and theories of home heat. Furthermore, through their explanations engineers may restrict end users' interaction with this technology, or remove control from their hands altogether. It is because of the strategies that engineers apply in negotiating customers' interactions with these devices that I conclude that there is a divergence between their constructions of customers and those adopted by designers and manufacturers in the development of these technologies. Engineers are tasked with reconciling these differences, and do not always do so in ways that ensure that central heating systems are operated in the most energy efficient way.

8.2 Types of customer and their understandings

> "Faye: Are people generally interested in the systems, or...?
>
> James: No, are they hell as like. No-one cares about 'em, as long as they got heatin' and hot water they don't care and it's cheap."
>
> (James, organisation, interview, 2013.07.04)

Customers are interested in two things: the cost of the work taking place, and the ability of the central heating system to deliver warmth and hot water. Costs were cited by many of my participants as the customer's primary motivator, this is the only thing that "90 per cent of householders understand" (Gary & Dale, organisation, interview, 2013.08.22), in particular, they may seek to minimise the cost of an installation as much as possible. These discussions usually take place during the initial quotation stage. Beyond this, it was suggested that customers are "very rarely" interested in what is happening during the installation (Brian, SE, interview, 2013.09.16). Instead, it was the initial quotation that was seen by some of my participants as an opportunity to gain the customers' trust, and make them feel comfortable. For Tim, this is a process of building a "friendship", which was particularly important because during the installation "you're gonna turn their life upside down" (Tim, SE, interview, 2013.12.10). Likewise, Martin uses the first meeting to "buil[d] their confidence up", this includes finding out what they want, and talking about the boiler and the system, until "they're quite happy to leave you to it" (Martin, SE, interview, 2013.09.10). Similarly, Brian suggested that "by the time [he's] finished talking at them" during the quotation the customer knows what work will be taking place in their home, and shows little interest thereafter (Brian, SE, interview, 2013.09.16).

These initial stages are not only important for the customer to receive information, they are a key moment for the engineer to establish what type of customer he is working with. For example, Doug highlighted that he can gather a lot of information "just by walking through the door"

> "You look at how, I know it sounds really terrible, the state of the existing system, erm, generally, erm, how people conduct themselves, if they're more professional you know they're gonna listen, if all, if some are just all they're interested in is the price and they just don't appreciate the difference between erm, say a plumber and a heating or mechanical engineer then you are wasting your time."
>
> (Doug, SE, interview, 2013.12.03)

Establishing the type of customer that he is working with, including whether they will listen to the expertise of the engineer, has become "instinct" for Doug. Similarly, Malc noted that he could 'tell by the state of the property' whether a customer would want a high quality heating system installed. If they did not take care of their property, they were unlikely to be 'bothered' about the quality of their central heating system (fieldnotes, PHEX, 2013.11.13). In fact, there is a "massive, massive…cross section" of customers and "you don't know who you're gonna come up against when you walk in the house" (Roy, SE, interview, 2013.08.08). In their everyday work, entering different properties on a daily basis, heating engineers interact with the "whole of human life" (Brian, SE, interview, 2013.09.16). Indeed, during our interviews my participants regaled me with stories of funny, dirty, difficult, entertaining, abusive, ignorant and messy customers. Although every customer may be different, heating engineers have established certain customer types that were particularly prevalent during my fieldwork. I will briefly introduce each of these customer types before discussing how heating engineers apply them, along with more general customer constructions, to determine appropriate central heating technologies and explanations.

8.2.1 Older people

By far the most prevalent type of customer discussed amongst engineers and during interviews was older people. These were often retired, and lived quite an isolated lifestyle, with few visitors. These were generally regarded as having a limited understanding of central heating systems, and in particular of the controls. When the functionality and suitability of these devices was discussed, it was most frequently with reference to older people, particularly the 'old dear' or 'old lady'. Engineers expressed a certain responsibility for the well-being of these individuals and would often describe them with fondness. For example, George noted that "older people are the best", they enjoy visits from heating engineers and will take the time to stop for a chat (George, SE, interview, 2013.10.15). Furthermore, these customers were regarded as not having much money, and a couple of my participants noted their "Robin Hood" tendencies (Jack, SE, survey debrief, 2013.10.30). For example, charging older customers a reduced rate for the work, or overlooking small costs for these individuals.

8.2.2 'Tech savvy' customers

The antithesis of the older people described above are 'tech savvy' customers. These "technical folks" like "up-to-date stuff" (Ben, organisation, interview, 2013.06.17), and the "fanciest thing going" (Gary & Dale, sales reps, interview, 2013.08.22). These "clearly intelligent, clued up" individuals are likely to conduct their own product research online ahead of the engineer's visit (Gerry, SE, interview, 2013.10.17). They may even show an active interest in the installation as it is taking place, as Roy pointed out "you get the occasional one who just won't leave you alone, wants to know if they can solder a joint" (Roy, SE, interview, 2013.08.08). These tech savvy individuals were suggested to be engineers, or have an engineering background (Gary & Dale, sales reps, interview, 2013.08.22; Gerry, SE, interview, 2013.10.17; Jack, SE, interview, 2013.09.11), or younger people. For example those using "smart phone technology" and "downloading apps" (Amir, merchant, interview, 2013.08.12). However, these individuals may eschew the engineer's advice (Carl, SE, interview, 2013.12.16), and be more impatient, for example, demonstrating "no tolerance, no understanding" during the installation when they have heating and hot water temporarily disabled (Tom, SE, interview, 2013.07.17).

8.2.3 Working people and families

Working people and families are those with particular routines. For example, in family life, activity levels are greatest during the mornings and evenings, and the property is presumed to be unoccupied during the middle of the day. Likewise, working customers are likely to be "out the house at certain times of the day" and have different weekday and weekend schedules (Roy, SE, interview, 2013.08.08). The schedules of these customer types are particularly a consideration in the settings that engineers might suggest for their central heating controls, and are discussed more in Section 8.4. It was also suggested that people who are "more professional" are more likely to listen to the engineer during the initial consultation (Doug, SE, interview, 2013.12.03).

8.2.4 Women

A final customer type that was particularly apparent in engineers' conversations was women. When I asked Doug if he could identify customers that struggle with the controls, he asked: "how can I say this without you hitting me?". After reassuring him that I was not going to be violent during an interview, Doug clarified that it is his "female customers" that "just don't wanna know" (Doug, SE, interview, 2013.12.03). My participants would often refer to women in their examples of customers who had difficulties. In particular, they would draw on the experiences of women close to them, for example, the way in which their wives, girlfriends and mothers (mis)understood and (mis)used control devices. Furthermore, women were generally regarded as desiring higher temperatures and being difficult to convince otherwise (Phil, manufacturer training, 2012.10.10; fieldnotes, manufacturer training, 2013.12.02). This was particularly frustrating for engineers if they were trying to encourage their customers to operate the heating at a lower temperature, for example, when suggesting the most suitable operating temperatures for the system to run efficiently.

It is these constructions of different types of customer that engineers use in the selection and explanation of heating controls. In the following sections, I elaborate on these user types, along with more general customer constructions, to look at how heating engineers match control devices to particular customer types before moving on to explore how these devices are explained.

8.3 The right controls for the right people

Heating engineers adopt different strategies in the selection and installation of central heating controls. Some fit a like-for-like controller; not only does this minimise disruption to the existing socio-technical arrangement in the dwelling (as discussed in Chapter 7), but it also ensures that the customer has a device that "they're used to" (Ben, organisation, interview, 2013.06.17; James & Eddie, organisation, interview, 2013.07.04). Alternatively, an engineer, or organisation, might always fit the same controls; this preference may be related to their own familiarity with the product (which can be used to demonstrate expertise, as detailed in Chapter 5), but also because of its proven ease of use. For example, Tim always specifies Stockman controls because "theirs is the most simplest one on the market" (Tim, SE, interview, 2013.12.10). However, different types of customer, and their different lifestyles might warrant the need for different types of control, as Roy discussed during his interview:

> "What do they want out of out of the system, erm, 'are you and your husband workin', are you out the house at certain times of the day',…is your weekend schedule different from your 5 day a week schedule, y'know, you need real, real flexibility on times, if it's erm, a retired couple, they really can't handle that technology, the 5 day, 2 day, 7 days…they don't really need all of that technology, all they wanna do really is stick it on manual, 'cos the old boy might get up at 6 o clock in the morning, he'll come downstairs and he'll switch it on…irrelevant of whether he's got an all singin' all dancin', so, it's extremely important that you sell the right control type to the right person."

(Roy, SE, interview, 2013.08.08)

Roy was not alone in identifying that differences between customers may be a consideration in the selection of central heating controls. Heating engineers would distinguish between three different types of heating control; mechanical, digital and smart. These devices place quite distinct requirements on users, and may be suited to different individuals. For example, during one manufacturer training session, the course instructor held up a mechanical programmer, stating, 'this one is for your little old lady', followed by a digital device that he suggested was 'for the young techy guy' (Burt, fieldnotes, manufacturer training, 2013.08.21). These different devices have no doubt been created using designers' own constructions of end users, and their consequent functionality may, in turn, script the way that users interact with them. However, they are also subject to an installation process, which may further script their use. In the following section, I take mechanical, digital and smart controls in turn, exploring how their selection varies according to heating engineers' constructions of their customers.

8.3.1 Mechanical devices

Figure 8.1 Example mechanical thermostat, 'push-pin' timer and programmer with 'sliders' for heating and hot water[31].

[31] Image sources, from left to right:

Heating engineers often regarded mechanical devices as the simplest control option. These include the mechanical thermostat, a device with a dial that is twisted to indicate the desired temperature setpoint, a 'push-pin' programmer where pins are pushed in to set the on-off times for the heating, and programmers with 'sliders' that are physically moved to select the preferred settings (see Figure 8.1). Gary and Dale noted that these are "archaic", but a large number are still sold because "everyone knows" them and "they're just easy to work" (Gary & Dale, sales reps, interview, 2013.08.22). These devices were particularly noted for their suitability for older people, who just want 'on or off" (Martin, SE, interview, 2013.09.10). According to Martin, "they tend to like the slider ones where you've just got hot water, heating [...] they can manually move rather than one that's on a display" (Martin, SE, interview, 2013.09.10). Phil, a course instructor at one training session, nicknamed the mechanical thermostat "the granny stat", highlighting that it was "idiot proof" and "if you can't use this product, then you shouldn't be left on your own" (fieldnotes, manufacturer training, 2012.10.10). At a different session Martin highlighted a mechanical programmer for its suitability for 'old ladies because they don't understand these new ones'. He noted that although these devices are not compliant with Building Regulations, they can be installed if the engineer is 'changing like-for-like' (this strategy is discussed more in Chapter 7) (fieldnotes, manufacturer training, 2013.06.04). It would appear then, that older people have been constructed as individuals who are most at home with simple, mechanical devices with limited functionality and flexibility. These mechanical devices are a significant removal from

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1) https://www.plumbnation.co.uk/site/danfoss-randall-rmt24--24v--electro-mechanical-room-thermostat-087n119600/;

2) http://www.which.co.uk/home-and-garden/heating-water-and-electricity/guides/boiler-and-heating-controls/types-of-boiler-and-heating-controls/ - accessed 2014.09.20;

3)https://www.google.co.uk/search?q=mechanical+central+heating+programmer&oq=mechanical+central+h&aqs=chrome.2.69i57j0l5.3789j0j1&sourceid=chrome&es_sm=91&ie=UTF-8#q=mechanical+central+heating+programmer&tbm=shop&spd=10534743019105122763 - accessed 2014.09.23

the digital and smart devices that are increasingly becoming the norm for central heating controls.

8.3.2 Digital devices

Figure 8.2 A digital programmable thermostat, and a digital room thermostat[32].

Digital devices, like those included in Figure 8.2, were regarded amongst some of my participants as being harder to understand, not only for the customer, but also the engineer. At one training session, it was suggested that the digital device was 'the one where you give it to the customer with the instruction manual and say "see you later", because you don't have a clue how it works!' (fieldnotes, manufacturer training, 2013.11.26). These devices tend to use digital screens, and buttons labelled with symbols, rather than text. They usually have greater flexibility than their mechanical counterparts, with the capacity to have different settings on different days of the week, for example. These devices are "a little bit more upmarket" and are suitable for a "young, professional couple" because these customers are "a bit more technical"

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[32] Image sources, from left to right:

1) https://orangeheatingsupplies.co.uk/product/honeywell-cm907-honeywell-cmt907/ [Accessed: 23.09.2014]
2) http://www.heatmiser.com/slimline-thermostat-series/ [Accessed: 30.06.2015]

(Jack, SE, interview, 2013.09.11). Indeed, their complexity led some of my participants to compare these devices to computers:

> "It's almost like teachin' someone 'ow to use a laptop, and they've never used one before, or say an ipad, easy enough to understand if you work with computers, but if you've never worked with one and you say 'right, 'ere it is', do this, this and this, and they don't, they don't even know the sequence of 'ow to start it up, 'ow to get the programmer to work, 'ow to get the times put in"
>
> (Jack, SE, interview, 2013.09.11)

It is in part their relation to computers that leads these digital devices to be regarded as unsuitable for older customers. For example, during one training session it was suggested that a programmer with 'quite a few whistles and bells' was 'not for granny' (manufacturer training, fieldnotes, 2013.06.04). Tom noted the "separation between different generations", drawing on his own experience to conclude: "if I put in too modern a room control, I struggle to understand how to use it and I'm 25. Someone who's 60 has got no clue" (Tom, SE, interview, 2013.07.17). Carl elaborated on this difficulty with reference to the specific symbols used in the "laptop world", he mentioned the 'return' key, highlighting that his mum, who's 87, "don't know what that means", but also "why should she know?" (Carl, SE, interview, 2913.12.16). Beyond a lack of familiarity with these 'computerised' devices, some of my participants highlighted the challenges that older users might be faced with because of the visual and dextrous requirements of these devices.

> "If their eyesight's bad I then go for a programmable room stat that's big numbers. It's no good giving a pensioner something with a pissy little number down in the corner and a little symbol with a flame. They can't see it. They want on, off, they wanna hear a click."
>
> (Carl, SE, interview, 2013.12.16)

According to Carl, rather than 'pissy little numbers' and symbols, older people just want to 'hear a click'. The 'click' he refers to is the sound a mechanical thermostat makes when it detects that the ambient temperature is not as desired and triggers the firing of the boiler. Thus, according to the engineer, the requirements scripted into the design of digital controls make them unsuitable for some users, particularly excluding older people. Instead, digital controls might be consigned to those with more familiarity with computer-like devices, for example younger, and more tech savvy people.

8.3.3 Smart devices

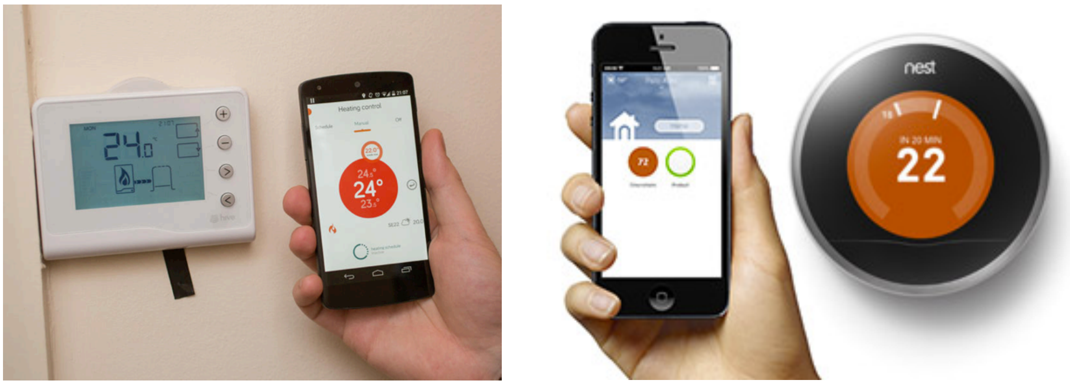

Figure 8.3 Smart heating controls[33].

Although they were far less prevalent during my fieldwork, smarter heating controls did sometimes feature in engineers' conversations. These devices usually include a digital user interface (a touchscreen, for example) and may encompass the use of multiple technologies, for example allowing remote operation of the central heating via a laptop or mobile phone (see Figure 8.3). It was suggested that these advanced devices might be suitable for "somebody that's clearly intelligent, clued up, maybe an

[33] Image sources, from left to right:

1) http://www.cnet.com/uk/pictures/hive-from-british-gas-puts-heating-control-in-your-hand-pictures/ [Accessed 30.06.2015];

2) http://www.which.co.uk/news/2014/09/could-you-save-money-with-smart-heating-controls-379160/ [Accessed 30.06.2015]

engineer or something like that", who will want the "fanciest thing going" (Gary & Dale, interview, 2013.08.22). During his interview, Roy referred to a particular brand of smart programmable room thermostat that you could "turn on from your laptop in Tokyo", suggesting that this was most suited to "upwardly mobile office people" (Roy, SE, interview, 2013.08.08). Meanwhile, Phil, a sales representative for a controls manufacturer, thought that controls with an 'iphone app' were for 'people who wanted to show off' (fieldnotes, sales rep, 2013.07.16). In another example, Chris told the story of a 'techy guy' who had 'found this new control from America'. Chris had not installed this control before, and had to spend some time understanding the new technology before he could install it (install - organisation, fieldnotes, 2013.10.21). This lack of familiarity was also highlighted by Dan, a course instructor at a manufacturer training day, who briefly discussed iphones being used to control central heating systems.

> He said that he had just been given his son's old iphone but he had no idea how to use it and he didn't want to sit and learn it so he would tap a few buttons and then put it down and come back to it some time later. Dan asked why you would want iphone control and described it as people thinking 'because I can, not because I need to'. He said that it just wasn't him though and that he didn't even shop online much, he just didn't like it and he was much more of a touchy feely person so he liked to see stuff in person.
>
> (fieldnotes, manufacturer training 2013.12.02)

Dan did not engage with smart devices himself, and did not understand why a customer would want that type of control for their central heating system. The lack of comprehension for why customers would want these devices was reflected by some of my other participants. For example, during another training session the conversation turned to being able to control thermostats remotely:

> One of the installers mentioned this in an 'apparently, you can control them remotely or something now' kind of way (as though he'd heard of it but never actually come

across it himself). Another said that British Gas do that, but you pay £400 for the pleasure, and he didn't see why customers would want to pay for it.

(fieldnotes, manufacturer training, 2013.03.21)

Some of my participants did not understand these devices themselves, and in turn, could not comprehend why a customer would want them. This was particularly problematic for Roy, a self employed engineer who sub-contracts for a large organisation, and sometimes has to fit the smart devices they specify. He told me that 'he doesn't know about them or understand them', so he just fits the controls and 'then there's an 0800 number that the customers have to ring to set them up' (merchant-chain, fieldnotes, 2013.07.22). Roy's limited understanding led him to suggest that customers use the organisation's central helpline for guidance on setting up these devices. Thus, the complexity of smart controls is such that it is only the most tech savvy customers that are eligible for them. Moreover, with heating engineers' apprehension and limited understandings of these devices, it seems that they are unlikely to recommend them for customers.

8.4 Suggested settings

Although heating engineers may specify controls that they believe to be suitable, this does not happen in all cases, nor does it guarantee that end users will understand them. Indeed, my participants generally felt that customers did not understand their heating controls, for example James noted that the technology does "baffle them" (James, organisation, interview, 2013.07.04). This was particularly true of the more complicated devices (such as the digital and smart controls detailed in Section 8.3), for which Gary (a sales rep who had previously been an installing engineer) noted "the majority of their function just goes unused" (Gary, sales rep, interview, 2013.08.22). Given the potential of these devices to reduce the energy consumed through space heating (as discussed in Chapters 2 and 3), it is important to understand why they are not being used to their full potential. The requirement to include an explanation and demonstration of heating controls is written into the commissioning and handover process, and stipulated on the Commissioning Checklist (this is discussed in Chapter 3). Like a user manual, any demonstration and explanation provided by the engineer during installation may shape the customer's interpretation and subsequent use of this technology (Woolgar 1991). Thus, it is important to explore what explanations engineers are providing in order to understand customers' subsequent use of these devices. The following three sections uncover the different strategies that heating engineers use for explaining heating controls, again linking back to how these might vary for different types of customer. In Sections 8.5. and 8.6, I will explore the way that engineers navigate end users' limited understandings of their controls, but first, I identify the suggested settings that heating engineers provide, including temperatures and heating schedules.

8.4.1 Comfortable temperatures

According to one training course instructor, "it's scientifically proven that the human is comfortable between eighteen and a half and twenty one and a half [°C]" (manufacturer training, audio, 2012.10.10). Being able to maintain a temperature within this comfort band was a key selling point of the room thermostat, in installing this device "we're not particularly bothered about saving the penguins, saving the ice cap, we just wanna be comfortable" (Chris, manufacturer training, audio, 2012.10.10). When discussing how to help customers reach this comfort band, Chris, the course instructor, offered the following strategy:

> "I suggest for the first two days, run it at 22 degrees, for the next two days, turn it down, each after two days and go down to 21 degrees, turn it down again, if you still feel comfortable, turn it down. Turn it down until you feel too cold and then you go back up one degree and you know you're there, you're controlling just above your too cold zone, yes?"
>
> (Chris, manufacturer training, audio, 2013.06.04)

Chris' strategy, to start from 22°C and incrementally reduce the thermostat setting according to comfort is not conducive to achieving energy savings through this device. For example, this strategy relies on customers actually turning the thermostat down from the initial 22°C setting. Furthermore, by starting at a high temperature and working down it might be that customers settle at a higher temperature than they perhaps would if starting from a lower temperature. When engineers discussed controls and settings, they would default to temperatures within, and sometimes above, this comfort band. For example, during an informal conversation, Brian told me about the digital thermostat that he tends to install. He listed one of the benefits as being able to know the exact readings, noting that 'if you switch the digital to 23-24 and then turn it down to 21, you would feel the difference, but with a manual you might not notice' (merchant-chain, fieldnotes, 2013.06.17). These temperatures manifest into actual recommendations for customers operating the systems. For example, Shaun noted leaving the thermostat at "21, 20, something like that" depending on the occupant's "personal preference" (Shaun, organisation, interview, 2013.08.22), whilst Tom suggested leaving the "room stat down, below 18, 19" (Tom, SE, interview, 2013.07.17). It was noted that higher temperatures were more suitable for older customers, and preferred by women. For example, Jack noted how his mum would alternate her thermostat setting between 30 and 15°C, if she was cold and hot, respectively. Jack tried to discourage from operating at these extremes by suggesting that she "just set it to 25" (Jack, SE, interview, 2013.09.11). Beyond temperatures, heating engineers might also suggest particular times for the heating to turn on and off, particularly in accordance with customers' lifestyles.

