Fresh air and low-carbon:

a practice approach to maintaining home ventilation

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A thesis submitted in partial fulfilment of the requirements for the degree of
Doctor of Philosophy

The University of Sheffield
Faculty of Social Sciences
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5 February 2021

Acknowledgements

A great many people have played a part in this research – I am deeply grateful to each and every one, for inspiration, encouragement and practical help along the way.

Thank you, firstly, to the many individuals who kindly invited me into their homes and workplaces and shared their experience and insights; the housing associations that willingly gave me access to their schemes; the numerous practitioners and academics who generously shared their expertise. Thank you especially to the National Housing Maintenance Forum for invaluable advice and help.

In particular, thank you to my principal supervisor, Professor Fionn Stevenson, for challenging me to move way beyond my comfort zone, and for unwavering support and expert guidance throughout, and to Professor Karim Hadjri for thoughtful feedback on my efforts. A huge thank you as well to Dr Kate Morland for sharing the journey and filling the conspicuous gaps in my digital skills so willingly.

A heartfelt thank you to friends, family and colleagues, too many to name, who kept me going when this seemed a step too far – you know who you are and I couldn't have done it without you.

In the end, this is for SJB.

'One does not discover new lands without consenting to lose sight of the shore for a very long time'

André Gide, quoted by Lewis Minkin, who encouraged me to see the art in research, in *Exits and Entrances: Political Research as a Creative Art* (1997)

Abstract

Fresh air and low-carbon: a practice approach to maintaining home ventilation

The imperative to reduce carbon emissions, to counter climate change, demands that new dwellings are airtight to minimise heat loss. Airtightness amplifies the need for effective home ventilation, to prevent negative consequences for indoor air quality and thus for occupants' health. This research is rooted in the intersection of these critical concerns for housing – healthy indoor air and minimal carbon emissions.

Previous research has focused on the design, installation and operation of ventilation systems, but little attention has been given to the *maintenance* of ventilation in occupied homes, critical to ongoing effectiveness. This gap in knowledge is investigated in the context of low-energy housing association homes in England, aiming to understand what shapes maintenance practice and how it impacts on the effectiveness of ventilation in the long-term.

These questions are explored and explained through qualitative, interpretive research in five case-study housing schemes. Using a Practice Theory framework, the breadth and complexity of practices that influence ventilation maintenance are revealed. The findings suggest a new theoretical dimension to practices that deepens understanding of how ventilation practices are bundled, shaped and interact together. Illustrating how diverse practices obstruct ventilation maintenance in a typical low-energy housing association dwelling provides the basis for an alternative view, offering the potential for change as identified through key recommendations.

Without effective ventilation, maintained through the life of the dwelling, the health of residents will be at risk, a danger brought sharply into focus by the advent of Covid-19. Revealing through this research a deeper understanding of how ventilation is maintained in low-energy homes, cutting carbon emissions *and* providing healthy indoor air, is therefore significant and timely and demands that the crucial role of ventilation maintenance is embedded in housing practice.

List of contents

List of Tables

List of Figures

Declaration

I, Jennifer Brierley, confirm that the Thesis is my own work. I am aware of the University's Guidance on the Use of Unfair Means (*www.sheffield.ac.uk/ssid/unfair-means*). This work has not been previously been presented for an award at this, or any other, university.

Chapter 1. Introduction

1.1 Context

> Global warming is no longer a philosophical threat, no longer a future threat, *no longer a threat at all.* It's our reality. (McKibben 2010: xiii)

Reality in the current century is that climate change, as a consequence of global warming, threatens the future of life on this planet (IPCC 2014, 2018). Action to slow global warming requires deep cuts in emissions of CO_2, the most prolific greenhouse gas, created principally by the burning of fossil fuels – gas, oil and coal (IPCC 2013). The UK Climate Change Act 2008 established a legally binding carbon reduction target, with five-year carbon budgets as the key driver for delivery. While CO_2 emission reductions outperformed targets in the early carbon budgets, this is not projected to continue and more challenging measures will be needed in future to achieve zero carbon emissions by 2050, the UK target mandated in 2019 (Committee on Climate Change 2020a).