8.4.2 Schedules for busy lives

For working customers, Jack would set the system to come on "half an hour before they get up", and off again "fifteen minutes before they go to work", he would then suggest a second evening heating period (Jack, SE, interview, 2013.09.11). Similarly, Gerry sets the heating to come on half an hour before his customer wakes up in the morning, but sets the hot water to come on fifty minutes beforehand. He noted that "it's important when you're designing the system, get the hot water load out the way" (Gerry, SE, interview, 2013.08.20). In this way, customers' lifestyles might shape the settings that heating engineers suggest. Scheduling programmes and settings is not only suitable for working customers, but also for families. Families in larger properties may particularly benefit from zoning, where the heating in different areas of the house can be independently controlled:

> “So if you’ve got mum and dad downstairs, two kids upstairs, mum and dad have got an extra heat source in the living room they’re nice and snug, turn the heating off, upstairs sits there completely cold.”
>
> (Phil, training, audio, 2012.10.10)

Phil, the course instructor who described this scenario noted that the parents downstairs would be watching Coronation Street; in this sedentary position they would presumably need more heat than the children upstairs (training, fieldnotes, 2012.10.10). In this family scenario, cooler settings might be used during the early evenings, “sort of 16 degrees”, whilst “the kids are coming in from school, they’re running around frantic” (training, audio, 2012.09.12). Later in the evening, “when you’ve, er, put them upstairs to do their homework and you just wanna sort of settle down” you might “up the temperature accordingly” (training, audio, 2012.09.12). Thus, the lifestyles of working customers and families might lend themselves to particular central heating schedules, with different temperatures at different times of the day. The suggestion here is that the heating is on in the mornings and evenings whilst the property is occupied, and off during the middle of the day when the residents are out. However, these different on-off schedules to suit busy lifestyles were not the only suggested control strategy.

8.4.3 Keep the heating on low and long

An alternative strategy is to keep the heating on, but at a lower temperature, perhaps only turning it up when required. Some participants felt that this strategy was a more energy efficient and cost effective way to operate the central heating system. For example, Martin noted:

> “If you actually keep the heating running at a low rate, it'll actually save you more money. They still think 'well, the boiler's on, the boiler's on' but the new boiler will work at, cheaply if it's on longer and lower, especially in an old house.”
>
> (Martin, SE, interview, 2013.09.10)

This was regarded as a better strategy because it requires a lower output from the boiler to maintain a constant baseline temperature, than to operate at maximum output in order to heat a property from a low temperature. In keeping with this, Phil recommended that the room thermostat should be kept at "12, 13, 14 degrees", and that will ensure that "every so often during the night" the boiler "will put a bit of heat into your house" (manufacturer training, audio, 2012.10.10). He elaborated on this, highlighting that:

> "14 degrees to 18-19 degrees is not a lot of work for your boiler to do first thing in the morning. 6, 7 degrees to 19 degrees is a lot of work for your boiler to do, and that's where people's heat, heat loss tend to happen the most."
>
> (Phil, training instructor, audio, 2012.10.10)

This recommendation is based on the understanding that it is better to retain the heat in the fabric of the building, and that the boiler operating at a lower output, but more regularly, is more efficient. This strategy was also suggested by Gary during an installation, where he highlighted to the customer that "keeping the fabric of the building tickin' over" was "actually a new thinking", but these ideas do go "backwards and forwards" (Gary, installation, audio recording, 2013.02.22). The energy consumed through the central heating system depends on the fabric of the building, and its capacity to retain heat; however, leaving the system on constant is likely to consume more energy than intermittent heating. In Gary's case, this recommendation was made for a semi-detached pre-fabricated property with 'very flimsy' walls constructed of a layer of brick and polystyrene (Simon, installation - organisation, fieldnotes, 2013.02.21). It is highly unlikely that this strategy was the most energy efficient option in this particular property due to its construction. Furthermore, in providing this advice to customers, heating engineers act as one of the folk channels of information identified by Kempton (1986), perpetuating customer understandings that it is more efficient to keep the system on constantly, but at a lower temperature. However, engineers' advice is not only based on their own understandings of heat, comfortable temperatures and efficient operating strategies, but also on what they believe the customer to be capable of. Indeed, heating engineers may simplify and adapt their explanations to accommodate their constructed customers' limited understandings of these devices.

8.5 Simple explanations

Sometimes the engineer is able to identify how much understanding the customer will have, and will use this to determine what to explain. For example, Ibrahim noted that "if you see that people…understands the technics or understands more about controls …you can tell them how they can do something", this includes programming the time and giving them the user guide which they can look at if they want to change the settings (Ibrahim, SE, interview, 2013.07.06). However, Roy suggested that detailed explanations were best for those "of an engineering background", and because of this he tries to "talk very concisely to people…they just want bog standard language, that they can understand" (Roy, SE, interview, 2013.08.08). It is beneficial for the engineer if the customer is able to understand and use central heating controls in such a way that they do not experience dissatisfaction, which might lead to call backs. This is when a customer asks an engineer to return to the property because they believe their system to be working incorrectly, or because they cannot operate it. Call backs are usually conducted at the expense of the engineer, done as a favour to the customer and to retain a good impression for future work and recommendations. Ben, the owner of a medium-sized installation company, estimated that "at least 80 per cent of [their] call backs are due to tenant misunderstanding of the controls…or not knowing what they are supposed to do" (Ben, organisation, interview, 2013.06.17). Likewise, in Gary's experience as a breakdown engineer, "the amount of call backs you get for people just not understanding how to work their controls is astronomical" (Gary & Dale, interview, 2013.08.22).

Call backs might be more prevalent with particular types of control, for example, the 'only time' Giovanni gets a call back is if he installs a 'new programmable thermostat' (fieldnotes, SE install, 2012.04.25). As discussed in Section 8.3, these digital devices may be more complex than their mechanical counterparts, and place a different set of requirements on the user. As Jack highlighted: "the more complicated they are, it's almost like you're gonna frighten them and they don't wanna know" (Jack, SE, interview, 2013.09.11). Likewise, Ibrahim described people as being 'scared' of the controls, particularly when they do not understand them (fieldnotes, manufacturer training, 2013.06.10). Roy's description was more extreme again, he noted that he would "never" sell a particular digital device to an "old couple" because:

> "It's totally far in advance of what they're capable of, of understandin', which is 'orrible really, 'cos it really does stress people out, honestly it does. They think if they're gonna touch that button, something's gonna blow up, y'know? […] it really does stress people out who don't know, they think there's something wrong with, their boiler, system and they actually call me to say look, there's these flashing or whatever it is, erm, and I'll say, look, please don't let it phase you […] erm, and it, it lights up, it's really luminescent, because they go into a dark kitchen and the first thing they get drawn to is this light flashing red and green and immediately, they get panic stricken."
>
> (Roy, SE, interview, 2013.08.08)

The complexity of this device leads to a great deal of distress for Roy's older customers. Roy is a self-employed engineer, but sub-contracts for a larger organisation who specify the controls that he installs. At a later point in his interview he noted that: "as an independent, I would never put one of those clocks in" (Roy, SE, interview, 2013.08.08). However, where these complex devices are installed, engineers may adopt a simple explanation strategy to ensure that their customers can 'use' them. For example, Roy detailed his strategy for this particular device:

> "What I do say to 'em is that I'll put it on manual for you, treat the plus and minus as an on off switch, if you want the heating on, press the plus button, keep your finger on it, it goes up to 30, don't go up any more. If you want the boiler off, press the minus button, it goes down to 5, it is off."
>
> (Roy, SE, interview, 2013.08.08)

Instead of detailing the operation of this digital device, Roy sets the system up so it is on 'constant', and is controlled simply by requesting a higher or lower temperature at the thermostat. This complex, digital device has been reduced to two buttons, the plus and the minus that control the temperature. Furthermore, Roy was not alone in simplifying explanations. Ibrahim explained that he would ask the customer what they want to do with the heating, if they just want to turn it on and off then he 'sets the timer' and 'tells them to just operate it by the thermostat', more specifically, he tells them to 'just turn the dial up or down' (Ibrahim, manufacturer training, fieldnotes, 2013.06.10). Ibrahim noted that this simple explanation is ideal for customers because 'if it's anything more than the basic facts, they just forget', but also for himself because he 'very rarely' gets call backs, unless it is another company that has performed the installation (Ibrahim, organisation, interview, 2013.07.06). Eric attributed this simplified strategy to his 'Duty of Care'. For Eric, it is important to ensure that customers " 'ave got the skill set to be able to have heatin' ", he explained:

> "Generally, unfortunately some will struggle, y, you can't get away from that, there's no, there's no mileage blinding them with something that you can, clearly see, they're, they're struggling, to comprehend, erm, because they're not gonna use it for the benefit. I'd rather have a, a warm resident that's probably not usin' the, the controls to the most sort of economic use than a, than a very very cold resident, that's err too frightened to use it."
>
> (Eric, organisation, interview, 2013.09.09)

In particular, Eric noted that this was the case with older people, whom he would simply advise: 'don't touch the clock, just turn your thermostat up and down'. Eric acknowledged that this was neither the most economic, nor 'environmentally correct' answer, but that it was the only way to ensure that he would have a warm resident, rather than someone that was too frightened to use their controls. Eric primarily worked on large social housing contracts, where the same digital programmer and separate thermostat are installed in every property, regardless of the tenant. Eric also adopted this basic explanation for those tenants that are 'not interested'. If the customer is “not gonna give me the ten minutes to explain”, then he just says: “there’s your thermostat, turn it on and off then” (Eric, organisation, interview, 2013.09.09).

Regardless of whether the engineer’s advice is informed by the customer’s lack of understanding, fear, or limited interest, the engineer may adopt a simple strategy to explain the controls. This manifests in the engineer setting the system to constant, and advising customers to turn their heating on and off using the thermostat. Here, the engineer may have a role in perpetuating incorrect theories of heating controls, in particular, that the thermostat operates as a switch (Kempton 1986). Moreover, by overriding the complex functionality of programming devices, for example, their capacity for multiple ‘on-off’ settings per day, this strategy essentially renders these heating controls useless. Heating engineers install heating controls that comply with the requirements stipulated in the building regulations (these requirements are detailed in Chapter 3), but, in the cases discussed in this section, advise their customers not to use them. In this, any script written into the design and development of these control devices is likely to be overridden by the alternative, opposing script provided by the engineer during installation. These simple explanations provide a vital contribution to our understanding of why end users may not understand their controls, or use them in efficient ways (as highlighted in the literature discussed in Chapter 2). However, this is not the only strategy that engineers might apply in overcoming limited understandings of heat.

8.6 Taking control out of customers’ hands

Thus far, I have detailed how engineers select and explain controls to their customers, suggesting that this may shape their subsequent use. However, as discussed in Chapter 7, much of the central heating system is not within the customer’s domain; consequently they may be urged against interacting with it. For example, Ben noted that following installation, the employees of his organisation “set the boiler to maximum at all times, to be efficient”, they then “openly discourage anyone from touching the boiler” (Ben, organisation, interview, 2013.06.17). This is perhaps unsurprising given that the boiler is placed within the territory of the expert engineer, and interaction with parts of this can pose a safety risk (this topic is discussed in Chapters 3, 5 and 7). However, the restriction of customers' access to the central heating system may also extend to the controls intended for the management of temperature settings and heating duration. As such, the focus of this section is the strategies that engineers might use to restrict customers' interaction with their heating controls, and their reasons for adopting these.

It may be considered a nuisance or frustration for the engineer if they get called back to a property because the customer has altered the settings on the heating controls. For example, Gerry described being perplexed when a customer's heating was turning on "at like 5:53 in the mornin' ", because he knew he had set the device to turn on at "6 o clock". For Gerry, this change in settings meant that the customer had "obviously been playin' with it" (Gerry, SE, interview, 2013.08.20). Similarly, Eddie described a job that he had been called back to because the customer had been complaining that the heating was coming on in the afternoon when it should not be. During his interview, Eddie speculated that the customer must have "bin playing around wi' the timer" (James & Eddie, organisation, interview, 2013.07.04). He also described how he would "cover his own ass" following an installation by noting the settings he has programmed into the controls on the documents that remain with the system. This strategy means that he knows when someone has tried to change the settings, or "buggered about with" the system (James & Eddie, organisation, interview, 2013.07.04). In fact, a similar electronic monitoring strategy is now a feature of some boilers, which keep a log of historic use. During one industry event, this was hailed as 'the best thing' about a new boiler because with this technology, engineers could tell 'if the customer had tampered with it' (fieldnotes, PHEX, 2013.11.13). Meanwhile, the course instructor at one training event noted that it's 'scary' that customers can go into the controls unit and change things, but what he found more frustrating was that customers might try to hide that they have accessed this forbidden domain:

> Dan said that the frustrating thing is that customers lie about what they've done, for example if they've been messing with the system and they tell you they haven't touched it….He says to them: 'you wouldn't lie to the doctor would you?' – if you had

a boil on your bum, you wouldn't tell them you had a sore throat because you'd want them to get straight to the problem.

(fieldnotes, manufacturer training, 2013.12.02)

Thus, not only do customers 'tamper', 'bugger about' and 'play around' with heating controls and the wider system, they might also lie about doing so. As in Chapter 7, the central heating system is once again compared to the human body. It is a complex system that requires diagnosis if it goes wrong, for this, the engineer needs to be provided with accurate information about the ailment. Furthermore, interaction with this device falls firmly within the remit of the expert engineer, or the doctor of the system, rather than the customer. One strategy that engineers might use for keeping this system within their domain, and to prevent tampering from customers, is to take control out of their hands altogether, which I discuss in the following section.

8.6.1 Limiting interactions

Doug, a self-employed engineer, installs weather compensating controls wherever possible, these automatically adjust the central heating settings according to external temperature and thus can reduce the energy consumed through the system. Doug will set the controls up on behalf of the customer, and "providing their lifestyle don't change too much [and] it's set up correctly", he suggested, they are "best left alone" (Doug, SE, interview, 2013.12.03). At one training session, this technology was noted as being advantageous because 'if the customer doesn't have a room stat then they have nothing to mess around with' (fieldnotes, manufacturer training, 2012.09.12). Meanwhile, some participants noted that on more standard devices they would physically set programmes for their customers, or retain the manufacturer's settings. For example, Brian explained that he enters the settings into the digital programmable thermostat that he installs, according a series of questions that he asks his customers:

"I would say, 'what time is, what time d'you get up? What time d'you go to bed? Are you in during the day? or are you out and about?' And explain that keeping your house warm is cheaper than cooling it down and heating it up again."

(Brian, SE, interview, 2013.09.16)

In this way, Brian can ensure that the customer's settings are appropriate for them, perhaps also limiting their need to interact with the device in the future. Indeed, these settings can have an enduring legacy. For example, George noted that some of the privately renting tenants he comes across "haven't got a clue", so they will leave the programmer with "whatever the installer has left it at", but to control the system they operate it with the power switch on the boiler (George, SE, interview, 2013.10.15). In this way, the customer is bypassing the central heating controls altogether. Another strategy that was mentioned was to point customers towards controls that have little impact on the operation of the system. For example, Burt, the course instructor at a boiler manufacturer training day, advised attendees that they could point customers towards certain controls with minimal impact:

> Burt described how the hot water dial was handy for 'the placebo effect' – he said that if the customer is complaining about something like a knocking in the system, you can advise them to turn down that dial and it won't actually do anything but the customer will think that they have made a difference…He compared it to being given a sugar tablet at the doctors for a bad leg and it not actually doing anything, but the patient's leg is miraculously better.

(Fieldnotes, manufacturer training, 2013.08.21)

The hot water dial on the boiler can be used to alter the temperature of the hot water at the outlets, but this has little actual impact on the operation of the central heating system. In making this suggestion, Burt has highlighted a useful 'placebo' that end users could interact with without doing any harm to the remainder of the system. Furthermore, customers can be physically restricted from altering the settings on the devices that are installed. It is possible to purchase 'range stops' or 'tap-its' that are positioned on mechanical thermostats (see Figure 8.1), to restrict the amount that the user can turn the dial. These were noted as being particularly useful for older people, to stop them reducing the temperature too much. As Phil noted, "although Mr and

Mrs Jones may want to turn it down, turning it down at that age can cause medical problems, so they tend to put it in there to stop them getting too cold" (manufacturer training, audio, 2012.10.10). Furthermore, these devices were also suggested as being useful for preventing women from "turning it round too high", particularly if their partner does not like high temperatures (manufacturer training, audio, 2012.10.10). Alternatively, if a customer complains that their thermostat is not working, it might be easier to deceive them than attempt to explain its operation, particularly if 'they just don't get it':

> Hasan used the example of someone calling and saying that it used to turn on when they switched it round to 15 but now it doesn't…he said that sometimes he goes in and twists the thermostat round so that the customer thinks it coming on at the temperature they want.
>
> (Fieldnotes, install, organisation, 2013.04.17)

I clarified with Hasan that the action he is referring to here is to remove the cover from the thermostat, twist the dial and replace it so that it looked like it was reading one temperature when in reality it was reading another. A similar, but alternative strategy that heating engineers might apply is to install a thermostat that is labelled with a numeric scale (for example, 1-5) instead of temperatures (for example, 10-30). A dispute about whether the thermostat is reading the correct temperature can be resolved with this device, which provides "comfort levels" instead (manufacturer training, audio, 2013.06.04).

Thus, whilst customers are constructed as individuals who 'tamper' and 'mess about' with heating controls, and the wider central heating system, their interaction with these devices may be restricted or limited. Heating controls are designed and stipulated in the Building Regulations (this is detailed in Chapter 3) with the intended purpose of allowing the end user to manage the heating system, ideally minimising the energy it consumes. However, this section demonstrates that at their most extreme, engineers' constructions of their customers may lead to quite a different outcome, with effort expended to limit any interaction at all between the customer and these devices.

8.7 Discussion: the implications of constructed customers

This concluding empirical chapter has explored the way in which users are scripted in the design and installation of central heating systems, particularly their controls. Heating engineers have previously been recognised for their role in shaping the central heating products installed in homes (Banks 2000a; Banks 2000b), and the provision of advice (Rathouse & Young 2004; DECC 2014b). However, the constructions of customers that engineers apply to these processes have not previously been identified or explored in any detail. The idea of scripting has been used to reveal these insights, providing a particularly fruitful "conceptual connection of processes of design with processes of use" (Jelsma 2003: 115). In the following section, I first discuss the insights gleaned through this theoretical approach, identifying some limitations in its application to central heating installation. Next, I outline the implications of engineers' strategies for the selection and explanation of controls for different customers. In particular, I elaborate on how the decisions made and advice provided during the installation process might shape the use of these systems.

8.7.1 Considering scripting and its limitations

The evidence presented in this chapter demonstrates that heating engineers play a significant role in selecting and explaining the heating controls installed in homes. The concept of scripting has provided a useful lens through which to think about the implications of engineers' actions, particularly, the ways in which these shape the use of central heating systems. Scripting has traditionally been critiqued for favouring designer perspectives (Oudshoorn & Pinch 2003: 16). In the case of the central heating system, the involvement of these intermediary actors in shaping the technologies installed suggests that scripting certainly does not begin and end with the designer. Instead, the scripting process continues as this device takes its place in the home. Engineers' adaptation processes, for example, using simplified explanations or setting the devices up on behalf of customers, suggest that there is a mismatch between the script written during the design and development of heating controls, and that written during their selection and installation. For example, complex digital heating controls may be accompanied by basic explanations or suggestions not to use all of their functions.

Furthermore, given that heating engineers' everyday work involves interacting with customers, it might be suggested that their strategies are based on their direct experiences of users, rather than designers' and manufacturers' idealised users (Akrich 1995). If engineers suggest controls based on their identified needs of particular users, it may be that they contribute to reconciling the idealised with the experienced user, thus overcoming some of the potential usability issues identified in Section 2.3.4. However, it is pertinent to question why engineers have to perform this reconciliation; that is, why heating controls are being developed that do not necessarily suit the needs of users. With such a mismatch, it is likely that heating controls will not be used in the way intended, or achieve the energy savings they are purported to. Additionally, whilst the customer constructions and associated installation strategies presented in this chapter are those that were most prominent in my data, they are unlikely to be the only ones that engineers apply. In particular, some engineers mentioned the fuller explanations they offered, but these cases, which may be deemed as less difficult or challenging, were not elaborated or discussed at length.

Moreover, this analysis does not extend to the end user and their appropriation of their central heating controls. Thus, whilst some of this data hints towards the way in which controls might be used by customers, it does not offer a full understanding of how these multiple, conflicting scripts play out following installation, nor does it tell us of alternative scripts that may contribute to this. As Jelsma notes:

> "An artefact constrains the user through its script, but never completely. While inscribing, the designer may have a fictive user in mind, but his/ her image of this user may be incomplete or mistaken, thereby leading to misfits between the text (script) as meant by the designer and the way users read it."
>
> (Jelsma 2003: 107)

Thus, there is the further possibility that neither the designer's nor the engineer's scripts are actually adhered to by the end user. In interpreting their heating controls, the user could recruit additional assistance, which may again influence their reading of these devices. For example, Woolgar highlights the role of peripheral texts such as manuals and guides for "helping readers to find and see the relevant features of the machine itself" (1991: 81). Thus, whilst the concept of scripting is useful for illuminating the ways in which heating engineers may shape the use of central heating controls, it does not definitively tell us what happens following installation. However, this concept has provided some useful insights into why heating controls might be used in different ways, which are detailed in the following two sections.

8.7.2 Users are scripted in the selection of central heating controls

Not only do heating engineers create specific groups of homogenised users, they use these categories to inform the types of control installed in homes and their associated explanations. For example, it was suggested that older people may be more comfortable with mechanical devices, which were familiar to engineers and customers alike, and were often regarded as the simplest option. In keeping with previous studies that have identified the exclusion of older people from digital heating controls (Caird & Roy 2008; Sauer et al. 2009; Combe et al. 2011; Combe et al. 2012; Combe et al. 2013), heating engineers sometimes reserve these more complex devices for those perceived to be more technologically competent. Furthermore, my participants sometimes noted their own limited understandings of digital heating controls, and also compared them to computers. This reflects Peffer et al.'s (2011) assertion that heating controls are increasingly borrowing buttons and conventions from the computing domain. It was, in part, this similarity that led heating engineers to suggest that those more familiar with computers, or from 'the digital age' may be more comfortable using digital heating controls. Meanwhile the smart controls that are receiving increasing amounts of interest amongst manufacturers and policy makers (as introduced in Chapter 3) are reserved for only the most 'tech savvy' of customers. However, whilst these strategies could be conducive to customers being matched with devices they can use, these are not applied in all cases. For example, where engineers always install the same device to exhibit their expertise, or select controls that blend in with existing socio-technical arrangements, as detailed in Chapters 5 and 7, respectively.

8.7.3 Engineers script through the provision of advice

It is not only the controls themselves but also any accompanying advice that might script users' subsequent interaction with them. As detailed in Chapter 3, a best practice requirement stipulated on the Commissioning Checklist is that heating engineers demonstrate "the operation of the boiler and system controls", and ensure that these are "understood by the customer" (HHIC 2014a). The different explanations revealed in this chapter demonstrate that this guidance is open to interpretation, and suggest the need to question its influence. Suggested settings include operating within a 'comfort band', but actual temperatures mentioned by engineers ranged from 18°C to 25°C, and even 30°C in one case. This differing advice may contribute to the previously identified variability in internal temperature settings in homes, discussed in Section 2.3 of my literature review. Furthermore, whilst heating engineers include particular temperatures and recommended settings in their advice, there is no doubt that they can be included amongst the intermediary actors that Shove et al. (2008) have recognised as purveyors of thermal comfort. In this role, they do not always encourage energy efficient control strategies, for example, suggesting that the system is left on constant.

Furthermore, through their provision of advice, the engineer acts as one of the 'folk channels' that Kempton (1986) previously identified for perpetuating theories of home heat. One proven strategy for minimising call backs due to limited customer understandings is to provide basic explanations of the controls, for example the suggestion to leave the system on constant and simply operate it via the thermostat. However, these brief explanations perpetuate the idea that the thermostat operates as a switch for the whole central heating system. Furthermore, they are likely to contribute to the perception amongst users that installers do not have the time to explain controls properly, as identified by Rathouse and Young (2004). These limited explanations also reinforce limited understandings, restricting the usability of these devices and users' subsequent interaction with them (Caird & Roy 2008; Rathouse & Young 2004). If customers are advised to only interact with the thermostat, it is unsurprising that they do not always recognise, or use, their other heating controls, such as programmers (Rathouse & Young 2004; Peffer et al. 2011; Revell & Stanton 2014).

Beyond advice and demonstration, engineers may take action to physically enter the heating settings themselves, or restrict the customer's interaction with the device. The latter strategy was particularly noted for older customers. Meanwhile, there was a suggestion that a daily heating schedule with the heating turning on and off twice a day might be more suited to working occupants, and some families. Applying the idea of scripted users suggests that this different advice might subsequently lead different user groups to operate their central heating in different ways. This is in keeping with Huebner et al.'s (2014) identification of different internal temperature profiles for different sociodemographic groups, in particular their recognition that two on-off settings per weekday were more present amongst higher income households (who might reflect the working occupants that heating engineers identify). Thus, it is clear that through both the selection of controls, and the provision of advice, heating engineers have a role in shaping the use of central heating systems. It is at this final stage, when the central heating system is handed over to the user, that my exploration of installation comes to a close. In the following section, I briefly bring together the different chapters presented, before proceeding to conclude this thesis.

8.7.4 Tying it all together

Within each empirical chapter, I have presented distinct aspects of the installation process that can shape the energy consumed through central heating systems. These have included insights into the culture of heating engineers, their relationships with wider supply chains, the materiality of the installation process and, finally, the way in which end users are considered in this process. All of these findings have important implications for further research, policy makers and industry representatives concerned with domestic energy consumption. In the concluding chapter that follows, I highlight the important contribution of this thesis and make suggestions for continuing work in this critical area for understanding domestic energy consumption.

9 Conclusions

9.1 The contribution of this investigation

This thesis has demonstrated a series of ways in which heating engineers, and installation practices, are likely to play a significant role in shaping the energy consumed through space heating. Prior to this investigation, the installation of domestic central heating systems had neither been subject to in-depth academic enquiry, nor received the attention of policy makers. However, the evidence presented here demonstrates that these middle actors, and processes, could be usefully engaged with in order to achieve the 80% greenhouse gas emissions reductions on 1990 levels necessary to meet the UK's climate targets. As such, they should be a priority focus for future academic scrutiny and policy discussions. This novel investigation has provided methodological and empirical contributions that are essential for furthering current debates in both domains.

Methodologically, I have demonstrated the strength of using in-depth socially-oriented methods, in particular ethnography, for revealing insights about the complexities of the built environment and how it is shaped. Applying cultural perspectives to understand the role of heating engineers provides an original contribution to studying these thus far overlooked actors. Furthermore, ethnographic approaches have not previously been used to investigate the role that any other building professionals have on energy consumption. Given their value in revealing the complexities of the built environment and the actors shaping it, as proven with this thesis, it would be incredibly fruitful for this research strategy to be applied more widely within energy and buildings research. This is especially true considering that there are still a vast number of different building professionals who, despite being involved in shaping the built environment (Janda & Killip 2010; Janda & Parag 2013), have not yet been subject to such scrutiny. Given that many professions operating in the construction industry are similarly disparate with changing work locations, it is likely that the strategies used here will be beneficial in researching such groups. For example, I have highlighted the challenges of researching a dispersed workforce, and the necessity of accessing this group through a variety of research methods (including interviews and observation) and sites (such as domestic properties and training sessions). Thus, my novel application of ethnography to heating engineers has provided valuable lessons for the conduct of such future investigations in this domain.

Empirically, I have identified four different ways in which the installation and use of central heating systems can be shaped, these include: heating engineers' learning, identity and membership as part of a community of practice; the interactions between engineers and their wider supply chains, in particular plumbers' merchants and sales representatives; the role of the central heating system and existing socio-technical arrangements in the home; and the way that engineers' constructions of their customers shape the selection and explanation of central heating controls. In particular, I have revealed the responsibilities and challenges managed on a daily basis by the actors central to this process, heating engineers. I am privileged to have been able to spend time with, and learn from, these individuals. In my experience, they take great pride in what they do and they are incredibly knowledgeable about their work. In their middle position, visiting homes on a daily basis, they are ideally positioned to participate in the sustainability agenda. The empirical insights gleaned through this investigation indicate some of the ways in which academics, policy makers and industry representatives might fruitfully engage with heating engineers to this end, and specific strategies for this are discussed in more detail throughout the remaining sections of this concluding chapter. In this, I first detail the findings from each empirical chapter and consider the relationship between the different theoretical frameworks that I have utilised throughout this thesis. Reflecting on the analytical choices made paves the way for an evaluation of the limitations of this current investigation, which are addressed in the fourth section of this chapter. Against these limitations, section five outlines a series of suggestions for future research, before recommendations for policy and industry stakeholders are outlined in section six. This chapter closes with an overall summary.

9.2 Findings

9.2.1 A community of craftsmen

The empirical section of this thesis commenced in Chapter 5 with an exploration of how heating engineers operate as part of a community of practice. In this, I revealed how the culture of this group has implications for the installation of central heating systems and the energy they consume. Through observing social interactions and having in-depth conversations with heating engineers, I have identified a number of ways in which engineers' practices are shaped by their membership within a community. In particular, I explored the way in which learning is an on-going aspect of heating engineers' work, and identified the informal and social means through which this takes place. Furthermore, engineers have a shared identity that is both obtained through, and demonstrative of, community membership. However, this is also a heterogeneous community, with members that follow different training trajectories and work in dispersed and varied contexts. Amongst this mixed community, I have demonstrated how and why different installation practices have come to emerge.

9.2.2 Supply chains and social networks

Beyond the community that exists amongst heating engineers, I also explored the relationships at play within their wider supply chains in Chapter 6. In particular, this chapter identified the social capital benefits that accrue to heating engineers, plumbers' merchants and sales representatives through both strong and weak ties to one another. This is the first study to provide any detail on the everyday interactions of these individuals, and consequently provides an essential first step in understanding their significance. Through observing these interactions I have been able to identify the existence of strong ties between merchants and engineers, these can help to ensure loyalty and repeat business for merchants whilst engineers are guaranteed a good service. Furthermore, the merchant might be considered as a trusted source of information, providing expertise and shaping the central heating products installed in homes. I have also identified sales representatives as transient actors who impart new information and provide technical expertise to heating engineers. Finally, sales representatives may foster strong ties to plumbers' merchants to gain information that can be used to shape the sales of their products.

9.2.3 Negotiating non-humans

In Chapter 7, the focus shifted away from the social actors that shape the installation process, towards the non-humans that also play an essential role in this story. Through prioritising the materiality of the installation process, this chapter identified the negotiations that take place between different humans and non-humans in the installation scene. This is the first time that the negotiation of central heating technologies as they take their position in the home has been revealed. Actor-Network Theory provided a valuable lens through which to consider these processes. Through illuminating the role of non-humans, this discussion demonstrated that new technologies and existing socio-technical networks can shape the central heating systems installed in homes. In this process, the regulations and sizing procedures stipulated in industry guidance are not always prioritised, meaning that the efficient operation of the central heating system may be overlooked. Instead, the positioning of the different system components is a process of minimising disruption; this might include fitting 'like-for-like' products, ones that will blend in with existing socio-technical networks, or devices that can be hidden in the home. Furthermore, despite having their own agency in the installation process, heating engineers may be constrained by the priorities and preferences of non-human actors.

9.2.4 Scripting end users

It is also important to acknowledge that heating engineers can apply their own priorities and preferences to the installation process, sometimes shaped by their ideas and understandings of what their customers will want. The focus of Chapter 8 was the constructions of customers that engineers apply to the selection and explanation of heating controls. Prior to this investigation, neither the extent to which heating engineers are involved in the selection of heating controls, nor the understandings and assumptions that they apply to this process had been revealed. Through spending an extended amount of time with engineers in a variety of settings, both observing their conversations with one another and speaking to them directly, I have been able to collect detailed insights into their understandings of customers. The concept of scripting, which suggests that the identity and actions of users are configured in the design and development of technologies, has been especially valuable in exploring the potential implications of engineers' constructions. In particular, engineers' ideas of different customer types, and the installation and explanation of particular control devices that correspond to these, can shape the way that customers subsequently interact with their heating controls and the energy consumed through these systems.

Through the empirical material presented, I found that heating engineers distinguished between the suitability of mechanical, digital and smart controls for different types of user. Beyond the selection of the devices, heating engineers also provide explanations to their customers, suggesting temperatures at which they will be comfortable, and schedules to match their assumed lifestyles. Furthermore, explanations of central heating controls may be overtly simplified in order to minimise potential misunderstandings. These basic explanations can result in simplified control strategies that might lead to higher than necessary energy consumption. This is particularly true of the suggestion to leave the heating on constant and operate the device from the thermostat, and to maintain heat in the fabric of the building by keeping the heating on for longer durations at lower temperatures. These brief explanations, accompanied by strategies such as setting up devices on behalf of customers, and restricting their interactions with them, are also likely to limit customers' subsequent interactions with their heating controls.

Additionally, although my analysis has necessarily focused on those aspects that emerged as most relevant for considering the energy consumed through central heating, this research has yielded a wealth of data about heating engineers and their practices. In keeping with the ethnographic approach, different aspects of the installation process have been explored using a variety of theoretical perspectives, as appropriate to the material under investigation. In the following section, I consider the choice of these theoretical perspectives and points at which they converge and diverge before proceeding to consider the limitations of this investigation.

9.3 Theoretical reflections

By applying distinct theoretical perspectives, this thesis has demonstrated the value of retaining an open mind when considering different approaches that can be used to illuminate the material under enquiry, and the strength of doing so to explore distinct aspects of a problem. It is only with this approach that this investigation has been able to identify a multitude of ways in which heating engineers, and installation practices, can shape the energy consumed through domestic central heating systems. However, although the theoretical perspectives applied in each chapter have been treated as discrete entities there are of course points at which these concepts diverge and converge. These overlaps make it important to reflect on the choices made and the borders drawn around each for the purposes of this investigation. Chapters 5 and 6 drew on the broadly sociological ideas of communities of practice and social capital, whilst Chapters 7 and 8 drew on concepts stemming from science and technology studies, in particular, Actor-Network Theory and the related concept of scripting. In the following sections, I discuss the selection of these approaches, along with their contrasts and comparisons.

9.3.1 Social capital and the community of practice

Social capital emerges from the networks of relationships in which people are embedded, thus, this could feature in both broader networks (like the supply chains that were the subject of Chapter 6), but also within a community where members share particular practices and traits (as in the engineers' community discussed in Chapter 5). This overlap sometimes leads the two concepts to be used together (for example, in Bresnen et al. 2005); however, for the purposes of this thesis, I used the two concepts separately, suggesting that amongst heating engineers a community of practice exists, whilst within their broader supply chains it is social capital at play.

Despite this, aspects of both communities of practice and social capital were apparent between heating engineers and within their broader supply chains. In particular, a clear point of overlap between these two concepts comes from the shared meanings, codes and language that these social groupings have. This is noted as a trait of a community of practice (Lave & Wenger 1991), but also acknowledged by those using social capital, for example, the 'cognitive dimension' defined by Nahapiet & Ghoshal (1998). Indeed, there is recognisable overlap in the demeanour, language and stories of heating engineers, plumbers' merchants and sales representatives. Operating within heating engineers' supply chains necessitates the ability to communicate with this group. However, for the purposes of Chapter 6, where my focus was on the ways in which the relationships between heating engineers and actors in their supply chain can shape the technologies installed, these ideas of shared language and meanings was largely implicit in the transactions taking place. Meanwhile, whilst the elements of loyalty and reciprocity that are central to the concept of social capital might exist amongst heating engineers' community, these were not strongly apparent within the data. As a group of individuals who primarily work alone it is perhaps feasible to suggest that, although these actors share similar ways of working and understandings of their role, they do not develop relationships with one another that yield the same social capital benefits as those with members of the supply chain. Thus, whilst exploring different types of relationships amongst social groups, the first two empirical chapters both applied broadly sociological theories. This focus shifted in Chapter 7, where relationships between quite different actors provided the focus.

9.3.2 Introducing non-humans to the analysis

In Chapter 7, my focus turned to applying ideas from STS to investigate the role of non-humans. Indeed, because of their relative absence from the earlier analyses, Chapter 7 sought explicitly to prioritise non-humans in the installation process using Actor-Network Theory. Arguably, with its focus on relationships and the negotiations taking place between both human and non-human actors for the formation of networks, ANT could also have been applied to understanding the networks at play amongst heating engineers and with their wider supply chains. However, I did not feel that this approach provided the tools or language necessary to interpret what was happening when heating engineers exchanged stories or met their plumbers' merchant. Instead, I found the strength of ANT for this research to be in interpreting the agency that non-humans can have in shaping the installation process, and this was the application that provided the focus of Chapter 7.

9.3.3 The utility of scripting across the installation process

These ideas were continued in Chapter 8, where the focus turned to the specific concept of scripting, which suggests that ideas of users are written into the design of technologies. Forming a key part of the ANT approach, this idea could have been applied in Chapter 7. The overlap here is that, through particular requirements being embedded into the technology, the actions of the heating engineer could be considered as being scripted. Indeed, Akrich notes that the scripting process is performed in association with the socio-technical arrangement that the device is to become a part of (Akrich 1992). In this way, scripting could be applied to both the installation process and the user (which provides the focus of Chapter 8). Despite this overlap, I found that engineers' ideas of end users and the scripting that this entailed constituted a very important aspect of the installation process that was usefully enhanced by extending this idea of scripting into processes of product selection and explanation. This is especially interesting in that ideas of scripting are often taken to begin and end with the design of a technology. Thus, although each of the theoretical concepts applied in this investigation have been treated separately, there are points at which the ideas overlap, and alternative ways in which they might have been used. However, it was through applying these ideas separately that different aspects of installation could be illuminated, with each being emphasised for its potential role in influencing domestic energy consumption. Although this strategy revealed a variety of fascinating findings, the ethnographic approach used here was necessarily limited; this is discussed in the following section.

9.4 Limitations

The qualitative, highly detailed approach used for this investigation has delivered a wealth of information that could not have been gleaned through other means. However, the application of this strategy is accompanied by restrictions in the sources of data available and the types of data that could be collected. With regard to accessing data, a snowball sampling strategy was used. Whilst this was essential for gaining access to this otherwise insular community (as discussed in Chapter 4), the routes that I used to access participants for this research have limited my observations of this group. For example, I established links with individuals via recommendation from others, or through attending manufacturer training sessions. In this way, my sample is made up of relatively conscientious individuals, who are highly regarded and actively involved in the industry. Whilst this has influenced all of the data collected, this is a particularly important limitation in relation to Chapter 5, which focuses on the informal and personal learning that heating engineers undertake. It is feasible that the more attentive individuals taking part in this investigation were some of the most active in maintaining and updating their knowledge of the changing requirements of their work.

9.4.1 The limitations of in-depth observations and interviews

Further, although the interviews and observations carried out for this investigation were fruitful in yielding detailed information, they were necessarily limited in number. This means that some aspects of the data collected were restricted to only a handful of instances. This is particularly the case in relation to Chapter 6's discussion of supply chains. The role of the supply chain in shaping the central heating products installed in homes is something that I had not considered before entering the field. Despite this, I soon realised that relations within supply chains were so significant that they could not be ignored. It was through ethnographic observations that I was able to follow the content of conversations and see these relations as they played out. However, whilst Chapter 6 revealed valuable, and never previously uncovered insights into these relations, my time spent within the supply chain was limited, and only included visits to a small number of venues. Thus, whilst I have indicated the reach of these actors in activities such as the sizing of central heating systems, I do not know how widespread these practices are.

Through enabling me to be situated alongside interactions between individuals and installation processes as they were performed, ethnography has been a particularly valuable approach for capturing detailed insights into engineers' practices. Despite observation being a particularly fruitful means of documenting what takes place, my accounts are limited to only those aspects of installation and individuals that I was afforded access to. For example, the accounts of negotiations between non-humans that provide the focus of Chapter 7 are limited to only some aspects of the installation process. As detailed in Chapter 3, there are multiple stages to a central heating installation, taking place over several days, often at short notice, and involving a variety of actors. It is because of this complexity that my data does not include a single installation from start to completion. Instead, I was afforded shorter insights into several different installations. Furthermore, the data presented in this chapter was largely from central heating surveys and installations taking place with contracting organisations, usually in social housing. These scenarios proved to be more accessible because the work was scheduled ahead of time, but are not necessarily representative of all central heating installations taking place.

9.4.2 Missing actors

Similarly, plumbers' merchants and sales representatives provide the focus of Chapter 6. It is unlikely that these are the only influential actors in engineers' supply chains; however, it is these actors that I saw and interacted with during my observations. Another key actor that is missing from this exploration is the user. This limitation is particularly relevant to Chapter 8. Whilst the evidence in this chapter suggests that heating engineers have a significant role in shaping central heating use, whether end users actually adopt the practices assumed of them in the selection and explanation of heating controls remains to be seen. Similarly, in Chapter 7, the negotiations taking place during installation are primarily focused on the priorities of non-humans and the installer. In some cases, the priorities and preferences of the end user may also play a significant role in shaping what is installed in homes. However, this was not captured by the observation and interview strategies applied here, which followed the installer. However, by applying this focus, the findings of this investigation provide valuable insights into our existing understandings of the role that heating engineers, and the installation process, can play in shaping the energy consumed through central heating systems. These findings also reveal a series of avenues for further academic enquiry, and suggestions for industry and policy stakeholders that are now addressed in turn.

9.5 Suggestions for further research

My suggestions for further research are related to the specific findings of each empirical chapter, but fall into three broad categories. The first set of suggestions are concerned with increasing the depth and breadth of our understandings of some of the phenomena revealed in this study. The second series of suggestions considers how other actors might be included in future research. This includes those interacting with heating engineers as part of the heating industry, but also a broader range of intermediaries operating in the built environment more widely. The final set of recommendations are explicitly concerned with heating controls, which, as the main interface for users to interact with the heating system, are a vital area for future investigation.

9.5.1 Developing further understandings of central heating installation

Firstly, there are several findings from the current investigation that warrant the need for more focused future research projects. Relating to the findings of Chapter 5, it is important to further investigate the diversity of those operating within heating engineers' community. For example, my current investigation has not captured the practices of the so-called 'cowboys' who operate under the radar of this community's formalised membership requirements. However, my analysis has shown that heating engineers have strong views on these individuals, positioning themselves in contrast to 'cowboys' who perform poor installation and have a negative impact on the community. Thus, it is essential to understand these individuals in more detail and how the community might be better enabled to ensure that 'cowboys' are performing within its remit. Another source of variation that I identified is the learning trajectory that new entrants are exposed to. Whilst heating engineers talked about the enduring influence of their initial learning, I have not been able to formally investigate how particular ways of working become indoctrinated. Thus, it would be beneficial to investigate how the existing processes and signifiers of community membership could be made more inclusive and consistently aligned with the delivery of energy efficient central heating systems.

Extending beyond the community, Chapter 6 demonstrated the significance of the relationships within the supply chains that heating engineers are a part of. However, these relationships are likely to vary according to the type of work the engineer performs, and the nature of the supply chain actors. For example, a self-employed engineer might prioritise different relationships to one working for an organisation, or specialising in social housing contracts, whilst the staff in a branch of a national chain of plumbers' merchants might maintain quite different relationships to those of an independent merchant. More comprehensive observational studies amongst supply chains are required for developing a deeper understanding of additional variations in the roles that different actors play and the nuances of these relationships.