The domestic sector accounted for 27% of total energy consumption in the UK in 2018, second only in scale to the transport sector (Department for Business Energy & Industrial Strategy 2019a). Performance on greenhouse gas emissions follows a similar pattern, with dwellings accounting for 19% of all emissions in the UK in 2019, not including emissions from the energy supply sector attributable to domestic energy use (Department for Business Energy & Industrial Strategy 2020a). Space and water heating in dwellings consumes the bulk of this energy, using 25% of all energy and generating 15% of all emissions in 2017 (Committee on Climate Change 2019:27). For the most part, energy used in home heating is natural gas, a carbon fuel, that currently heats approximately 85% of UK homes. Although direct emissions from residential buildings fell by 9.6% in the decade to 2019, as higher temperatures reduced heating demand and energy efficiency improved, decarbonising domestic space and water heating continues to be one of the greatest challenges to achieving overall carbon emission reductions. Consequently, this imperative drives policy initiatives to increase heating energy efficiency and promote low-zero-carbon heating sources (Department for Business Energy & Industrial Strategy 2020b).

Preventing unplanned heat loss, by increasing the airtightness of dwellings, is an integral element of strategies to cut energy use for heating (Zero Carbon Hub 2013), thereby reducing carbon emissions generated by the domestic sector. The mandatory maximum air leakage from new homes in England has been progressively reduced in the last thirty years, to a current rate of $10m^3/hr/m^2@50Pa$ (see glossary) (Department for Communities and Local Government 2015). However, the proposed update to Building Regulations for England (Ministry of Housing Communities & Local Government 2019a) will require air leakage to be below $8m^3/hr/m^2@50Pa$ and indeed many new homes are already built to significantly higher standards of airtightness. For example, the rigorous, but voluntary, Passivhaus standard specifies a maximum air change rate of 0.6 ACH_{50} (see glossary), a differently calculated metric that defines a near-airtight dwelling (BRE 2014).

While all dwellings require effective ventilation, for the health and comfort of occupants and to prevent damage to the building fabric, as the airtightness of the building increases, attention to the ventilation strategy and performance becomes more critical. As Howieson et al. (2014) comment, 'a building cannot be too airtight, but it can be under ventilated' (Howieson, Sharpe, and Farren 2014: 475). Although natural ventilation may be considered an effective strategy, even for low-energy homes (McGill and Sharpe 2017; Passe 2015; Sassi 2013), this is contested with respect to highly airtight dwellings (Committee on Climate Change 2019) and indeed, proposed changes to the Building Regulations will restrict this option to less airtight dwellings. As a consequence of the highly airtight construction required to prevent heat loss and reduce carbon emissions, mechanical whole-house ventilation (see glossary) is expected to become the norm in new house building (Committee on Climate Change 2019; Ministry of Housing Communities & Local Government 2019e).

The interaction between heating, ventilation, building fabric, health and the environment is, however, complex and the unintended consequences of inadequate ventilation are well documented (Bone et al. 2010; Shrubsole et al. 2014; Shrubsole et al. 2015; Lomas and Porritt 2017). There is evidence that negative impacts may be exacerbated in densely occupied dwellings, typically rented properties occupied by low-income households (Shrubsole et al. 2014). Perversely, in homes intended to be highly energy efficient, inadequate ventilation may *increase* energy use and carbon emissions through unplanned heat loss and the use of mechanical cooling to mitigate overheating, an increasing concern in the UK as the climate warms. This research aims to understand how the effectiveness of ventilation in homes designed to a low-energy standard is obstructed or supported in occupied homes over time. A low-energy dwelling is defined in this research as having designed air permeability of less than or equal to $5m^3/hr/m^2$ at 50Pa (see section 3.3.1).

This study focuses on ventilation effectiveness in new-build properties, given the ultra-high level of airtightness that will be required in new dwellings and projections of build and demolition rates that indicate at least 20% of the UK housing stock in 2050 is still to be built (Boardman 2012). The scale of low-energy new construction by housing associations, and the particular challenge of adequate ventilation in low-income households, makes this an appropriate sector for the research. This focus enables exploration of the topic in the context of rented housing, where maintenance of ventilation by the association and day-to-day operation of ventilation by the resident both impact on its effectiveness.