In keeping with the need to capture the variation at play in the heating industry, a more concerted qualitative investigation of installations taking place in private properties would be beneficial. Such a study could help to reveal important differences between those and the processes and procedures taking place in social housing, which provided the focus of much of the shadowing that yielded data for this study. In particular, it would be valuable to establish how the priorities and preferences of different actors play out in the private setting. It is likely that the role of occupants, technologies, regulations and guidelines are likely to vary significantly in these two scenarios. Understandings of this variation would be useful in developing targeted policies that seek to ensure that more energy efficient technologies are installed in homes. For example, the socio-technical arrangements of homeowners may be more or less flexible than those of social housing tenants. If this is the case, it may be worthwhile developing different strategies to ensure that efficient central heating systems are installed in these different properties.

9.5.2 Including different actors in future investigations

Secondly, this current investigation is limited in the actors that have been included. The scope of our understanding of the installation process could be expanded by considering more of the actors in heating engineers' supply chains, but also the end users of central heating systems. For example, performing a more formal Social Network Analysis would help to identify potentially overlooked, but important actors and relationships within this highly dispersed industry. A starting point would be to further map the structure of these networks, which would help to reveal their shape, but also the significance of different actors for different heating engineers (for examples of sampling techniques for a more formal Social Network Analysis see Lin 1999). For example, some of my participants mentioned turning to the Internet, or family members working in the industry, if they had a query, whilst others might refer directly to manufacturers. Although these were not as prominent as the day-to-day interactions with merchants and sales representatives discussed in my data analysis, they do demonstrate that not everyone valued or maintained these supply chain relationships in the same way. This would be a helpful means to further define these networks within the heating industry and how they operate to shape the installation of, and energy consumed through, central heating systems.

Moreover, it is essential to investigate the extent to which engineers' constructions shape the end use of central heating systems. This is a vital piece of the puzzle in understanding and addressing the energy consumed through space heating. Empirically, this would require an extension of my current strategy, to capture not only the installation and handover of heating controls (which provided the focus of Chapter 8), but also customers' perspectives of this and the way in which a system is used after this process. Here, it would be interesting to consider the roles that I have suggested of engineers, particularly as purveyors of thermal comfort and channels of folk knowledge. For example, do end users retain the advice and understandings that engineers provide during the installation process, and incorporate these into their space heating practices? Furthermore, although significant, heating engineers are unlikely to be the only intermediaries scripting the use of central heating systems. Indeed, whilst suggestions have been made for where users' understandings and ideas of heat originate, for example, with relatives, friends, estate agents and landlords, there has not yet been a concerted effort to understand the role of these different actors. Additionally, the role of designers and manufacturers in scripting central heating technologies, and their subsequent use, has not previously been considered. Consequently, further work to investigate other intermediaries who may shape the use of central heating systems would be valuable for a fuller understanding of how the practices surrounding these systems are shaped.

Whilst considering other actors, it would be valuable to explore other building professionals through a communities of practice frame, like that applied in Chapter 5. Communities of practice have currently been identified amongst a narrow group of building professionals, primarily, those involved in construction (for example, Gherardi & Nicolini 2002; Tutt et al. 2013). However, this has not been extended to consider the huge variety of actors operating in the built environment, in particular, those involved in the design, dissemination and installation of domestic technologies that could have a role in shaping domestic energy consumption. My analysis has demonstrated that, amongst heating engineers the presence of a community and the identities and practices inherent in it can play a role in influencing the way in which heating systems are installed, and the energy they subsequently consume. Thus, it would be pertinent to question where else these communities exist amongst building professions, but also how their identities and practices might be shaping domestic energy consumption. In particular, it would be germane to investigate the potential emergence of communities of practice amongst newly developing professions, for example those acting as low carbon advisors or installing low carbon technologies. With information about whether, and how, these professions operate within communities of practice we could be better able to influence the transition towards a low carbon built environment.

9.5.3 Developing understandings of heating controls

The final set of recommendations for further investigation are explicitly concerned with heating controls. These devices are heralded for their potential to reduce the energy consumed through central heating systems, and yet their installation does not always guarantee savings. This study has revealed two important ways for heating controls to be further investigated. The first stems from Chapter 7, which revealed how heating controls can come to be hidden in the home, whilst the second relates to Chapter 8, where I investigated how heating engineers select and explain heating controls.

Firstly, finding that heating controls may be hidden to minimise disruption goes some way to explaining why heating controls may not be used in the ways anticipated, or deliver the energy savings expected. The practice of hiding is particularly significant for the installation of the smart heating controls that are currently being promoted for their usability and energy saving potential. These devices often have complex user interfaces, and may rely on occupancy sensing technologies, for example. Thus, hiding them could have an especially detrimental impact on their functioning and their capacity to deliver the energy savings promised. However, whilst my qualitative evidence provides detail on why heating controls are hidden, it does not reveal the extent of this practice. Given the potentially significant implications of this, it would be valuable to conduct work to quantify how frequently heating controls come to be hidden in the home. This evidence base is essential for future strategies to encourage the appropriate installation and subsequent effective use of central heating controls.

Secondly, in their selection of controls and provision of information, heating engineers rely on constructions of particular user types, for example, older people and those that are more technologically aware. It is against these typologies that they tailor central heating control solutions. However, whilst I suggest that these user types are based on engineers' everyday interactions with their customers, I do not know the extent to which they reflect reality. For example, is it that older people actually do struggle to use digital heating controls, or is it that engineers assume this to be the case? Evidence from usability studies suggests that older people are excluded from the use of digital heating controls (Combe et al. 2011; Combe et al. 2012). If the distinctions that engineers have identified do exist amongst the population, it would be fruitful to explore what these different groups want from their central heating controls. This would also build on the work of Rubens and Knowles (2013), who established different types of central heating user, but did not relate these to sociodemographic factors. The different customer types that have been identified, and the strategies that heating engineers use to manage these, suggest that there is not a one-size-fits-all solution for central heating controls. Thus, a study that establishes a greater understanding of different user types is essential for developing control solutions that ensure that different sections of the population can use their central heating in an efficient way. Furthermore, given heating engineers' central role in the selection and explanation of heating controls, it would be valuable to communicate this information back to them in order to support the better alignment of customers and controls. As with many of these recommendations, achieving outcomes from this research that support the installation and energy efficient operation of central heating systems will rely on the involvement of policy makers and industry. Indeed, there are a series of suggestions stemming from the current investigation that policy makers and industry representatives might effectively respond to. Suggestions for these stakeholders provide the focus of the following section.

9.6 Suggestions for policy and industry

This research has been conducted amidst changing policy and industry strategies to achieve reductions in the energy consumed through domestic space heating. In particular, this includes DECC's Heat Strategy, which is detailed in *The Future of Heating: Meeting the challenge* (2013). This strategy includes efforts to influence the users of domestic heating, along with changes in the technologies that provide home heat and the recruitment of both installers and supply chains to the low carbon agenda (DECC 2013). These efforts to reduce the energy consumed through heating also tie into the Government's fuel poverty strategy, which aims to reduce energy bills and increase comfort for those living in the coldest low income homes (HM Government 2015), and the smart-meter roll-out, aims to have smart meters in every home by 2020 (DECC 2014d). These ambitious aims are admirable; however, the results of this research suggest that there are some specific areas that may require further thought and perhaps alternative approaches to those considered so far. In the following, I detail a series of suggestions for policy makers and industry, these fall into three broad themes. First, I consider the adoption of alternative technologies; secondly, I make suggestions regarding the use of existing guidelines and industry structures to shape installation practices; and thirdly, I look at how the role of heating engineers might be better aligned with sustainability agendas. Throughout, I consider the implications of these suggestions for specific policy strategies.

9.6.1 The adoption of alternative technologies

My first recommendation is especially pertinent in relation to current proposals to install alternative space heating technologies, for example, heat pumps and biomass systems. The socio-technical aspect of this analysis, in particular the application of Actor-Network Theory in Chapter 7, demonstrated that well-established existing arrangements are difficult to negotiate. The location of pipework and the desire not to disrupt existing décor could have significant implications for the uptake of low carbon technologies which can require a very different infrastructure to a gas central heating system. For example, DECC's heat strategy calls for alternative sources of heat. These include heat pumps, which can require larger heat emitters for efficient operation, and alternative sources of hot water, such as solar panels, which elicit the need to replace water tanks (many of which have been removed with the addition of a combination boiler). Thus, in designing and promoting alternative technologies, it is essential to consider how they might fit into existing properties and the spaces available in established socio-technical arrangements. In developing policy strategies around the projected uptake of such devices, it would be pragmatic to consider the limitations that are in place for them actually making their way into homes, and who and what may need to be recruited in order to ensure their success.

Similarly, these socio-technical insights suggest the need for caution in pursuing the current industry and policy focus on promoting smart heating controls in the home. Central heating systems are black boxed, not only through the alignment and enrolment of multiple components into a single unit, but also through additional efforts to make the system invisible. One particularly important component that can be subject to this hiding is central heating controls. If newer smart heating controls are to be hidden away and ignored like their standard counterparts, their potential efficacy in assisting end users to reduce their energy consumption must be considered. The significant attempts that are made to hide central heating systems, and controls, demonstrate that these products may not be desirable, and raises the question of whether a 'fit and forget' strategy is the most appropriate for this active member of the home that accounts for the majority of energy consumed. Thus, it would be valuable for manufacturers to consider how to engage with installers in thinking about how upcoming control products might be positioned and talked about, but also to ensure that they are desirable enough to be recognised and used once installed in the home.

Further, in thinking about and developing alternative technologies to install in domestic properties, it may be constructive to engage heating engineers. These actors are positioned at the 'coal face' of energy consuming activities. As intermediaries who enter homes on a daily basis they can play a role in the construction of domestic energy consuming practices. Furthermore, I have noted how engineers have come to develop particular constructions of their customers that they use in determining the selection and installation of central heating technologies. Their frequent interaction with customers suggests that their constructions are likely to be derived from their lived experiences with end users, as opposed to the representations developed by manufacturers or ideas circulating in the media that might not be based on actual interactions. Thus, in their middle position, heating engineers could play a valuable role in the design and development of heating controls. Through sharing their customer experiences, heating engineers could potentially contribute to bridging any current disparity between the understandings of end users that designers and developers apply to heating controls, and those that heating engineers have experienced. In this way, heating engineers could be recruited for helping to ensure heating controls are designed in such a way to suit the needs of different end users.

9.6.2 The use of existing industry strategies

Beyond considering the technologies being installed, and how they are fitted, it is important to think about who performs the installation. In Chapter 5, I explored how electricians operate within the heating engineers' community, in particular, performing the installation of controls. The different individuals involved at this stage of installation emerge as a result of the complexity of these devices, which encompass both electrical and mechanical features, but also the way in which this process is addressed in the guidance provided by the heating industry. The installation of heating controls is explicitly written out of the Gas Safety Installation and Use Regulations 1998 (GSIUR), meaning that this process can be performed by those that are not required to demonstrate their competence as community members. Thus, both heating engineers and electricians can legitimately perform this task. However, within this no man's land, this is not always completed in a way that encourages the efficient operation of central heating controls. Consequently, it is essential that policy and industry stakeholders seek to harness the tools of this community in order to better ensure the appropriate installation of these devices. For example, the GSIUR could be modified to incorporate the installation of controls, thus, clearly assigning this task to a qualified member of the heating engineers' community. Alternatively, it may be fruitful to ensure that, if electricians are operating in this community, they are exposed to the same guidance, communication and informal interactions that members experience. Through these means, the installation of heating controls may be made more consistent. More broadly, exactly who is performing the installation of different technologies in homes is an important consideration, particularly amidst a shift towards technologies that encompass a range of different domestic energy networks. This is especially true of smart meters, which are electronic devices that can be connected to both gas and electricity networks in the home. In implementing the smart meter roll-out, it may be important to consider whether these are the domain of heating engineers, electricians, or other actors, for example.

Further, although the installation of controls can contribute to reductions in the energy consumed through central heating systems, this is not guaranteed. The requirement to install controls is currently stipulated in the Building Regulations;

however, in order to actually achieve desired savings, I recommend that these requirements are supplemented with robust guidelines for how these devices are to be set up and explained. As detailed in Chapter 3, according to the Commissioning Checklist, designed to guarantee installation standards, heating engineers are required to "demonstrate the operation of the boiler and system controls", and ensure that they are "understood by the customer" (HHIC 2014a). However, the data presented in Chapter 8 suggests that, whilst engineers may sometimes detail these devices to their customers, they can also provide limited explanations or set up devices on their customers' behalf. It is clear that, amidst the variety of strategies employed by heating engineers in the installation and explanation of heating controls, this guidance is open to interpretation. Consequently, a recommendation to industry is to re-visit these guidelines, scrutinising what customer understandings are desired and whether engineers' current strategies are sufficient to achieve these. Furthermore, whilst in the longer term, DECC's heat strategy proposes that gas central heating systems are to be phased out, in the short to medium term they highlight the importance of promoting the more efficient use of gas central heating (DECC, 2015). However, as it is currently worded, the Commissioning Checklist does not specify that the controls should be explained in a way that promotes their energy efficient operation. Given the potential of these devices to reduce the energy consumed through central heating systems, it could be pertinent for both industry and policy makers to position the engineers' advisory role towards energy efficiency in these guidelines. Indeed, the findings of this research suggest that there are several ways that heating engineers might be better engaged in energy efficiency strategies. These are discussed in the following section.

9.6.3 Engaging heating engineers with sustainability agendas

In Chapter 5, I explored the existence of a community of practice amongst heating engineers. Of particular importance for energy efficiency considerations is the way in which, as members of this community, heating engineers present themselves to outsiders. I found that engineers' maintenance of an expert identity can restrict the products installed in homes to those that they are most familiar with. This conservative practice may act as a “stumbling block” (Banks 2000a: 8.8) to heating engineers’ uptake of energy efficient technologies. Meanwhile, heating engineers’ need to ‘talk-the-talk’ in order to demonstrate their expertise can result in brief discussions with customers about the products fitted in their homes. However, given that these individuals enter properties on a daily basis, selecting products and interacting with building occupants, they have the potential to act as purveyors of energy efficiency. This role could prove particularly relevant for strategies to alleviate fuel poverty through encouraging the more efficient use of home heating. Indeed, the potential role of non-health professionals, including plumbers and heating engineers, in recognising and alerting authorities to those living in fuel poverty was recently highlighted by the National Institute for Health and Care Excellence (Nice 2015). Thus, policy makers and industry stakeholders could work with the community in order to shift this identity towards more sustainable means. In particular, they could use established means of community formation and maintenance, for example the use of industry publications and stories, in order to foster the identity of energy efficient product specialists and advisors amongst heating engineers. Engaging with the community through these informal means is a quite distinct, but potentially complementary, strategy to those currently used to influence the practices of heating engineers, for example the updating of Building Regulations and the provision of training (which are currently the predominant approaches considered in DECC’s Heat Strategy).

Indeed, in considering different approaches to engage heating engineers in this energy efficiency agenda, it could also be effective to engage those within heating engineers’ supply chains. In agreement with Owen et al. who highlight that “the technology supply chain might be more amenable to policy influence” (2014: 178), I would suggest that policy makers turn their attention to supply chains, and the potential role of the actors in these. In particular, they could make use of the strong ties that heating engineers have with plumbers’ merchants and sales representatives, as demonstrated in Chapter 6, in efforts to shape engineer practices and reduce the energy consumed through space heating. For example, my investigation has revealed that the plumbers’ merchant can be a trusted source of information and expertise, whilst I also demonstrated that sales representatives can disseminate useful information during their visits to these sites. Thus, these actors are well positioned to encourage the sale of energy efficient products and provide energy efficiency advice that engineers might then pass to their customers. Indeed, the role of both plumbers' merchants and the breakfast mornings they host have been identified for their capacity to deliver water efficiency messages to plumbers (Bowden et al. 2012). Although this hasn't previously been considered for the heating industry, my ethnographic investigation suggests that this could be a similarly effective strategy to influence the installation practices of heating engineers.

Furthermore, the presence and function of social capital as part of relationships could potentially be harnessed within other supply chains that play a role in shaping the energy consumed in the buildings. This is particularly pertinent given the significance of supply chains in decarbonising the built environment. For example, the adoption of low carbon heating technologies is reliant on installers, but also a network of suppliers. Whilst some of these actors will be new to the industry, many will be part of existing supply chains which may exhibit social capital in comparable ways to the heating industry. With my data, I have demonstrated that the expertise and preferences of those in supply chains can be influential in shaping the technologies installed in buildings. Thus, the role that supply chains, and the social capital in them, might have in shaping the success of these schemes cannot be ignored, and as such, they should be a priority consideration for future policy making.

With this final suggestion to be aware of, and utilise, the knowledge and understandings of these important actors, I come to the end of detailing the findings and recommendations from this investigation. In the following section, I close this thesis with a brief summary.

9.7 A final word

In the introduction to this thesis, I laid out two overarching aims. The first was to explore the role of central heating installers, and installation practices, in shaping the energy consumed through domestic central heating systems. The second was to demonstrate the power and relevance of socio-cultural research methods within the energy and buildings field that has traditionally been defined and approached using more technical strategies and individualistic models of end users.

Through applying an ethnographic approach to explore this previously overlooked phenomenon I have identified a series of distinct ways in which the installation process might shape the energy consumed through space heating. It was only through remaining open to topics that emerged throughout my time in the field, and the variety of theoretical concepts that could help to illuminate these, that I have identified a number of different ways in which heating engineers and installation processes are significant. With this approach, I have been able to make a series of distinct recommendations for how industry stakeholders and policy makers might better account for, and influence, the installation of central heating systems in future. Furthermore, I have outlined a series of vital avenues of enquiry if we are to develop our understandings of the ways in which the energy consumed through central heating is shaped, and subsequently hope to influence this. Thus, this exploration has demonstrated the significance of middle actors and processes in shaping domestic energy consumption. The wealth of findings presented in this thesis demonstrates that the application of cultural approaches is paramount for revealing and understanding the complexity of the built environment and the roles of the different actors shaping it.

It is against these findings that I conclude that the energy consumed in domestic buildings is not just a story of technologies and end users, but it is one constructed by an array of actors and practices extending far beyond the home. Following the precedent set by this thesis, it is essential that we continue to use and develop the appropriate research tools for understanding this complexity if we are to make significant inroads in reducing the energy consumed in the built environment.

10 References

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11 Appendices

Appendix I Condensing boiler operation

The source of heat in a boiler is the ignition of incoming gas to trigger the exothermic combustion of methane in oxygen. This process takes place at the burner head, and produces a series of flue gases and heat, which is transferred to incoming water ('flow' water) at the 'first' heat exchanger. Meanwhile, the gaseous combustion products, including water vapour, pass through a 'second' heat exchanger, which has cooler 'return' water (that returning into the boiler after passing through the radiator circuit) flowing through it. When the hot flue gases hit the cool surface created by the return water, water vapour that is contained in them condenses, emitting latent heat to the secondary heat exchanger and subsequently to the return water flowing into the boiler. The condensed water vapour is collected in a condensate trap, and drained via a discharge pipe. Passing the flue gases through a second heat exchanger means that any heat energy that would have previously been emitted as waste is harnessed, thus maximising the efficiency of the boiler. Gaseous combustion products remaining after passing through the secondary heat exchanger are discharged via the flue.

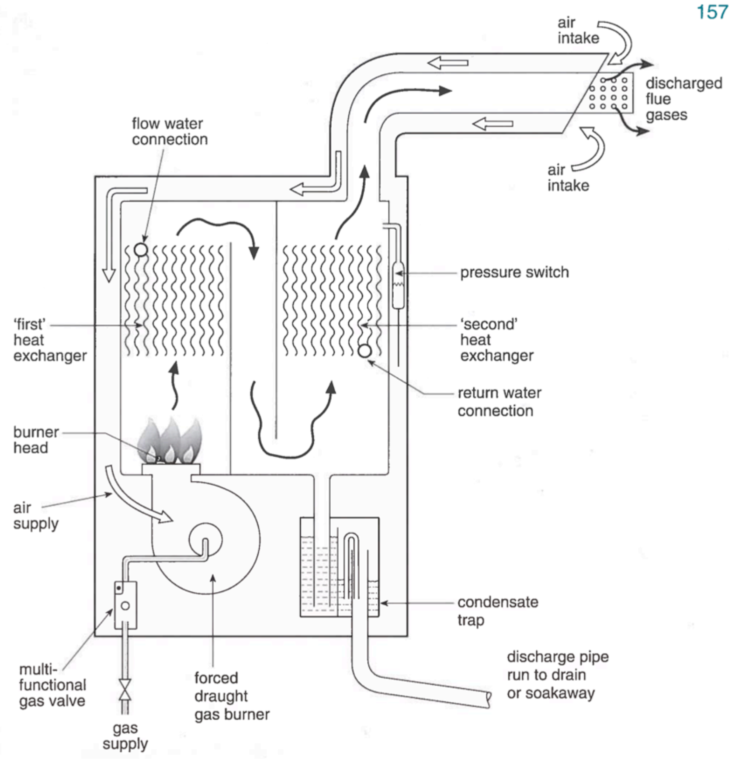


Figure 11.1 A condensing boiler, source: (Treloar 2006: 157).

Appendix II Central heating system design

Calculating heat load

BS EN 12831: 2003 outlines a standard for the calculation of the total design heat load for a heated space. This calculation assumes steady state conditions with uniform temperature distribution in the property. The premise here is that, to achieve a particular temperature within a property, the heat output of the system must equal the property's heat loss through the building fabric. Thus, to calculate the required system output (boiler size), the engineer must calculate the property's heat loss. A full calculation method is provided, however, for the purposes of understanding what the sizing process involves, I refer only to the simplified calculation method (for comprehensive detail, see BSi 2013c).

The total design heat loss for a heated space (i), Φ_i, is calculated as follows:

$$\Phi_i = (\Phi_{T,i} + \Phi_{v,i}) \cdot f_{\Delta\theta,i} \qquad [W]$$

$\Phi_{T,i}$ = design transmission heat loss for heated space (i) in Watts (W);

$\Phi_{v,i}$ = design ventilation heat loss for heated space (i) in Watts (W);

$f_{\Delta\theta,i}$ = temperature correction factor taking into account the additional heat loss of rooms heated at a higher temperature than the adjacent heated rooms, e.g. bathroom heated at 24°C.

(BSi:2013c: 32)

Design heat loss is a combination of transmission and ventilation heat losses through the building fabric. Transmission heat losses are those lost via thermal conduction through the building envelope to the exterior, the ground (through the floor) and to adjacent buildings (through party walls, i.e. those adjoining two properties). They are calculated by taking the area (m^2) of a building element and multiplying by the U-value (thermal transmittance, $W/m^2 \cdot K$) of that element. Because of the varying thermal transmittance of different building elements (an external wall is very different to a party wall, for example), all elements should be treated separately, and summed, as outlined below.

The design transmission heat loss, $\Phi_{T,i}$, for a heated space (i) is calculated as follows:

$$\Phi_{T,i} = \Sigma_k f_k \cdot A_k \cdot U_k \cdot (\theta_{int,j} - \theta_e) \quad [W]$$

Where:

f_k = temperature correction factor for building element (k), taking into account the difference between the temperature of the appropriate case considered and the external design temperature;

A_k = area of building element (k) in square metres (m^2);

U_k = thermal transmittance of building element (k) in Watts per square metres per Kelvin ($W/m^2 \cdot K$)

$\theta_{int,j}$ = internal design temperature of heated space (i) in degrees Celsius (°C);

θ_e = external design temperature in degrees Celsius (°C)

(BSi:2013c: 32)

The second element of the heat loss calculation is the ventilation heat loss, that is, heat lost through ventilation or infiltration through the building envelope. This is calculated by multiplying the air change rate by the volume of the heated space and a constant, 0.34 (the product of the density of air multiplied by its specific heat capacity).

The design ventilation heat loss $\Phi_{v,i}$, for a heated space (I) is calculated as follows:

$$\Phi_{v,i} = 0.34 \cdot V_{min,j} \cdot (\theta_{int,i} - \theta_e)$$

$V_{min,j}$ = minimum air flow rate of heated space (i) required for hygienic reasons, in cubic metres per hour (m^3/h), is determined according to:

$$V_{min,j} = n_{min} \cdot v_i$$

where:

n_{min} = minimum external air exchange rate per hour (h^{-1});

V_i = volume of heated space (i) in cubic metres (m^3), calculated on the basis of internal dimensions.

(BSi:2013c: 33)

Thus, the parameters fed into heat loss calculations are: the dimensions of the building elements (walls, floors etc), the U-values of these elements, the difference between internal and external design temperature and the volume of the space. There are standard U-values available for different building elements, for example those listed in the EST Domestic heating sizing method (2010) and CIBSE Domestic heating design guide (2013). Heat losses are calculated on a room-by-room basis, and the heat output required for each room is used to determine the size of radiator required (CIBSE 2013). The selection of radiators is discussed more in the following section. All rooms are then summed to calculate the heat loss for the whole property, and this, along with the power required to cater for the hot water requirements, is used to determine the boiler output.

Types of radiator and operation

The most common type of heat emitters, panel radiators, have a series of channels that heated water passes through. This large heated surface area then creates a convection current in the room. Convection is a process whereby heat is transferred to the air surrounding the radiator. This warm air rises, displacing cooler air which circulates to the radiator where it is, in turn, heated. Additional panels and fins can be used to increase the surface area of the radiator, and help convection currents to flow, thus increasing the heat output. There are several types of panel radiator, depicted in Figure 11.2.

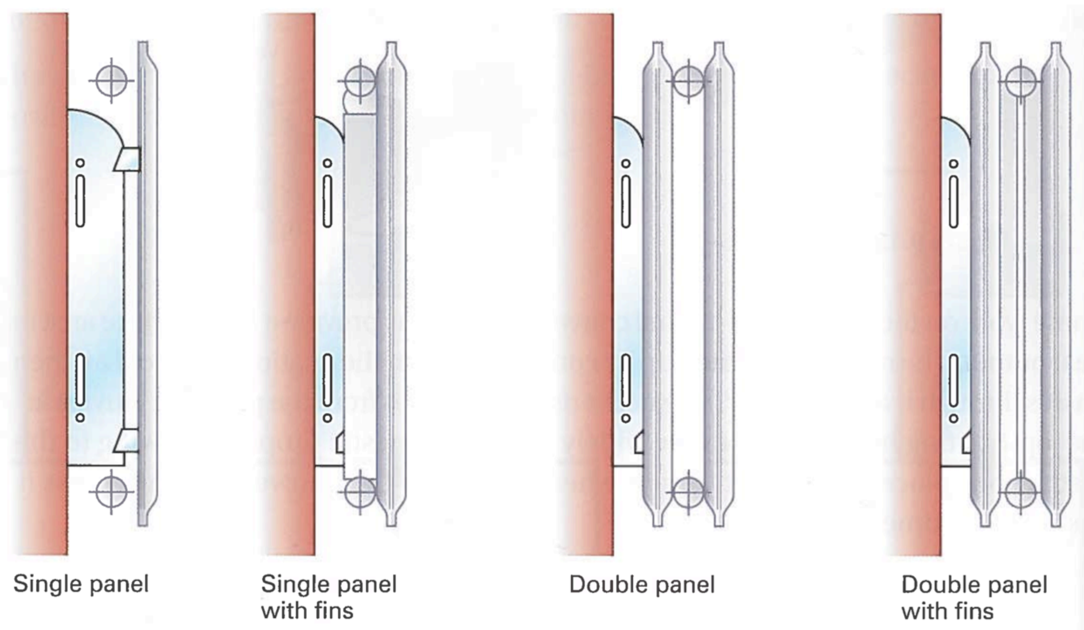


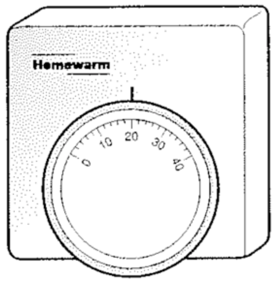
Figure 11.2 Types of panel radiator, these increase in output with the addition of panels and fins from left to right. Source (JTL 2008: 280).

Appendix III Controls

The following details the different types of heating control required for compliance with the Building Regulations, as introduced in Section 3.2. The images are sourced from (Treloar 2006: 147), apart from the TRV, which is from (BES 2015).

Room thermostat

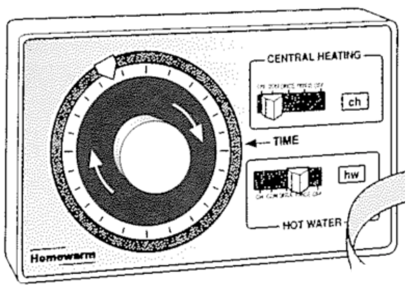
This device measures the air temperature within the room where it is positioned and communicates with the boiler, activating it when there is a demand for heat (that is, when the room temperature drops below that indicated by the set point on the device) (JTL 2008). Traditional mechanical devices use the expansion and contraction of a bimetallic strip to operate a switch (EST 2008). More modern devices tend to use electronic interfaces, measuring and reacting to temperature more accurately.



Room thermostat

Programmer

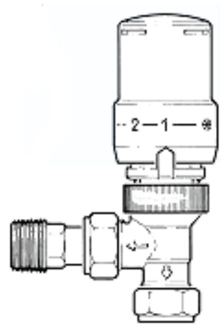
This device uses a time clock that allows for time setting to automatically switch on the heating and hot water independently. A programmable room thermostat combines the functionality of a room thermostat to provide time and temperature control in a single device. It allows for different temperatures at different times of the day and on different days of the week.



Basic programmer

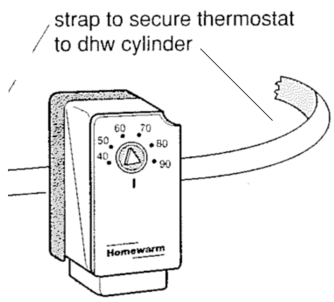
Thermostatic Radiator Valve (TRV)

These are positioned on each radiator (except in a room where there is a room thermostat – the 'reference room') and they restrict the flow of water to the radiator depending on the air temperature of the room. In this way they manage the temperature in individual rooms (whilst the room thermostat manages the overall temperature and operation of the system).



Cylinder thermostat

This device is attached to the side of a hot water cylinder, it is used in conjunction with a motorised valve to provide close control of hot water temperature and boiler interlock (EST 2008). When the water in the cylinder reaches a pre-set temperature, the cylinder thermostat signals for the hot water circuit to be deactivated. This is only necessary for a system boiler which uses a stored hot water tank.

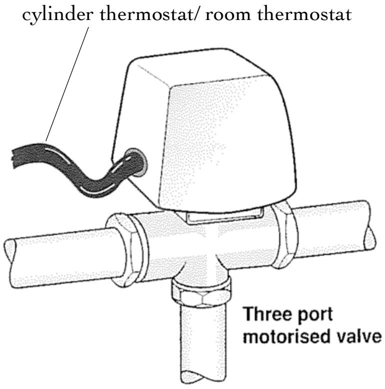


Cylinder thermostat

Motorised zone valve

These valves manage the flow of water through the system, directing it to the heating and/or hotwater circuit as it is demanded. The valves are electrically operated according to the switching of the room thermostat, programmer and cylinder thermostat.

Electrical connection to programmer/ cylinder thermostat/ room thermostat



Boiler interlock

Rather than being a control per se, boiler interlock is a wiring arrangement that prevents the boiler from firing, and turns the pump off, when there is no demand for heat or hot water (EST 2008: 24). The essential electrical components to achieve boiler interlock are a programmer, thermostat and zone valve. These are wired in such a way that ensures that the programmer and room thermostat 'speak to' a motorised zone valve, which changes position depending on whether there is a demand for heat. If there is no demand, the zone valve will sit in the 'off' position, ensuring that the boiler is not cycling.

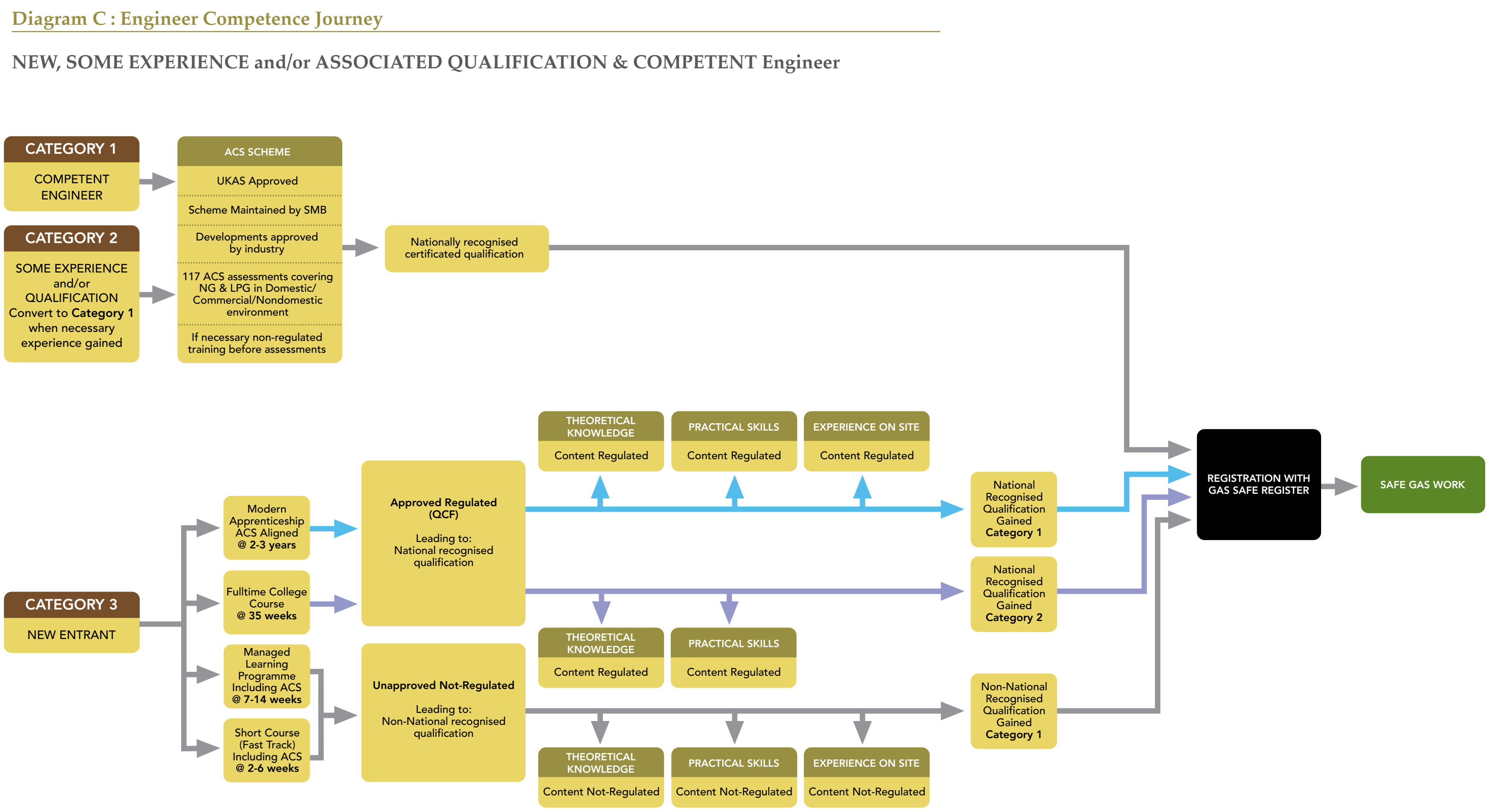
Zoning

Zoning is the provision of multiple space heating zones, for example, being able to heat the upstairs rooms of a property independently of those downstairs. The requirement for zoning stipulates that:

> "a. Dwellings with a total floor area > 150 m^2 should have at least two space heating zones, each with an independently controlled heating circuit.
>
> b. Dwellings with a total floor area ≤150 m^2 may have a single space heating zone."
>
> (DCLG 2013: 18)

An 'independently controlled heating circuit' is one which has a number of radiators controlled by its own zone valve and room thermostat (or programmable room thermostat). Thus, in a zoned property, such as the upstairs/ downstairs configuration detailed above, there should be at least two room thermostats, one controlling the upstairs zone and another for the downstairs zone.

Appendix IV Engineer competence journey, source (GSR 2011: 34)



Benchmark Commissioning and Servicing Section

It is a requirement that the boiler is installed and commissioned to the manufacturers instructions and the data fields on the commissioning checklist completed in full.

To instigate the boiler guarantee the boiler needs to be registered with the manufacturer within one month of the installation.

To maintain the boiler guarantee it is essential that the boiler is serviced annually by a Gas Safe registered engineer who has been trained on the boiler installed. The service details should be recorded on the Benchmark Service Interval Record and left with the householder.

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GAS BOILER SYSTEM COMMISSIONING CHECKLIST

This Commissioning Checklist is to be completed in full by the competent person who commissioned the boiler as a means of demonstrating compliance with the appropriate Building Regulations and then handed to the customer to keep for future reference.

Failure to install and commission according to the manufacturer's instructions and complete this Benchmark Commissioning Checklist will invalidate the warranty. This does not affect the customer's statutory rights.

Customer name:	Telephone number:
Address:	
Boiler make and model:	
Boiler serial number:	
Commissioned by (PRINT NAME):	Gas Safe register number:
Company name:	Telephone number:
Company address:	
	Commissioning date:
To be completed by the customer on receipt of a Building Regulations Compliance Certificate*	
Building Regulations Notification Number (if applicable):	

CONTROLS (tick the appropriate boxes)				
Time and temperature control to heating	Room thermostat and programmer/timer		Programmable room thermostat	
	Load/weather compensation		Optimum start control	
Time and temperature control to hot water	Cylinder thermostat and programmer/timer		Combination Boiler	
Heating zone valves	Fitted		Not required	
Hot water zone valves	Fitted		Not required	
Thermostatic radiator valves	Fitted		Not required	
Automatic bypass to system	Fitted		Not required	
Boiler interlock			Provided	

ALL SYSTEMS				
The system has been flushed and cleaned in accordance with BS7593 and boiler manufacturer's instructions			Yes	
What system cleaner was used?				
What inhibitor was used?	Quantity			litres
Has a primary water system filter been installed?	Yes		No	

CENTRAL HEATING MODE measure and record:			
Gas rate	m³/hr	**OR**	ft³/hr
Burner operating pressure (if applicable)	mbar	**OR** Gas inlet pressure	mbar
Central heating flow temperature			°C
Central heating return temperature			°C

COMBINATION BOILERS ONLY				
Is the installation in a hard water area (above 200ppm)?	Yes		No	
If yes, and if required by the manufacturer, has a water scale reducer been fitted?	Yes		No	
What type of scale reducer has been fitted?				

DOMESTIC HOT WATER MODE Measure and Record:			
Gas rate	m³/hr	**OR**	ft³/hr
Burner operating pressure (at maximum rate)	mbar	**OR** Gas inlet pressure at maximum rate	mbar
Cold water inlet temperature			°C
Hot water has been checked at all outlets	Yes	Temperature	°C
Water flow rate			l/min

CONDENSING BOILERS ONLY		
The condensate drain has been installed in accordance with the manufacturer's instructions and/or BS5546/BS6798	Yes	

ALL INSTALLATIONS							
Record the following:	At max. rate:	CO	ppm	**AND**	CO/CO_2	Ratio	
	At min. rate: (where possible)	CO	ppm	**AND**	CO/CO_2	Ratio	
The heating and hot water system complies with the appropriate Building Regulations						Yes	
The boiler and associated products have been installed and commissioned in accordance with the manufacturer's instructions						Yes	
The operation of the boiler and system controls have been demonstrated to and understood by the customer						Yes	
The manufacturer's literature, including Benchmark Checklist and Service Record, has been explained and left with the customer						Yes	

Commissioning Engineer's Signature	
Customer's Signature	
(To confirm satisfactory demonstration and receipt of manufacturer's literature)	

*All installations in England and Wales must be notified to Local Authority Building Control (LABC) either directly or through a Competent Persons Scheme. A Building Regulations Compliance Certificate will then be issued to the customer.

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Appendix VI Scoping study interview schedule

Were you the main point of contact with the plumber? If not, who was, and why?

What was the reason for contacting plumber?

Who completed the job and why did you select these people? (e.g. local plumber vs. British Gas, would you use them again?)

What work did you have done? (e.g. boiler repair, CHS full installation, replacement radiators?)

What was the procedure from initial contact to the finished job (including lead times – did the plumber turn up as scheduled, how far in advance did you know the plumber was coming?)? (e.g. how many points of contact, how was boiler sizing/ location etc decided?) – What forms of communication were used?

Were you given any information about how to operate the system before the plumber had left?

Have you had any further interactions/ follow up phone calls etc… since the job?

Did you know how to use your boiler/ central heating system when the installer had left?

Appendix VII Ethics approval

UCL RESEARCH ETHICS COMMITTEE

COPY OF ETHICS APP FORM - AS SUBMITTED

UCL

IMPORTANT: ALL FIELDS MUST BE COMPLETED. THE FORM SHOULD BE COMPLETED IN PLAIN ENGLISH UNDERSTANDABLE TO LAY COMMITTEE MEMBERS.

SEE NOTES IN STATUS BAR FOR ADVICE ON COMPLETING EACH FIELD. YOU SHOULD READ THE ETHICS APPLICATION GUIDELINES AND HAVE THEM AVAILABLE AS YOU COMPLETE THIS FORM.

APPLICATION FORM

SECTION A APPLICATION DETAILS

A1 **Project Title: Investigating the requirements of decision support to assist plumbers in providing the most appropriate central heating solutions to householders**

Date of Submission: 21/03/2012	Proposed Start Date: 01/04/2012
UCL Ethics Project ID Number: 3763/001	Proposed End Date: 01/10/2014

If this is an application for classroom research as distinct from independent study courses, please provide the following additional details:

Course Title: Course Number:

A2 **Principal Researcher**

Please note that a student – undergraduate, postgraduate or research postgraduate cannot be the Principal Researcher for Ethics purposes.

Full Name: Dr David Shipworth	Position Held: Reader in Energy and the Built Environment
Address: UCL Energy Institute, Central House, 14 Upper Woburn Place, London, WC1H 0NN	Email: d.shipworth@ucl.ac.uk Telephone: 02031085998 Fax:

Declaration To be Signed by the Principal Researcher

- I have met with and advised the student on the ethical aspects of this project design *(applicable only if the Principal Researcher is not also the Applicant).*
- I understand that it is a UCL requirement for both students & staff researchers to undergo Criminal Records Checks when working in controlled or regulated activity with children, young people or vulnerable adults. The required Criminal Record Check Disclosure Number(s) is: 001353987818
- I have obtained approval from the UCL Data Protection Officer stating that the research project is compliant with the Data Protection Act 1998. My Data Protection Registration Number is: Z6364106/2012/03/05
- I am satisfied that the research complies with current professional, departmental and university guidelines including UCL's Risk Assessment Procedures and insurance arrangements.
- I undertake to complete and submit the 'Continuing Review Approval Form' on an annual basis to the UCL Research Ethics Committee.
- I will ensure that changes in approved research protocols are reported promptly and are not initiated without approval by the UCL Research Ethics Committee, except when necessary to eliminate apparent immediate hazards to the participant.
- I will ensure that all adverse or unforeseen problems arising from the research project are reported in a timely fashion to the UCL Research Ethics Committee.
- I will undertake to provide notification when the study is complete and if it fails to start or is abandoned.