1.2 Maintaining fresh air

> Clean air is a basic requirement of life. (World Health Organisation 2010: xv)

Indoor air quality (IAQ) (see glossary) describes the cleanliness or content of the air inside buildings, particularly as it relates to the health of occupants. Gases or particles released into the indoor air that may affect health arise from multiple sources, as wide-ranging and common as gas cookers, new carpets and furniture, cleaning products, and the materials used in construction of the dwelling. To these are added excess moisture in the air, the presence of biological agents, and polluted air from external sources.

The effects on health of polluted indoor air may be experienced in the short-term or after repeated exposure, although determining a specific link between exposure and symptoms is far from simple, given variations in the physical environment, individual sensitivity and underlying medical conditions. Nevertheless, the evidence indicates that the health impact can be severe (RCP & RCPCH 2016, 2020).

Added to the health risks of polluted indoor air, is the discomfort of stuffiness and smells in the home and, in the long-term, potential damage to the fabric of the property as a result of dampness and mould (Sustainable Homes 2018a). Although these impacts of 'poor' indoor air quality are well documented, there is no single accepted definition of 'good' indoor air quality and no legislation regarding air quality in homes in the UK. There are, however, metrics for a range of individual pollutants and guidance on standards (World Health Organisation 2009, 2010; Public Health England 2019).

Controlling pollutants at source is clearly the primary strategy for ensuring good IAQ (Woolley 2016) but the essential secondary strategy is to ensure adequate ventilation in the property. The objective of ventilation is to dilute pollutants in the air and disperse them to the outside. While this can occur naturally in buildings that allow infiltration through openings and gaps in the fabric and ventilation through opened windows and doors, as a result of air movement due to temperature differences between inside and outside air and due to wind, these means will not be adequate to ventilate an airtight building. In that case, mechanical means of ventilation are necessary, ranging from room-based extract fans and tricklevents where the fabric allows some natural air exchange to whole-house ventilation systems in highly airtight dwellings.

There is a complex relationship between airtightness, heating and ventilation. However, specifying and installing a means of ventilation and heating appropriate for the designed airtightness of a dwelling, as prescribed in the Building Regulations Approved Document F, does not ensure 'ventilation effectiveness' (see glossary):

> While it is possible to predict what the ventilation effectiveness of a system should be, there is currently insufficient knowledge of the actual ventilation effectiveness achieved in buildings to allow designers to guarantee performance. (Department for Communities and Local Government 2015: 16)

Given the increasing levels of airtightness achieved in new homes to reduce energy use, the relationship between airtightness, ventilation and air quality, and the evidence of health risks of polluted indoor air, it is argued that a lack of understanding of 'actual ventilation effectiveness' (ibid.: 16) is a significant gap in knowledge.

Approved Document F acknowledges that 'factors beyond the designer's control' (ibid.: 16) will influence ventilation effectiveness and specifically refers to occupant usage of the dwelling, although there is no mention of the impact of maintenance on the ongoing effectiveness of ventilation. It is evident that occupant usage of the dwelling impacts on the effectiveness of ventilation and indoor air quality, whether homes are ventilated naturally or mechanically (de Selincourt 2014). Post-occupancy evaluations (see glossary) of low-energy homes have referenced the impact of both dwelling-related factors and user-related factors on ventilation performance (Baborska-Narozny and Stevenson 2015; Innovate UK 2016b), although the impact of maintenance is rarely considered beyond referring to its importance.

The responsibility in rented housing for maintenance of the means of ventilation (dwelling-related) and the day-to-day operation of ventilation in the home (user-related) are divided between the owner (landlord) and the occupant (tenant). In a typical housing association, the landlord's maintenance responsibilities will be managed by in-house maintenance practitioners, with the operational tasks carried out by an in-house team or by external contractors or, commonly, by a mix of these arrangements. The practices of both maintenance practitioners, responsible for ensuring the means of ventilation are functioning effectively, and the practices of residents relating to ventilation in their homes, are thus relevant to the effectiveness of ventilation, and indeed these practices are interrelated in their impact. Understanding what promotes or hinders effective ventilation in housing association rented homes therefore requires investigation of practices both of maintenance practitioners and of residents, as well as the interrelationship between these practices.