Signature: David Shipworth Date: 2012-03-20

A3	**Applicant(s) Details** *(if Applicant is not the Principal Researcher e.g. student details):*	
	Full Name: Faye Wade	
	Position Held: MPhil/ PhD Candidate	
	Address: UCL Energy Institute, Central House, 14 Upper Woburn Place, London, WC1H 0NN	Email: faye.wade.10@ucl.ac.uk Telephone: 02031085915 Fax:
	Full Name:	
	Position Held:	
	Address:	Email: Telephone: Fax:

A4 **Sponsor/ Other Organisations Involved and Funding**

a) **Sponsor:** ☒ **UCL** ☐ **Other institution**
If your project is sponsored by an institution other than UCL please provide details:

b) **Other Organisations:** If your study involves another organisation, please provide details. *Evidence that the relevant authority has given permission should be attached or confirmation provided that this will be available upon request.*

c) **Funding:** What are the sources of funding for this study and will the study result in financial payment or payment in kind to the department or College? *If study is funded solely by UCL this should be stated, the section should not be left blank.* Engineering and Physical Sciences Research Council

A5 **Signature of Head of Department or Chair of the Departmental Ethics Committee**
(This must not be the same signature as the Principal Researcher)

I have discussed this project with the principal researcher who is suitably qualified to carry out this research and I approve it. The project is registered with the UCL Data Protection Officer, a formal signed risk assessment form has been completed, and appropriate insurance arrangements are in place. *Links to details of UCL's policies on data protection, risk assessment, and insurance arrangements can be found at: http://ethics.grad.ucl.ac.uk/procedures.php*

UCL is required by law to ensure that researchers undergo a Criminal Record Check if their research project puts them in a position of trust with children under 18 or vulnerable adults.
Full details of UCL's policy on criminal record checks can be found at http://www.ucl.ac.uk/hr/docs/criminal_record.php

HEAD OF DEPARTMENT TO DELETE BELOW AS APPLICABLE

I am satisfied that checks: **(1) have been satisfactorily completed**
~~(2) have been initiated~~
~~(3) are not required~~

If checks are **not** required please clarify why below.

Print Name: T. ORESZCZYN	
Signature: [signature]	Date: 21/3/2012

Chair's Action Recommended: ☒ Yes ☐ No

A recommendation for Chair's action can be based only on the criteria of minimal risk as defined in the Terms of Reference of the UCL Research Ethics Committee.

SECTION B DETAILS OF THE PROJECT

B1 **Please provide a brief summary of the project in simple prose outlining the intended value of the project, giving necessary scientific background** *(max 500 words).*

Previous research has shown that householders often have difficulty in operating their central heating systems. In some cases individuals are not aware of the functions of the control systems used, for example thermostats, programmers and thermostatic radiator valves. This often results in the householder not operating the central heating in the most efficient way. It is important to investigate the underlying reasons for this, particularly in light of the fact that space heating accounted for 58 % of domestic carbon emissions in 2008. It has been highlighted that as the installer of the system, the plumber has an influential role in determining the habitual behavior of the householder with regard to their central heating system. Consequently, the installation of domestic central heating forms the focus of this research. During installation, decisions are made regarding the technical parameters of the system, something that can be influential to its final energy use, and information is exchanged between the plumber and the householder.

The aim of this project is to improve our knowledge of the information exchanged, both verbal and non-verbal, during the installation process. The investigation will reveal how the plumber currently makes decisions with regard to the central heating systems, particularly what resources they draw upon. Information regarding how much the householder utilizes the information provided by the plumber in adopting the system and consequently the importance of the information they receive during installation will also be established. Understanding this process will help in developing policy that addresses and improves this interaction, consequently helping to effectively reduce the energy consumed by domestic central heating.

B2 **Briefly characterise in simple prose the research protocol, type of procedure and/or research methodology (e.g. observational, survey research, experimental). Give details of any samples or measurements to be taken** *(max 500 words).*

To capture a detailed account of this interaction, an ethnographic approach will be used. This will involve shadowing plumbers for several weeks, in order to establish sufficient rapport. Once trust is established, the installation of central heating will be observed within domestic properties. During the installation there will also be informal interviews conducted with both the plumber and the householder. This will be followed up by a short return visit to the property, to establish how the householder is using the system. Again, this will involve observation and informal interviewing.The informal interview topic guide for both plumbers and householders is attached. At all stages of the research data will be captured via field notes, the interviews will be audio recorded with prior consent from the participants and photographs will be used to take images of the central heating system.

Access to plumbers is currently being negotiated via a gatekeeper, this is a person who manages apprentice plumbers' training in the field, and as such has frequent access to the companies that employ the apprentices. With validation from the gatekeeper, it is hoped that the plumbers will trust the researcher enough to allow them into the field. The use of a gatekeeper also provides an additional element of safety for the researcher in the field.

Attach any questionnaires, psychological tests, etc. (a standardised questionnaire does not need to be attached, but please provide the name and details of the questionnaire together with a published reference to its prior usage).

B3 **Where will the study take place (please provide name of institution/department)?**
If the study is to be carried out overseas, what steps have been taken to secure research and ethical permission in the study country? Is the research compliant with Data Protection legislation in the country concerned or is it compliant with the UK Data Protection Act 1998?

The study will take place in domestic properties in the UK and potentially on UK construction sites. The research is compliant with the UK Data Protection Act 1998, UCL Data Protection registration number: Z6364106/2012/03/05.

B4 **Have collaborating departments whose resources will be needed been informed and agreed to participate?**
Attach any relevant correspondence.

N/A

B5 **How will the results be disseminated, including communication of results with research participants?**

The anonymised results will be published in a PhD thesis. Some anonymised results may be used for journal publications and conference proceedings. There may be some recommendations for decision support for plumbers, based on the findings of this work. Recommendations in terms of central heating practices may be fed back to participants, although a direct account of the results will not be provided. Any images of the central heating will be shown to participants before leaving the research site, to ensure that the participant is happy for them to be used for data analysis.

B6 **Please outline any ethical issues that might arise from the proposed study and how they are be addressed.** *Please note that all research projects have some ethical considerations so do not leave this section blank.*

Consent:

- Initial access to plumbers will be granted by a gatekeeper, who will seek consent in principle, at this stage the plumber may not be fully aware of what involvement entails. When initial access has been granted, the researcher will explain the project and ask the plumber to read and sign an informed consent letter before commencing with any data collection.

- Initial access to householders will be granted by the plumber, who will seek consent in principle from the householder before the researcher arrives on site (this is necessary because of the last minute nature of plumbing work, a plumber may not know where he will be in time for the researcher to plan this in advance and contact the householder, hence, the plumber will confirm with the householder that it is ok for a researcher to join). As soon as the researcher arrives on site, the project will be explained to the householder who will be asked to read and sign the informed consent letter before commencing with any data collection.

- The research is being conducted in domestic properties, there is a chance that multiple people will be present during the data collection. If several people become involved, the researcher will seek informed consent from all participants prior to data collection.

- The consent letter will not provide full detail of the research questions. One of the primary research questions is to establish the normal information exchanges that occur between householder and plumber. There is a danger that if the plumber is aware of this, they will provide more information than normal to the householder – invalidating the data collection. Consequently, this will not be detailed on the informed consent note. This is a form of deception, however, the potential harm to the participants as a result of this deception is minimal, especially because all data collected will be anonymised.

- The researcher's extended presence in the field may make plumbers off guard to the fact that research is being carried out, for example at times when they would not expect research to be conducted (e.g. travelling between jobs). As much as possible, the researcher will be open about when research data is being collected, the participants will be informed before recording equipment is used or photographs are taken.

Harm:

- If the researcher witnesses the plumber not fulfilling the requirements of their job/ the requirements of their employers, there is a risk of damage to the professional credibility of the plumber. This risk will be minimized by anonymising all data. The only circumstance in which a plumbers' anonymity would be compromised is if the researcher witnesses the plumber leaving a central heating system in an unsafe condition within a domestic property, because it is a gas system, it is appropriate to inform someone in this circumstance. This is extremely unlikely as GasSafe certified plumbers are being used in this study, they undergo regular checks for professional standards.

- The householders studied will not be known prior to the researcher being on site, there is a small risk that vulnerable adults and children could be on site when the research is taking place, these people will not be asked to participate in the research, only responsible adults will be asked to participate. The researcher has obtained a CRB check to provide reassurance whilst on site if necessary.

- There is a small potential for the research to reflect badly upon the plumbing profession in general, for example if the results lead to recommendations for altering plumbing practices. The researcher is aware of this potential and will be sensitive to it in writing up and disseminating the results.

- There is the potential for the researchers presence to cause distress to the householder, although this is extremely minimal. The researcher will provide every assurance to the householder that this is not an attempt to be invasive to their privacy and personal information will not be shared. The topics discussed in informal interviews are not regarded as sensitive topics and are not particularly personal in nature; therefore, potential harm to the householder is minimal. Householders may object to photographs being taken of their property. The content of any photographs will only be of the central heating system; the photographs will be shown to participants before the researcher leaves the site, to ensure that they are happy that the images do not contain any personal material.

SECTION C — DETAILS OF PARTICIPANTS

C1 **Participants to be studied**

C1a. Number of volunteers:	<50
Upper age limit:	N/A
Lower age limit:	16

C1b. Please justify the age range and sample size:

The participants studied will be competent householders who have chosen to have a central heating upgrade. Any minors and vulnerable adults will not be asked to participate in the study. The plumbers observed will have been in the role for a number of years, they will therefore be over 16. This study does not have an upper age limit.

C2 **If you are using data or information held by a third party, please explain how you will obtain this. You should confirm that the information has been obtained in accordance with the UK Data Protection Act 1998.**

There will be no data used from a third party.

C3	**Will the research include children or vulnerable adults such as individuals with mental health problems or with learning disabilities, the elderly, prisoners or young offenders?** ☐ Yes ☒ No How will you ensure that participants in these groups are competent to give consent to take part in this study? *If you have relevant correspondence, please attach it.*

C4	**Will payment or any other incentive, such as gift service or free services, be made to any research participant?** ☐ Yes ☒ No If yes, please specify the level of payment to be made and/or the source of the funds/gift/free service to be used. Please justify the payment/other incentive you intend to offer.

C5	**Recruitment** (i) Describe how potential participants will be identified: - Plumbers will be identified and approached by a gatekeeper. The gatekeeper has high levels of contact with plumbing firms, for the purposes of training apprentices. - After plumbers have been recruited, they will identify householders who are having central heating installations appropriate for this study, and informed the researcher of this. (ii) Describe how potential participants will be approached: - Plumbers will be approached via a gatekeeper and asked if they are willing to particpate in the study. If they grant the researcher access, the researcher will then meet the plumber in person to discuss full consent. - The plumber will ask their client if they are willing to have a researcher on site for the work. If the householders consent at this stage the researcher will arrive on site and discuss full consent. (iii) Describe how participants will be recruited: - The researcher will meet with the plumber and discuss the project, at this point the plumber will be asked to read and sign the informed consent letter. - When the plumber visits the client, the researcher will shadow. On initial entry into the property, the researcher will fully explain the project to the particpant and provide the informed consent letter. If the householder does not consent to participating, the researcher will leave the site. *Attach recruitment emails/adverts/webpages. A data protection disclaimer should be included in the text of such literature.*

C6 **Will the participants participate on a fully voluntary basis?** ☒ Yes ☐ No

Will UCL students be involved as participants in the research project? ☐ Yes ☒ No

If yes, care must be taken to ensure that they are recruited in such a way that they do not feel any obligation to a teacher or member of staff to participate.

Please state how you will bring to the attention of the participants their right to withdraw from the study without penalty?

The consent letter contains the following statement:

"It is voluntary to take part and you are free to withdraw at any time without giving a reason."

This will also be clarified verbally with all participants.

C7 **CONSENT**

Please describe the process you will use when seeking and obtaining consent.

A gatekeeper will ask for preliminary consent from the plumbers. If preliminary consent is granted, the researcher will meet the plumber and provide an informed consent letter. The research will only proceed if the plumber read and signs the informed consent letter and is happy to proceed.

The plumber will ask for preliminary consent from their clients before arriving on site with the researcher. If preliminary consent is granted, the researcher will provide an informed consent letter for the householder. The research will only proceed if the householder reads and signs the informed consent letter and is happy to proceed.

Please see section B6 for further details of the informed consent letter, which is attached to this application.

A copy of the participant information sheet and consent form must be attached to this application. For your convenience proformas are provided in C10 below. These should be filled in and modified as necessary.

In cases where it is not proposed to obtain the participants informed consent, please explain why below.

C8 **Will any form of deception be used that raises ethical issues? If so, please explain.**

The research involves minor deception, the informed consent letter details the subject of the study - central heating systems, but not specific research questions. One of the main aims of the research is to understand the interaction between householders and plumbers when central heating is installed. To minimise any alteration in normal behaviour, this aim is not detailed on the informed consent. The primary concern is that if the participants are aware of this they may alter their normal behaviour. This level of deception is deemed to be of minimal risk to the participants, particularly because the subject of the data is not sensitive and all data collected will be fully anonymised.

Please see attached informed consent sheet.

C9 **Will you provide a full debriefing at the end of the data collection phase?** ☐ Yes ☒ No

If 'No', please explain why below.

There will be a basic debrief to address any issues that the plumber or householder may have. This will not be a formal debrief as the project involves a minimal form of deception, it is anticipated that this will not have a negative impact on the participants.

C10 **Information Sheets And Consent Forms**

A poorly written Information Sheet(s) and Consent Form(s) that lack clarity and simplicity frequently delay ethics approval of research projects. The wording and content of the Information Sheet and Consent Form must be appropriate to the age and educational level of the research participants and clearly state in simple non-technical language what the participant is agreeing to. Use the active voice e.g. "we will book" rather than "bookings will be made". Refer to participants as "you" and yourself as "I" or "we". An appropriate translation of the Forms should be provided where the first language of the participants is not English. If you have different participant groups you should provide Information Sheets and Consent Forms as appropriate (e.g. one for children and one for parents/guardians) using the templates below. Where children are of a reading age, a written Information Sheet should be provided. When participants cannot read or the use of forms would be inappropriate, a description of the verbal information to be provided should be given. Please ensure that you trial the forms on an age-appropriate person before you submit your application.

SECTION D DETAILS OF RISKS AND BENEFITS TO THE RESEARCHER AND THE RESEARCHED

D1 **Have UCL's Risk Assessment Procedures been followed?** ☒ Yes ☐ No

If **No**, please explain.

D2 **Does UCL's insurer need to be notified about your project before insurance cover can be provided?** ☐ Yes ☒ No

The insurance for all UCL studies is provided by a commercial insurer. For the majority of studies the cover is automatic. However, for a minority of studies, in certain categories, the insurer requires prior notification of the project before cover can be provided. For example, you will need to complete an insurance registration form for the following types of studies: clinical trials which use drugs or vaccines; trials of medical devices; studies which use radiation, surgery or anesthesia as the intervention; studies which will enroll over 5000 subjects.

If **Yes**, please provide confirmation that the appropriate insurance cover has been agreed. *Please attach your UCL insurance registration form and any related correspondence.*

D3 **Please state briefly any precautions being taken to protect the health and safety of researchers and others associated with the project (as distinct from the research participants).**

The major safety consideration for this work is that the researcher will be working alone in the field, which is domestic properties. Because of this, a routine of contacting the fieldwork supervisor regarding all site visits will be establsihed as follows:

Prior to commencing fieldwork:

-Issue a log to fieldwork supervisor, includng timings of visits, fieldwork location and routes to and from it, participant contact information;

-Contact fieldwork supervisors before going on site;

- Contact fieldwork supervisors when leaving site;

- Estimated duration of site visit will be agreed between supervisor and researcher prior to visits;

- If fieldworker fails to return or make contact at appointed time, emergency procedures to be instigated.

Researcher will carry mobile phone and personal alarm for use in emergency situations.

Further details of the health and safety considerations of the research are included in the attached risk assessment form.

D4 **Will these participants participate in any activities that may be potentially stressful or harmful in connection with this research?** ☐ Yes ☒ No

If **Yes**, please describe the nature of the risk or stress and how you will minimise and monitor it.

The research is deemed to be of minimal risk to the participants. Participants may find the researcher's presence on site stressful, in this situation full reassurances will offered, if required, the researcher will leave the site. This is unlikely because the topic being researched is not sensitive or personal in nature.

D5 **Will group or individual interviews/questionnaires raise any topics or issues that might be sensitive, embarrassing or upsetting for participants?**

If **Yes,** please explain how you will deal with this.

No

D6 **Please describe any expected benefits to the participant.**

There are minimal expected benefits to the participants. This is an observation of normal practice, there are no intended interventions that will be carried out. The researcher will not offer advice to the plumber to improve plumbing practices. The householder may benefit from an increased understanding of their central heating system through discussion with the researcher.

D7 **Specify whether the following procedures are involved:**

Any invasive procedure(s) ☐ **Yes** ☒ **No**

Physical contact ☐ **Yes** ☒ **No**

Any procedure(s) that may cause mental distress ☐ **Yes** ☒ **No**

Please state briefly any precautions being taken to protect the health and safety of the research participants.

D8 **Does the research involve the use of drugs?** ☐ **Yes** ☒ **No**

If **Yes**, please name the drug/product and its intended use in the research and then refer to Appendix I

Does the project involve the use of genetically modified materials? ☐ **Yes** ☒ **No**

If **Yes**, has approval from the Genetic Modification Safety Committee been obtained for work? ☐ Yes ☐ No

If **Yes**, please quote the Genetic Modification Reference Number:

D9 **Will any ionising radioactive substances be used on the research participant(s)?** ☐ **Yes** ☒ **No**

If **Yes**, please refer to Appendix II.

Will x-rays be used? ☐ **Yes** ☒ **No**

If **Yes**, please refer to Appendix II.

CHECKLIST

Please submit ether 12 copies (1 original + 11 double sided photocopies) of your completed application form for full committee review or 3 copies (1 original + 2 double sided copies) for chair's action, together with the appropriate supporting documentation from the list below to the UCL Research Ethics Committee Administrator. You should also submit your application form electronically to the Administrator at: ethics@ucl.ac.uk

Documents to be Attached to Application Form (if applicable)	Ticked if attached	Tick if not relevant
Section B: Details of the Project		
• Questionnaire(s) / Psychological Tests	☐	☒
• Relevant correspondence relating to involvement of collaborating		

department/s and agreed participation in the research.	☐	☒
Section C: Details of Participants		
• Parental/guardian consent form for research involving participants under 18	☐	☒
• Participant/s information sheet	☒	☐
• Participant/s consent form/s	☒	☐
• Advertisement	☐	☒
Section D: Details of Risks and Benefits to the Researcher and the Researched		
• Insurance registration form and related correspondence	☐	☒
Appendix I: Research Involving the Use of Drugs		
• Written signed statement from the pharmaceutical/industrial company stating their agreement to abide by the guidelines on compensation of the Association of British Pharmaceutical Industry (ABPI) or other insurance certificate	☐	☒
• Proposed volunteer contract	☐	☒
• Full declaration of financial or direct interest	☐	☒
• Copies of certificates: CTC/CTX/DDX etc...	☐	☒
• Relevant correspondence relating to agreed arrangements for dispensing with the pharmacy	☐	☒

Please note that correspondence regarding the application will normally be sent to the Principal Researcher and copied to other named individuals.

Appendix VIII Informed consent sheet

Informed Consent for Research Project Participation: Central Heating Installation

Dear Roy,

I am a research student at University College London, looking at the installation of central heating. I am especially interested in how central heating systems are being upgraded and how people use their central heating after these changes.

I would like to interview you today to understand a bit more about your job and the process of surveying. I have some questions I'd like to ask, but the interview is mostly an informal conversation. I'd like to audio record the interview. The recording will then be typed up word for word and stored on my computer.

If you are happy to be included in this, you will be asked to sign two copies of this sheet; you will be given one to keep. It is voluntary to take part and you are free to withdraw at any time without giving a reason. The project is registered under data protection; any information I collect will be confidential and stored securely in accordance with the Data Protection Act 1998. The results will be anonymised before they are discussed with colleagues or included in academic documents such as my PhD thesis, research papers or conferences. Any names and personal information will be removed; this means that you cannot be identified from the data or results.

This study is funded by the Engineering and Physical Sciences Research Council (EPSRC). The research has been fully approved by the UCL ethics committee and a full risk assessment for all those involved has been carried out.

Thank you very much for giving your time to this study, which will help me learn more about the installation of central heating systems. If you have any questions please feel free to ask me, or contact me using the details below.

Thank you
Faye Wade

07818658241
faye.wade.10@ucl.ac.uk
UCL Energy Institute, Central House
14 Upper Woburn Place, London
WC1H 0NN

If you are willing to participate in the research project outlined above, including the recording of our conversation, please sign here.

Signature. …………………………………………………………………….
Date. …………………………………………………………………………

RISK ASSESSMENT FORM
FIELD / LOCATION WORK

The Approved Code of Practice - Management of Fieldwork should be referred to when completing this form
http://www.ucl.ac.uk/estates/safetynet/guidance/fieldwork/acop.pdf

DEPARTMENT/SECTION UCL ENERGY INSTITUTE
LOCATION(S) CENTRAL HOUSE, 14 UPPER WOBURN PLACE, LONDON, WC1H 0NN
PERSONS COVERED BY THE RISK ASSESSMENT Faye Wade

BRIEF DESCRIPTION OF FIELDWORK Observing the installation of central heating systems in domestic properties, conducting informal interviews and potential follow up interviews or questionnaires with the householders and plumbers. Some fieldwork may take place on construction sites.

Consider, in turn, each hazard (white on black). If **NO** hazard exists select **NO** and move to next hazard section.
If a hazard does exist select **YES** and assess the risks that could arise from that hazard in the risk assessment box.
Where risks are identified that are not adequately controlled they must be brought to the attention of your Departmental Management who should put temporary control measures in place or stop the work. Detail such risks in the final section.

ENVIRONMENT	**The environment always represents a safety hazard. Use space below to identify and assess any risks associated with this hazard**
e.g. location, climate, terrain, neighbourhood, in outside organizations, pollution, animals.	Examples of risk: adverse weather, illness, hypothermia, assault, getting lost. Is the risk high / medium / low ? Low Working in domestic properties, risk of getting lost when going to/ from the property, potentially working in unpleasant areas, risk of attack/ abuse in unknown areas; Construction sites can have high risk associated with them, particularly from masonary and machinery in use on the site.
CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**

☐	work abroad incorporates Foreign Office advice
☐	participants have been trained and given all necessary information
☐	only accredited centres are used for rural field work
☒	participants will wear appropriate clothing and footwear for the specified environment
☐	trained leaders accompany the trip
☐	refuge is available
☒	work in outside organisations is subject to their having satisfactory H&S procedures in place
☐	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

Researcher to always carry UCL ID and be prepared to identify myself.