1.3 Knowledge gap and research aim

The imperative to reduce domestic carbon emissions has driven the requirement for greater airtightness in new homes and focused attention on design, construction and ventilation technologies for low-energy homes. There is also a body of research focusing on how occupants experience low-energy homes in use (Baborska-Narozny and Stevenson 2015; Gram-Hanssen and Georg 2017). However, a literature search revealed little or no research aimed at understanding the practice of maintenance in low-energy homes. In particular, the maintenance and operation of ventilation in low-energy rented homes, from the perspective of maintenance practitioners and residents, appears to be unexplored.

The *knowledge gap* identified is how the multiple interrelated practices relating to the maintenance and occupation of low-energy homes influence the effectiveness of ventilation in these homes.

The *aim of this research* is to understand how the bundled maintenance practitioner and resident practices, and the interaction between these practices, influences the maintenance of effective ventilation and healthy indoor air in low-energy homes.

1.4 Research questions, objectives and scope

The research seeks to achieve this aim by answering three questions, as set out in table 1.

Table 1. Research questions

Research question	
RQ1	What are the key practices of maintenance practitioners and residents that shape the maintenance and operation of ventilation in low-energy housing association homes?
RQ2	What shapes the interaction between bundled practices related to ventilation and how does this impact on ventilation effectiveness?
RQ3	What are the underlying themes that inform the effectiveness of ventilation in low-energy housing association homes?

The objectives of the research, and how they address each research question, are shown in table 2.

Table 2. Research objectives

Research objective		RQ1	RQ2	RQ3
1	Explore the state-of-the-art in relation to the maintenance and operation of ventilation for low-energy homes	x		
2	Scope typical maintenance practices of UK social housing organisations in respect of ventilation in low-energy homes	x	x	
3	Investigate maintenance and operational practices in respect of ventilation in low-energy rented housing association homes, from the perspective of maintenance practitioners and residents	x	x	
4	Understand how the practices of maintenance practitioners and residents, and their interrelationship, influence ventilation effectiveness		x	x
5	Develop themes from the data that advance understanding of the maintenance of ventilation in low-energy housing association homes			x

The scope and limitations of the research are as follows:

- Low-energy new homes (see glossary, low-energy and home) are the focus of the study, defined in relation to airtightness (see 3.3.1), as future new homes are required to be highly airtight, necessitating effective ventilation to ensure healthy indoor air.
- Case-studies are housing schemes built between 2005 and 2015. Older schemes are typically built to a less airtight standard. Newer schemes do not offer sufficient experience of homes in occupation.
- The study will purposefully focus on housing association homes (see glossary), as this sector has taken a leading role in developing and managing low-energy homes and continues to be a significant developer of new homes in the UK.
- Research will focus on practice in England, as housing policy and regulations that influence practice vary internationally and within the UK.
- Rented homes will be the site of investigation, as practices in rented properties influencing ventilation maintenance involve both owners (landlords) and occupants (tenants) and the interrelationships between these parties.

- Low rent homes (see glossary) will be selected for study, as these are typically fully occupied, by households on low incomes, factors potentially influencing ventilation practice.
- The research will primarily investigate the practice of maintenance practitioners (see glossary) and residents (see glossary), as well as considering their interrelationship with each other.

1.5 Research approach and design

The ventilation problem identified is typically conceptualised in terms of technology (ventilation equipment), behaviour (residents' individual decision-making) or legal structure (contractual landlord and tenant relationship). However, it is argued that these approaches offer only a partial and inadequate understanding of the issue.

By contrast, a practices approach (Schatzki 2002; Gram-Hanssen 2009) is taken in this research, which regards human activity (in this case, the activities of maintaining means of ventilation, day-to-day living and ventilating the home, and communication between landlord and tenant) as a field of interwoven practices. Individuals and organisations are regarded as practitioners or carriers of practices, which are created, reinforced, abandoned and changed through their myriad actions. Thus, multiple practices interact to sustain, or compromise, effective home ventilation.

The research design, illustrated in figure 1, sets out an exploratory study of the research topic, taking an interpretive philosophical stance and using both inductive and abductive reasoning. A practice-based theoretical framework is adopted, taking the definition of Practice Theory developed by Gram-Hanssen (2009) as the basis.