Domestic properties:
- Avoid areas known to be unpleasant if possible;
- Seek information about the area before setting out, details of local authorities, transport links, local map;
- Walk with purpose and confidence;
- Do not carry more money/ valuables than required

Construction site visits:
- Any Personal Protective Equipment (PPE) requirements of the site will be adhered to.
- Appropriate health and safety training undertaken before entering construction sites

EMERGENCIES	**Where emergencies may arise use space below to identify and assess any risks**
e.g. fire, accidents	Examples of risk: loss of property, loss of life

Low
Enhanced risk of emergency on construction sites.
In the domestic environment there is a small risk of attack/ abuse and personal injury.

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**

☐	participants have registered with LOCATE at http://www.fco.gov.uk/en/travel-and-living-abroad/
☐	fire fighting equipment is carried on the trip and participants know how to use it
☒	contact numbers for emergency services are known to all participants
☒	participants have means of contacting emergency services
☐	participants have been trained and given all necessary information
☒	a plan for rescue has been formulated, all parties understand the procedure
☐	the plan for rescue /emergency has a reciprocal element
☐	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

Mobile phone will be carried at all times.

Construction sites:
Researcher to familiarise herself with any on-site first aid and emergency procedures before entering the site.

Domestic properties:
In the first instance, keep calm, attempt to placate the situation or leave. Contact the police if necessary.

Be familiar with a map of the local area, escape routes, public transport links and contact details for local authorities.

EQUIPMENT	**Is equipment used?**	**Yes**	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. clothing, outboard motors.	Examples of risk: inappropriate, failure, insufficient training to use or repair, injury. Is the risk high / medium / low ?		

Equipment use will be by the trained plumber on site, the researcher will be observing this but not physically using any equipment, this is a minimal risk situation.
Risk of injury from equipment in use on construction sites.

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**
☐	the departmental written Arrangement for equipment is followed
☐	participants have been provided with any necessary equipment appropriate for the work
☐	all equipment has been inspected, before issue, by a competent person
☐	all users have been advised of correct use
☐	special equipment is only issued to persons trained in its use by a competent person
☒	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

Construction Sites:
Any PPE requirements of the site to be adhered to.
Any PPE used will be a suitable size for the researcher and maintained and stored appropriately throughout the fieldwork.

LONE WORKING	Is lone working a possibility?	Yes	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. alone or in isolation lone interviews.	Examples of risk: difficult to summon help. Is the risk high / medium / low?		

Medium - Potential difficulty of summoning help and low risk of personal attack/ abuse when travelling to/ from site or on site.

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
☐	the departmental written Arrangement for lone/out of hours working for field work is followed
☐	lone or isolated working is not allowed
☒	location, route and expected time of return of lone workers is logged daily before work commences
☒	all workers have the means of raising an alarm in the event of an emergency, e.g. phone, flare, whistle
☐	all workers are fully familiar with emergency procedures
☒	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

The following requirements are to be met when recruiting participants and planning fieldwork.
1. Only conduct field work with people that I have approached. Never accept field work opportunities from people that approach me.
2. As far as possible, conduct the fieldwork in a public place (this is acheivable with interviews, but not when shadowing in homes).
3. When shadowing in homes, try to arrange shadowing opportunities through management, so that someone knows when I am shadowing their employee.
4. Use Call Buddy Procedure outlined below when conducting any fieldwork.
5. When completing Call Buddy Log, provide details of additional contacts (for example, management if the participant works for a company). Also provide additional details of access route and mutual contacts that myself and the participant have.
6. If travelling in a vehicle with a participant - send car registration details to Call Buddys with arrival text.

Call Buddy Procedure
1. Faye to have completed Call Buddy Log and sent to allocated Call Buddys (2 buddys per visit) prior to commencing fieldwork. Call Buddy Log to contain the following details about the fieldwork event: date, meeting point, approximate start and finish time, researcher contact details, contact details of both allocated call buddys, contact details for research participant, details of access route and mutual contacts, contact details for those to contact in the event of an emergency.
The following stages vary depending on the fieldwork situation. Possible fieldwork scenarios include:
A) An interview in a public place,
B) An interview or shadowing in a private property,
C) Shadowing in several private properties in one day

If A) in a public place:

2. Faye to text on arrival at location (and provide name of venue where possible) - text to read: "arrived [+ location details if appropriate]"
3. Faye to text when leaving fieldwork site - text to read: "All done. Faye"
4. If running over approximate finish time, Faye to text call buddys with revised approximate finish time. Faye to include word 'orange' in text as indicator that it is her writing it. Text to read: "orange + 1 hour [or other time as appropriate]"
5. If 'orange' not included in the above text, or no text received, call buddys to contact each other and attempt to contact Faye. (Faye to keep phone in pocket, on vibrate, so she is aware of incoming calls).
6. If approximate or newly revised finish time runs over by half an hour, call buddys to contact police (999) and provide any known details of Faye's location and the research participant.

If B) interview or shadowing in a private property:

2. As above.
3. Faye to text when she is inside property and is comfotable with installer (within 15 minutes of arriving) - text to read:

"orange comfort"
4. Faye to text after 30 minutes in property - text to read: "orange 30"
5. As per stage 3 above.
6. If running over approximate finish time or no text received within 30 minutes of me being in the property see 4. - 6. abovey.

If C) shadowing in several private properties in one day (with single installer)
2. As above.
3. Faye to text at each new property that is visited - texts to read: "orange new [+ location details as far as possible]"
4. Faye to text when leaving fieldwork site - text to read: "All done. Faye"
5. If running over approximate finish time see 4.-6.

In event of emergency
In the first instance, remain calm, attempt to leave the situation and contact the police.

ILL HEALTH	The possibility of ill health always represents a safety hazard. Use space below to identify and assess any risks associated with this Hazard.
e.g. accident, illness, personal attack, special personal considerations or vulnerabilities.	Examples of risk: injury, asthma, allergies. Is the risk high / medium / low? Low - research involves minimal physical demand. There is a greater potential for injury when working on construction sites.

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
☐	an appropriate number of trained first-aiders and first aid kits are present on the field trip
☐	all participants have had the necessary inoculations/ carry appropriate prophylactics
☐	participants have been advised of the physical demands of the trip and are deemed to be physically suited
☐	participants have been adequate advice on harmful plants, animals and substances they may encounter
☐	participants who require medication have advised the leader of this and carry sufficient medication for their needs
☒	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

Construction sites:
In the event of injury, follow on-site health and safety procedures.

TRANSPORT	Will transport be required	NO		Move to next hazard
		YES		Use space below to identify and assess any risks
e.g. hired vehicles	Examples of risk: accidents arising from lack of maintenance, suitability or training Is the risk high / medium / low? Low - transport to and from fieldwork sites within London and the surrounding area. Travel will be via public transport, private vehicle hire or pre-booked taxi.			

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
☒	only public transport will be used
☒	the vehicle will be hired from a reputable supplier
☐	transport must be properly maintained in compliance with relevant national regulations
☐	drivers comply with UCL Policy on Drivers http://www.ucl.ac.uk/hr/docs/college_drivers.php
☐	drivers have been trained and hold the appropriate licence
☐	there will be more than one driver to prevent driver/operator fatigue, and there will be adequate rest periods
☐	sufficient spare parts carried to meet foreseeable emergencies
☐	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

DEALING WITH THE PUBLIC	Will people be dealing with public	Yes	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. interviews, observing	Examples of risk: personal attack, causing offence, being misinterpreted. Is the risk high / medium / low? Low - risk of personal attack or abuse, aggressive behaviour, injury from people's pets.		

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
☐	all participants are trained in interviewing techniques
☐	interviews are contracted out to a third party
☐	advice and support from local groups has been sought
☒	participants do not wear clothes that might cause offence or attract unwanted attention
☐	interviews are conducted at neutral locations or where neither party could be at risk
☐	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

Seek training in interpersonal communication skills.
Be polite, do not react to dirty/ smelly surroundings that may offend people;

Carry UCL ID card, be prepared to identify myself;
If the people are drunk/ aggressive, do not enter the property;
Have transport to/ from the site arranged in advance - e.g. pre-booked taxi;
Don't spend long continuous spells in the field, this will help the researcher to be alert to risk situations.

If aggressive situations arise:
Placate rather than provoking them, stay calm, speak gently and slowly;
Maintain neutral body language, avoid an aggressive stance;
Maintain distance, don't touch someone who is angry;
Keep an eye on potential escape routes;

In the event of physical attack:
Move away quickly towards a place where there will be other people;
Carry a personal alarm

WORKING ON OR NEAR WATER	Will people work on or near water?	No	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. rivers, marshland, sea.	Examples of risk: drowning, malaria, hepatitis A, parasites. Is the risk high / medium / low?		

The researcher will be observing plumbers working with a wet system in the home. This is of low risk to the researcher.

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
☐	lone working on or near water will not be allowed
☐	coastguard information is understood; all work takes place outside those times when tides could prove a threat
☐	all participants are competent swimmers
☐	participants always wear adequate protective equipment, e.g. buoyancy aids, wellingtons
☐	boat is operated by a competent person
☐	all boats are equipped with an alternative means of propulsion e.g. oars
☐	participants have received any appropriate inoculations
☐	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

N/A

MANUAL HANDLING (MH)	Do MH activities take place?	No	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. lifting, carrying, moving large or heavy equipment, physical unsuitability for the task.	Examples of risk: strain, cuts, broken bones. Is the risk high / medium / low?		

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
☐	the departmental written Arrangement for MH is followed
☐	the supervisor has attended a MH risk assessment course
☐	all tasks are within reasonable limits, persons physically unsuited to the MH task are prohibited from such activities
☐	all persons performing MH tasks are adequately trained
☐	equipment components will be assembled on site
☐	any MH task outside the competence of staff will be done by contractors
☐	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

SUBSTANCES	Will participants work with substances	No	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. plants, chemical, biohazard, waste	Examples of risk: ill health - poisoning, infection, illness, burns, cuts. Is the risk high / medium / low?		

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
☐	the departmental written Arrangements for dealing with hazardous substances and waste are followed
☐	all participants are given information, training and protective equipment for hazardous substances they may encounter
☐	participants who have allergies have advised the leader of this and carry sufficient medication for their needs
☐	waste is disposed of in a responsible manner
☐	suitable containers are provided for hazardous waste
☐	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

OTHER HAZARDS	Have you identified any other hazards?	No	If 'No' move to next section If 'Yes' use space below to identify and assess any risks
i.e. any other hazards must be noted and assessed here.	Hazard: Risk: is the risk		

CONTROL MEASURES	Give details of control measures in place to control the identified risks

Have you identified any risks that are not adequately controlled?	NO	☒	Move to Declaration
	YES	☐	Use space below to identify the risk and what action was taken

Appendix X Interview schedule

Briefing

- Why?
  - Researching CH installation and use
  - Understanding from an installer perspective – what the job involves
  - Funded by EPSRC – university based project
- The interview
  - Approx. 1 hour
  - Informal conversation – question sheet as guide
  - Recorded
  - Confidential – securely stored
  - Anonymised outputs
- Any questions?

Section 1: Background

Could you tell me about your current job?
- Working for a company/ self employed?
- If with company – what kind of company, what size?
- Specializing in particular role (surveyor/ engineer/ breakdowns)?
- How long in the job?

Section 2: The Installation process

Could you talk me through the process of a central heating installation, so from the first point of contact with a customer to the point where they have a new, working central heating system? [Doesn't have to be full system – just boiler/ controls]

Survey/ Quotation:
Can you explain to me how each part of the system is chosen?
- Boiler, radiators, controls
- Preferred suppliers / manufacturers – reasons? Always same?
- Makes, models, location
- Involvement of customer? Products specified by contract?
- Sizing – calculations, tools [Are customer routines relevant to this?]

Physical install
What sort of issues might you get during the physical installation? How are these resolved? Need to talk to customer?

Commissioning
Can you talk me through the commissioning process?
- Filling in documents – what documents? Who receives copies?
- Documents signed by customers – do you explain the documents/ do they ask questions about the documents before signing?

- What is tested?
- Any problems/ difficulties during commissioning?

Section 3: Handover/ Customers

Do you show customers their new system?
    - Set up programmers for them? Ask customers about their routines?
    - Leave instructions?

Do you get customers who struggle to use their system? Do you get call backs from people?
How do you avoid or deal with call backs?
  - Explain?
  - Install simple controls?

How are customers with you? Interested in the system? Not bothered? Away from the house?

Are some customers easier to deal with than others? Which ones are easy/ difficult? Funny stories?

What do you think is the most efficient way to use a central heating system?

Section 4: Maintaining expertise

Why did you decide to become a central heating installer?

Could you talk me through what training you went through to become a central heating installer?
- What training routes? [college, NVQ, training through company?]
- What qualifications?
    - NVQ's/ GasSafe/H&S

Is there a lot of change in the field?
- What sorts of changes? [Different qualifications? Regulations?]

If so, could you tell me how you keep up to date with these changes?
- Training courses/ GasSafe renewal
- Sources of information?
    - Particular contacts?
    - Documents? Publications?
    - Professional bodies?

If recruited at manufacturer training course:
- How did you find out about it?
- Why did you attend?
- Continuing contact – other installers? Trainers/ manufacturers?

Section 5: Wrap Up

What do you like about your job?
What don't you like about your job?

Appendix XI Fieldwork schedule

Date	Observation/ Interview	Type	Duration (days)
2013.06.17	Interview	Organisation - managing director	0.5
2013.07.04	Interview	2 engineers working for an organisation	0.5
2013.07.06	Interview	1 engineer working for an organisation	0.5
2013.07.13	Interview	Self-employed engineer	0.5
2013.08.08	Interview	Self-employed engineer	0.5
2013.08.12	Interview	Self-employed engineer	0.5
2013.08.20	Interview	Self-employed engineer	0.5
2013.08.22	Interview	2 sales representatives (1 ex-engineer)	0.5
2013.09.04	Interview	Industry representative	0.5
2013.09.05	Interview	1 engineer working for an organisation	0.5
2013.09.10	Interview	Self-employed engineer	0.5
2013.09.12	Interview	Self-employed engineer	0.5
2013.10.15	Interview	Self-employed engineer	0.5
2013.11.28	Interview	Industry representative	1
2013.12.03	Interview	Self-employed engineer	0.5
2013.12.16	Interview	Self-employed engineer	0.5
	Interview	Industry representative	0.5
2013.09.09	Interview	1 engineer working for an organisation	0.5
2013.09.16	Interview + Observation	Self-employed engineer - on site at boiler servicing	0.5
2013.12.10	Interview + Observation	Self-employed engineer - on site during boiler replacement	1
2012.04.25	Observation	Self employed installation - boiler + radiators	1

2012.05.23	Observation	Self employed installation - boiler + radiators + controls	0.5
2013.02.14	Observation	Organisation - survey - boiler replacement	1
2013.02.20	Observation	Organisation - boiler servicing	1
2013.02.21 - 26	Observation	Organisation installation - boiler replacement + wiring controls + commissioning	3
2013.03.04	Observation	Self employed installation - boiler removal + replacement	1
2013.03.19-20	Observation	Organisation installation - boiler removal + replacement + wiring controls	2
2013.04.17-18	Observation	Organisation installation - boiler replacement + wiring controls	2
2013.06.17-25	Observation	Merchant - national chain	3
2013.07.16	Observation	Shadowing a sales representative	1
2013.07.17	Observation	Organisation - surveys - boiler replacement	1
2013.07.26	Observation	Organisation - surveys - boiler replacement	1
2013.08.12	Observation	Merchant - independent	1
2013.09.23	Observation	Industry event	1
2013.10.17	Observation	Self employed installation - boiler + radiators + controls	1
2013.10.21	Observation	Organisation - boiler + controls replacement	1
2013.10.23	Observation	Organisation - surveys - boiler replacement	1
2013.10.30	Observation	Self-employed - survey + debrief	0.5
2013.11.12	Observation	Organisation - surveys - boiler	1

		replacement	
2013.11.13	Observation	Industry event - PHEX	1
2013.11.16	Observation	Organisation - wiring controls	1
2013.11.18	Observation	Organisation - handover + commissioning	1
2013.11.20	Observation	Self-employed - boiler replacement	1
2013.12.17	Observation	Organisation - surveys - boiler replacement	1
2012.10.10	Observation	Training day - controls manufacturer	1
2012.09.12	Observation	Training day - controls manufacturer	1
2013.03.21	Observation	Training day - boiler manufacturer	1
2013.06.04	Observation	Training day - controls manufacturer	1
2013.06.10	Observation	Training day - boiler manufacturer	1
2013.07.18	Observation	Training day - boiler manufacturer	1
2013.08.21	Observation	Training day - boiler manufacturer	1
2013.11.26	Observation	Training day - boiler manufacturer	1
2013.12.02	Observation	Training day - boiler manufacturer	1

Technical Bulletin 143

Developed with HHIC

Title: CO and combustion ratio checks using an Electronic Combustion Gas Analyser (ECGA) when commissioning a condensing boiler incorporating air/gas ratio control valve technology.

Date issued: 10 July 2013

This Technical Bulletin provides guidance to Gas Safe registered businesses and engineers on the procedure for checking and recording the CO level and combustion ratio of the flue gases when commissioning a newly installed condensing boiler.

This procedure does not apply to service and maintenance activities involving, or requiring adjustment of the air/gas ratio control valve. Separate guidance on this is available in boiler manufacturers' instructions and Gas Safe Register TB 126.

Background

Following concerns arising from a very small number of carbon monoxide (CO) incidents involving newly-commissioned condensing boilers, the Heating and Hotwater Industry Council (HHIC), working with boiler manufacturers and other industry organisations, has developed and introduced the following generic procedure for checking and recording of CO level and combustion ratio (CO/CO_2) in the boiler flue gases as part of the commissioning process.

The measured values for CO and combustion ratio (assuming they are within expected tolerances) must then be recorded on the appropriate commissioning documentation. This will give both the customer and the registered commissioning engineer confidence (and evidence) that the boiler has been left in a safe and efficient working condition.

The checking procedure is illustrated in the form of a flowchart (see **Appendix 1**) which is designed to ensure that Electronic Combustion Gas Analyser (ECGA) measurements are carried out in a consistent and technically correct manner, so that accurate readings are obtained for recording purposes.

Note 1: *The ECGA used to carry out the measurements should be of the correct type, as specified by BS 7967.*

Use of Process Flowchart

The process flowchart included in this TB **(Appendix 1)** is intended as a generic guide. All HHIC boiler manufacturers have agreed that this process will form the basis of their own installation instructions. ***The boiler manufacturer's guidance must be followed if available.***

Boiler manufacturers have advised that CO levels and combustion ratios should be well within the limits indicated in this TB and may therefore choose to give specific "action levels" for CO and combustion ratio in their boiler instructions. In the absence of specific instructions, manufacturers have agreed that the key action levels given in this TB (*CO level less than or equal to 350ppm and Combustion Ratio less than or equal to 0.0040*) will ensure that the boiler can be considered safe.

The flowchart **(Appendix 1)** gives additional information (*see the preliminary information box directly above the flowchart*) which must be noted before carrying out the checking procedures. It then follows a process of:

- setting the boiler to maximum rate in accordance with manufacturer's instructions
- verifying flue integrity using the ECGA (where possible)

- checking CO and combustion ratio at maximum rate using the ECGA and taking remedial action if required
- setting the boiler to minimum rate (where possible and specified)
- checking CO and combustion ratio at minimum rate using the ECGA and taking remedial action if required

Where CO level and combustion ratio are found to be outside the specified tolerances/limits, basic remedial actions are suggested, but if these are unsuccessful then contact with the manufacturer is required (*see details in the* ⬭ *shaped boxes in flowchart*). No adjustment of the air/gas ratio valve should be attempted without first contacting the manufacturer's Technical Helpline for advice.

If both CO level and combustion ratio are within the expected limits the commissioning process can be completed (see details in the ⬭ shaped box in flowchart. The measured values of CO and the combustion ratio must then be recorded on the appropriate commissioning documentation.

Recording of CO level and Combustion Ratio

Assuming commissioning checks of the boiler are successful, the HHIC Benchmark Commissioning Checklist included in all UK boiler manufacturers' manuals should be used to record the CO level and combustion ratio measured. HHIC boiler manufacturers have agreed that completion of the Benchmark Checklist is regarded as a condition of manufacturer's warranty – hence failure to record CO level and combustion ratio on commissioning may affect warranty provision for the customer.

Although the current version of the Benchmark Commissioning Checklist allows an option for recording "if required", HHIC will shortly issue a revised version with a formal requirement to record CO and combustion ratio. This version will be used by all UK boiler manufacturers from April 2014 - at which time the measurement and recording of CO and combustion ratio on commissioning will be a requirement. From April 2013, it is a recommendation that existing Benchmark Checklists should be used for recording purposes.

Completion of appropriate commissioning documentation is a requirement of Building Regulations and therefore as part of their follow-up inspection processes, Gas Safe Register will defect an installation for non-compliance if the CO level and combustion ratio are not correctly recorded on the commissioning documentation.

Note 2: *Similar requirements apply in other geographical areas covered by Gas Safe Register. For details of current gas safety legislation, building legislation and industry standards for the geographical areas covered by Gas Safe Register, see the Legislative, Normative & Informative Document List (LNIDL)*[(1)] *at: https://engineers.gassaferegister.co.uk - login and visit the Technical Information area.*

Note 3*: Further guidance on the use of ECGAs is given in BS 7967*[(2)].

Note 4: *TB 126*[(3)] *provides guidance on the actions to take when undertaking work on condensing boilers incorporating Air/Gas ratio valves and can be viewed at: https://engineers.gassaferegister.co.uk - login and visit the Technical Information area.*

Note 5 *For general information about the process behind the development of Gas Safe Register Technical Bulletins and the expectations for all Stakeholders, see TB 1000*[(4)] *at: https://engineers.gassaferegister.co.uk - login and visit the Technical Information area.*

Bibliography [Ariel Bold – blue – 9pt]

(1) *Gas Safe Register Legislative, Normative & Informative Document List*
(2) *BS 7967 - Carbon monoxide in dwellings and the combustion performance of gas-fired appliances.*
(3) *TB 126 - Combustion performance information for condensing boilers incorporating air/gas ratio control valve technology*
(4) *TB 1000 - An introduction to Gas Safe Register Technical Bulletins*

Note: *Gas Safe Register Technical Bulletins and the Legislative, Normative & Informative Document List can be viewed at: https://engineers.gassaferegister.co.uk - login and visit the Technical Information area*

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Appendix 1

FLOWCHART FOR CO LEVEL AND COMBUSTION RATIO CHECK ON COMMISSIONING A CONDENSING BOILER

Important Preliminary Information on Checks

The air gas ratio valve is factory-set and must not be adjusted DURING COMMISSIONING unless this action is recommended following contact with the manufacturer.