The methodology adopted is qualitative, using multiple methods. The initial stage uses survey and focus group methods to scope the topic, leading to the core data collection through a small number of in-depth case-studies.

The case-study design employs interviews, observation and document study methods, in one time period. Case-studies are selected using an 'information-oriented' approach (Flyvbjerg 2006: 230) to provide the widest variation of characteristics relevant to the research topic as defined in 1.4, within a small number of examples.

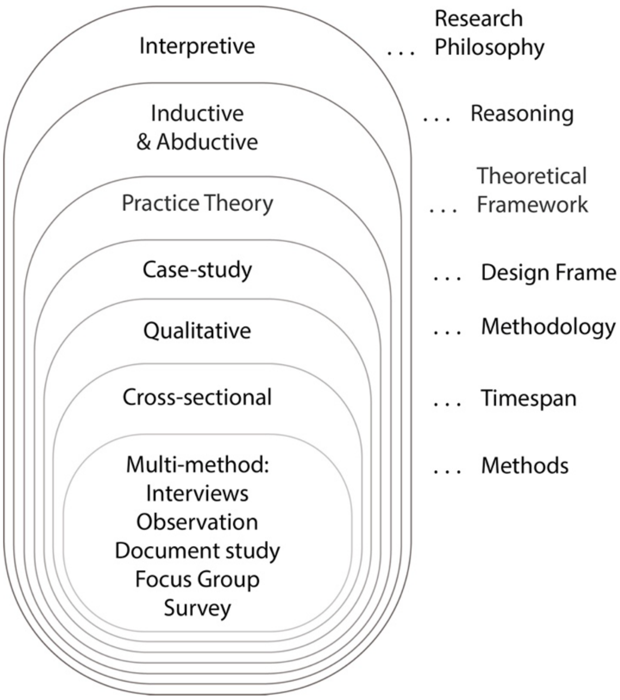

Figure 1. Research design

After Saunders (2007: 102)

1.6 Thesis structure

Table 3 outlines the scope of each chapter and sets out the structure of the thesis.

Table 3. Thesis structure

Thesis chapter		Chapter content
1	Introduction	Context of climate change, reduction of domestic carbon emissions, airtight homes and ventilation Definition of fresh air, impact on health, ventilation strategies Knowledge gap and research aim Research questions, objectives and scope of the study

		Approach and design of the research and thesis structure *The following chapter locates the work within a theoretical framework, explaining the reasons for the approach selected.*
2	Practice Theory framework	The roots, development and continuing evolution of Practice Theory, link with philosophical standpoint. Practice-based energy research, rationale for adopting this framework and Gram-Hanssen's definition. *In the next chapter, the research topic is located in its wider context and the gap in knowledge is evidenced.*
3	Home ventilation: state-of-the-art	Critical review of literature, including grey literature, existing research and current policy and practice, related to low-energy housing, ventilation, air quality and health. Gap in knowledge explored and evidenced. *The methodology and methods for investigating the gap in knowledge, using the theoretical framework adopted, are explained in the next chapter.*
4	Methodology	Methodological approach and rationale, data collection methods, analysis methods. *The following chapter sets out the results of the application of each data collection method.*
5	Results	Outcome of each stage of data collection, survey, focus group, case studies. *In the next two chapters, the empirical data collected is analysed using the analysis methods set out in chapter 4, within the theoretical framework adopted. Data related to residents is analysed in chapter 6 and data related to maintenance practitioners in chapter 7.*
6	Analysis: Resident practice and perspectives	Practice, experience and perspectives of residents analysed, using framework described in chapter 2. *The data related to maintenance practitioners is analysed in the next chapter.*
7	Analysis: Maintenance practitioner practice and perspectives	Practice, experience and perspectives of maintenance practitioners analysed, using framework described in chapter 2. *In the next chapter, the first theme in the data, the concept of Time Horizons and its influence on practice, is discussed.*
8	Discussion: A concept of Time Horizons	A concept described as Time Horizons is defined and related to notions of time in the literature and to Practice Theory specifically. Drawing on the analysis in chapters 6 and 7, the influence of Time Horizons on ventilation maintenance practice, as performed by residents and maintenance practitioners, is discussed.