If any such adjustment is recommended and further checking of the boiler is required the installer/service engineer must be competent to carry out this work and to use an electronic combustion gas analyser (ECGA) accordingly.

If the boiler requires conversion to operate with a different gas family (e.g. conversion from natural gas to LPG) separate guidance will be provided by the boiler manufacturer with any conversion kit supplied and this must be followed.

PRIOR TO CO LEVEL AND COMBUSTION RATIO CHECK

The boiler manufacturer's installation instructions must have been followed (where available), gas type verified and gas supply pressure / gas rate checked as required prior to commissioning.

As part of the installation process, **ESPECIALLY WHERE A FLUE HAS BEEN FITTED BY PERSONS OTHER THAN THE BOILER INSTALLER**, visually check the integrity of the whole flue system to confirm that all components are correctly assembled, fixed and supported. Check that manufacturer's maximum flue lengths have not been exceeded and all guidance has been followed (e.g. Gas Safe Register Technical Bulletin (TB) 008 where chimney/flues are in voids).

The ECGA should be of the correct type, as specified by BS 7967

Prior to its use, the ECGA should have been maintained and calibrated as specified by the manufacturer. The installer must have the relevant competence for use of the analyser.

Check and zero the analyser IN FRESH AIR in accordance with the analyser manufacturer's instructions.

Key:
CO = carbon monoxide CO_2 = carbon dioxide **O_2** = oxygen
Combustion Ratio = The CO reading measured in ppm divided by the CO_2 reading first converted to ppm
ppm = parts per million
GS(I&U)R = Gas Safety (Installation and Use) Regulations

Start

SET BOILER TO MAXIMUM GAS RATE

In accordance with boiler instructions, set boiler to operate at maximum rate (full load condition). Allow sufficient time for combustion to stabilise.
Note. Do not insert analyser probe during this period to avoid possible 'flooding' of sensor

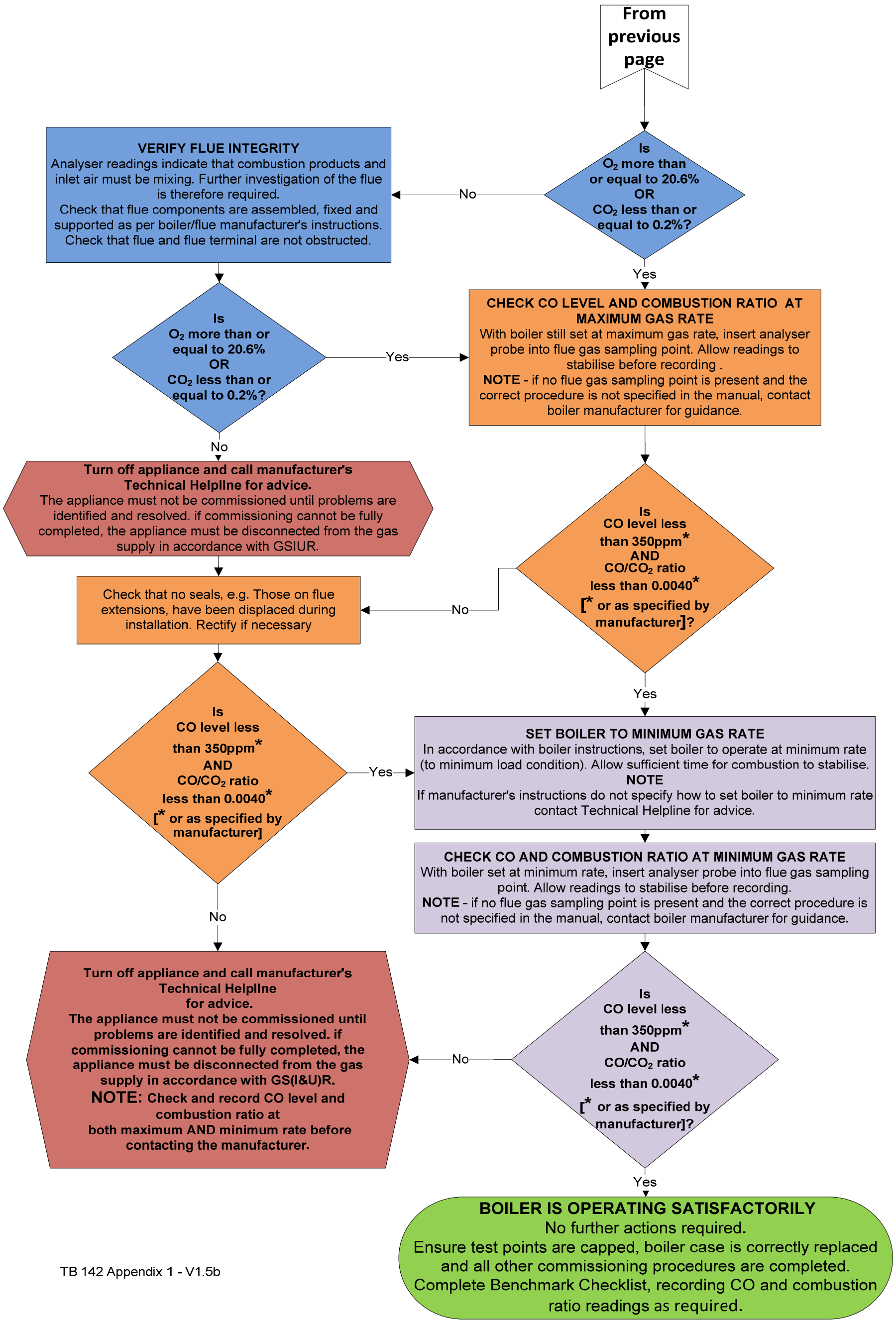
CARRY OUT FLUE INTEGRITY CHECK USING ANALYSER

Insert analyser probe into air inlet test point (where available) and allow readings to stabilise.

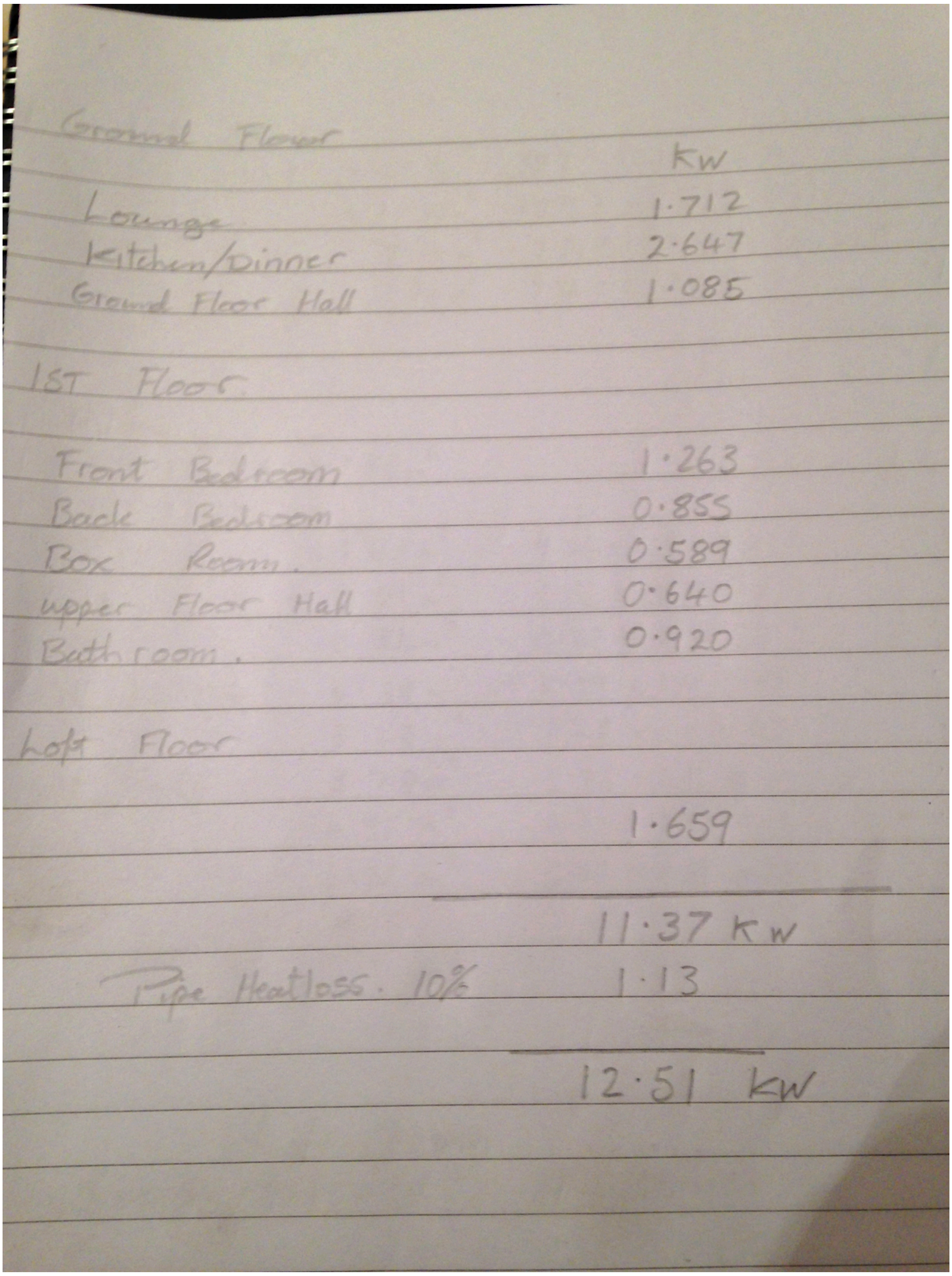
NOTE - where no air inlet test point is provided then a flue integrity check with the analyser is not possible. The installer should verify that flue integrity has been visually checked in accordance with the "***Prior to CO level and combustion ratio check***" box above (see above), before proceeding to the "***Check CO level and combustion ratio at maximum rate***" stage below.

To next page

Appendix 1 (Continued)

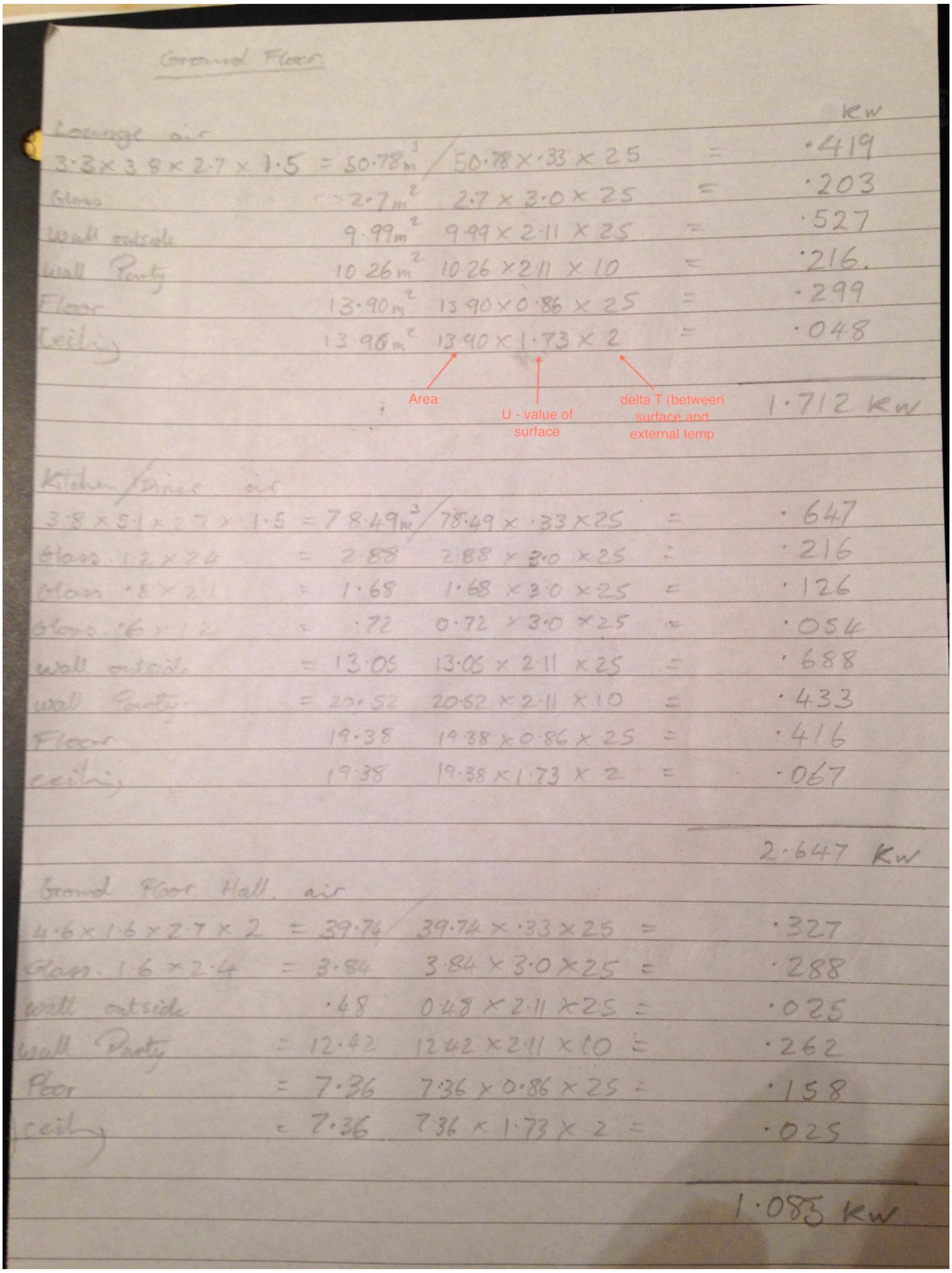


TB 142 Appendix 1 - V1.5b



Ground Floor

	kw
Lounge	1·712
Kitchen/Dinner	2·647
Ground Floor Hall	1·085
1ST Floor	
Front Bedroom	1·263
Back Bedroom	0·855
Box Room.	0·589
upper Floor Hall	0·640
Bathroom.	0·920
Loft Floor	
	1·659
	11·37 kw
Pipe Heatloss. 10%	1·13
	12·51 kw



Ground Floor

				kW
Lounge air				
3.3 × 3.8 × 2.7 × 1.5	= 50.78 m³	50.78 × .33 × 25	=	·419
Glass	2.7 m²	2.7 × 3.0 × 25	=	·203
wall outside	9.99 m²	9.99 × 2.11 × 25	=	·527
wall Party	10.26 m²	10.26 × 2.11 × 10	=	·216
Floor	13.90 m²	13.90 × 0.86 × 25	=	·299
ceiling	13.90 m²	13.90 × 1.73 × 2	=	·048
				1.712 kW
Kitchen/Diner air				
3.8 × 5.1 × 2.7 × 1.5	= 78.49 m³	78.49 × .33 × 25	=	·647
Glass 1.2 × 2.4	= 2.88	2.88 × 3.0 × 25	=	·216
Glass .8 × 2.1	= 1.68	1.68 × 3.0 × 25	=	·126
Glass .6 × 1.2	= .72	0.72 × 3.0 × 25	=	·054
wall outside	= 13.05	13.05 × 2.11 × 25	=	·688
wall Party	= 20.52	20.52 × 2.11 × 10	=	·433
Floor	19.38	19.38 × 0.86 × 25	=	·416
ceiling	19.38	19.38 × 1.73 × 2	=	·067
				2.647 kW
Ground Floor Hall air				
4.6 × 1.6 × 2.7 × 2	= 39.74	39.74 × .33 × 25	=	·327
Glass 1.6 × 2.4	= 3.84	3.84 × 3.0 × 25	=	·288
wall outside	·48	0.48 × 2.11 × 25	=	·025
wall Party	= 12.42	12.42 × 2.11 × 10	=	·262
Floor	= 7.36	7.36 × 0.86 × 25	=	·158
ceiling	= 7.36	7.36 × 1.73 × 2	=	·025
				1.083 kW

1st Floor

Front Bed Room air

3.9 × 3.15 × 2.5 × 1	= 30.71 m³	30.71 × .33 × 25 =	.253
Glass	2.56 m²	2.56 × 3.0 × 25 =	.192
walls outside	8.82 m²	8.82 × 2.11 × 25 =	.465
walls Party	9.75 m²	9.75 × 2.11 × 10 =	.205
Floor	12.28 m²	12.28 × 1.73 × −2 =	− .043
ceil →	12.28	12.28 × 0.62 × 25 =	.190
			1.263 kw

Back Bedroom air

3.9 × 3.15 × 2.5 × 1	= 30.71 m³	30.71 × .33 × 25 =	.253
Glass .9 × 1.60	= 1.44 m²	1.44 × 3.0 × 25 =	.108
wall outside	2.68 m²	2.68 × 2.11 × 25 =	.141
Wall Party	9.75 m²	9.75 × 2.11 × 10 =	.205
Floor	12.28 m²	12.28 × 1.73 × −2 =	− .042
ceiling	12.28 m²	12.28 × 0.62 × 25 =	.190
			0.855 kw

Box Room air

2.9 × 1.8 × 2.5 × 1	= 13.05 m³	13.05 × .33 × 25 =	.108
Glass .8 × 1.6	= 1.28 m²	1.28 × 3.0 × 25 =	.096
wall outside	= 3.22 m²	3.22 × 2.11 × 25 =	.169
wall Party wall	= 7.25 m²	7.25 × 2.11 × 10 =	.153
Floor	5.22	5.22 × 1.73 × −2 =	− .018
ceiling	5.22	5.22 × 0.62 × 25 =	.081
			.589 kw

1ST Floor.

Upper Hall air

1·8 × 4·3 × 2·5 × 2	= 38·7 m^3	38·7 × ·33 × 25 =	·319
wall Party	= 10·75 m^2	10·75 × 2·11 × 10 =	·227
Floor	= 7·74 m^2	7·74 × 1·73 × -2 =	-·026
Ceiling	= 7·74 m^2	7·74 × 0·62 × 25 =	·120
			·640 KW

Bathroom

1·5 × 2·9 × 1·8	= 7·83 m^3		
1·5 × 2·9 × 0·7 =			
÷ 2	= 1·52 m^3	= 9·35 × ·33 × 25 =	·077
Glass	0·51 m^2	= 0·51 × 3 × 25 =	·038
	0·32 m^2	= 0·32 × 3 × 25 =	·024
wall outside	4·39 m^2	= 4·39 × 2·11 × 25 =	·231
	3·23 m^2	= 3·23 × 2·11 × 25 =	·170
wall Party	3·25 m^2	= 3·25 × 2·11 × 10 =	·068
Floor	4·35 m^2	= 4·35 × 1·73 × -2 =	-·015
ceiling	5·22 m^2	= 5·22 × 2·51 × 25 =	·327
			0·92 KW

Loft Room.

air/5 × 4·5 × 2·4 × 1·5	= 81 m^3	= 81 × ·33 × 25 =	·668
Glass	2·4	= 2·4 × 3 × 25 =	·180
	2·4	= 2·4 × 3 × 25 =	·180
walls outside	9·36 + 7·2 =	16·56 × ·34 × 25 =	·141
walls Party	9·36 + 2·34 =	11·7 × 2·11 × 10 =	·247
Walls internal	7·5	7·5 × ·34 × 25 =	·063
Floor	22·5	= 22·5 × 1·75 × 0 =	0
ceil Roof	22·5	= 22·5 × ·32 × 25 =	·180
			1·659 KW

Appendix XIV Keith's survey sheet, collected 26.07.2013

Parking			Floors				Ceiling	Roof		Windows	
Good/Poor	Meter	Exemp/Req		Lower	First	Second		Pitched	✓	Single	
✓	ESTATES		Solid	✓	✓	✓		Flat		Double	✓
			Timber								

Gas Services		Meter Type (gas)		Meter Type (electric)		Materials Required		Rad Valves	
Supply Req.		Credit	✓ U6	Credit	✓	Boiler 30SI COMBI	✓	Lockshields	
Meter Req.		Card		Card		Cylinder		TRV's	
Carcass Req.		Slot		Slot		F&E Tank			
Comments		Comments		Comments		Sealed System	✓		

Boiler	Required	Flue Ext.	Plume Kit	Flue 90 Bend	Flue 45	Plume 90	Plume 45	Bracket	Plume Ext.
Baxi									
Worcester	30SI COMBI	x1	x1		[illegible]		x2		x2
Ideal									
Vaillant									
Other									

Copper Tube				Asbestos Requirements	Fittings (28mm)		Pipe Boxing	
	15mm	22mm	28mm		Elbows			
Gas	6mtrs	6mtrs			Couplings		Length	
Heating	6mtrs	6mtrs			22-28mm Reducers		Size	
Plumbing	6mtrs							

Boiler / Cylinder		Bonding		Controls		Gas		Make Good	
System / Standard	✓	Full Bond		S Plan		BP Elbow	x1	Brickwork	
Combi	✓	Cross Bond		Y Plan	✓	Bayonet	x1	Brickwork Colour	✓
Condensing				Room Stat	✓	G/M Union	x1	Flue Hole	✓
Immersion				Pro	✓				

Room	Width	Length	Height	External Walls	Window W x H	Exg Radiator Sizes: Height	Width	Type	Maximum Radiator Sizes: Height	Width	Type
Lounge						1150	1150	D/P	600	1400	DPF
Lounge 2											
Dining Room											
Kitchen											
Hall	ADDITIONAL + PIPES								600	600	S/C
Landing											
Bathroom						590	490	S/C	600	500	S/C
W/C											
Bedroom 1						450	1280	S/C	600	1400	S/C
Bedroom 2											
Bedroom 3											
Bedroom 4											
Bedroom 5											
Bedroom 6											
Other											

Comments: IDEAL ISAR SYS CONDENSING. (2007).
OLD CONVECTOR RADS - OLD TRVS
OLD LAGGED CYLINDER, H/L CISTERN - REMOVE.

Signed S.B[illegible] Print 26/7/13 Date 26/7/13

(3 BAR GOOD FLOW)