		The interrelationship between resident and maintenance practitioner practice is considered, with reference to Time Horizons. Relevance of Time Horizons to understanding the research topic is discussed. *In the following chapter, the second theme in the data, the influence on ventilation of interactions between bundled practices, is discussed.*
9	Discussion: Bundled practices, interactions and ventilation	Nature of interactions between bundled practices in relation to ventilation practice discussed, drawing on the analysis in chapters 6 and 7. Relationship between the two themes is explored by considering the nature of interactions and the influence of Time Horizons at points in the lifespan of a low rent, low-energy home. *In the final chapter, the research questions are answered, drawing on and integrating the two themes and relating the findings to the literature. The contribution and limitations of the research are considered and directions for future work are suggested.*
10	Conclusion	Aim and context of research summarised. Key findings in relation to the research questions, with reference to the literature and the themes in chapters 8 and 9. Contribution to knowledge, theory, practice and policy. Reflections and limitations. Recommendations for dissemination and further research.

Chapter 2. Practice Theory framework

2.1 Introduction

Following the introduction to the thesis in chapter 1, this chapter sets out the philosophical underpinning for the research and introduces the theoretical framework adopted. The rationale for a practice-based approach is explained.

This is followed in chapter 3 by a review of the state-of-the-art regarding ventilation maintenance, evidencing the gap in knowledge. The methodology is then set out in chapter 4, designed to investigate the knowledge gap using the practice-based framework outlined in this chapter.

2.2 Philosophical standpoint

The interpretivist philosophical and ontological concept of reality underpinning this research, reflecting the researcher's worldview (Willis and Nilakanta 2007), contends that the quality of ventilation in dwellings has real-world consequences and that the habits, knowledge and beliefs of individuals in respect of this issue, though these may be contradictory and only partially observable, are meaningful in shaping action and experience. The theoretical framework adopted for this research, consistent with this interpretivist philosophical stance, is outlined in this chapter. While social theories can 'never reach the bedrock of a real social world' (Reckwitz 2002: 257), a means of conceptualising the research questions and an 'ordering-framework' (Sayer 1992: 50) contribute to achieving a sound understanding and interpretation of lived experience.

The theoretical lens underpinning this research inevitably influences what the researcher sees and the emphasis placed on particular issues and instances (Spaargaren, Lamers, and Weenink 2016). Practice Theory, the lens applied to this research, is not a single, well defined approach that determines a specific methodology. Nevertheless, the essential elements that collectively constitute a practice-based approach influence every step of the research design. The focus of Practice Theory on how people and organisations act in the real world is particularly suited to this research topic, investigating practices in everyday domestic life.

2.3 The roots of Practice Theory

A growing body of research in the field of domestic energy consumption uses Practice Theory as a construct to understand what is observed in real-life situations (Warde 2005; Shove et al. 2008; Røpke 2009; Gram-Hanssen 2010, 2014). As Schatzki (1997) acknowledged, the nature of practices and analysis of social phenomena varies widely between social theorists and thus 'the term *practice theory* designates at best a family of accounts' (Schatzki 1997: 284). Indeed Practice Theory may not be an adequate term for this approach, which according to Schatzki is more accurately characterised as a 'humanistic type of social theory' (Nicolini 2017: 24). Setting this debate aside, the terms Practice Theory, practices and practice-based framework are used to describe the approach adopted in this thesis.

While there are significant variations in how practices are defined, the roots of the theory lie in the work of Schatzki and Reckwitz around the turn of the last century (Schatzki 1997; Reckwitz 2002; Schatzki 2002), building on earlier work by Bourdieu and Giddens. Bourdieu (1977) and Giddens (1984) explored how social structures emerge, persist, develop and change. Bourdieu cited the notion of 'habitus' as an explanation of human behaviour, expressed as skills and practical know-how, internalised in the body and mind and acted out by habit. Giddens expanded on Bourdieu's work, proposing, in his Structuration Theory, that social institutions and ways of life are continually reproduced and reinforced through the relationship between 'structure' and 'agency'.

Schatzki (1997), influenced by Wittgenstein (1958), criticised Bourdieu's and Giddens' 'overintellectualizing accounts of human activity' (Schatzki 1997: 283). He asserted that they failed to grasp the 'practical nature of practical understanding' (ibid.: 300), as expounded by Wittgenstein, and had adopted instead a formulaic analysis of daily life.

In Giddens' view, 'practices' are realised through shared understandings that people hold in the form of formal or informal rules. However, the assumption that habit and rules alone could fully explain human action was contested by Schatzki, who added a third dimension to the notion of practices, the role of meanings, linked to aims or purposes, that he called 'teleoaffectivity' (Schatzki 1997: 300). Thus the field of practices that Schatzki defined as 'nexuses of activity…rooted in shared understandings' (Schatzki et al. 2001: 9), comprised three dimensions: skills and practical know-how expressed as habit, explicit rules, and meanings. Schatzki described this analysis of social life as 'a Wittgensteinian-inspired multicomponential account of practice and action' (Schatzki 1997: 300).

A further dimension was added to the understanding of social practices through the work of Reckwitz in respect of the impact of material objects on human activity:

> For practice theory, objects are necessary components of many practices – just as indispensable as bodily and mental activities. (Reckwitz 2002: 252)

Reckwitz is here building on Latour's definition of material objects as 'actants' in human activity (Latour 1993), a key component of Actor-Network Theory, in which human and non-human actors/actants are accorded equal treatment. Indeed, Lystbaek (2018), drawing on Nicolini (2013), asserts that 'practices without material resources are not conceivable' as it is objects that make practices 'durable and interconnected across time and space' (Lystbaek 2018: 366).

Schatzki acknowledged that human activity is 'materially mediated' (Schatzki et al. 2001: 11) and later incorporated 'material arrangements' as a socio-technical dimension in Practice Theory (Schatzki 2010: 129). His work thus links directly to the understanding of Practice Theory adopted by current researchers in the field of energy consumption (Shove et al. 2008; Gram-Hanssen 2010), compared in section 2.7.

In this research, material things, the physical means of ventilating the home, are key to understanding ventilation practice. For maintenance practitioners and residents in low-energy homes, the introduction of unfamiliar ventilation 'things' relevant to airtight dwellings, and accompanying changes in ventilation 'rules', challenge established ventilation ‘habits’ and ‘meanings’. The socio-technical nature of the research topic therefore makes a practice-based approach that incorporates material things as a key component of practices particularly apposite.

2.4 A ‘flat’ ontology

Schatzki explains his view of social reality as a ‘flat’ ontology (Schatzki 2016), a reality in which social life is made up of a non-hierarchical collection of events, entities and arrangements, with equal ontological status. Nicolini concurs, defining practice-based theory as a social ontology, ‘a new and still tentative form of empirical philosophy’ (Nicolini 2017: 26). A practice-based approach to empirical research (a practice in its own right?) is adopted in this investigation of domestic ventilation, taking Schatzki’s view that a non-hierarchical ontology is able to enrich our understanding of the practice and frees the researcher to interpret this social phenomenon in new ways.

Schatzki (2016) specifically challenged Giddens’ notion of a duality between structure and agency and argued that objects and people are equally active in ‘bundles’ of practices. Although Schatzki asserted that all social life exists on a single level, organised only by interactions in time and space, he did not claim that a ‘flat ontology’ reflects an equality of influence or outcome. As Shove (2017) points out:

> It’s the ontology that’s flat, not the social world itself. In other words, ‘flat’ does not mean lacking in mountain ranges of inequality and power. (Shove 2017: 3)

The real-life world of housing in the UK exhibits massive inequalities of power and outcome (Chartered Institute of Housing 2020). Although inequalities are not the principal focus of this research, the literature confirms that those living in social housing are more vulnerable to the impact of ineffective ventilation. Consequently, this investigation is targeted at ventilation maintenance in low-energy housing association homes.

2.5 Collective and individual practices

Practices, rather than individuals, are the starting point for this investigation of ventilation in the home and represent the 'unit of analysis', with individuals being regarded as 'carriers' of practice (Reckwitz 2002). As Giddens observed, the focus of study 'is neither the experience of the individual actor, nor the existence of any form of societal totality, but social practices ordered across space and time' (Giddens 1984: 2). Nicolini argues that social practice theorists therefore seek 'to navigate the choppy waters between the *Scylla* of methodological individualism…and the *Charybdis* of old structural notions' (Nicolini 2017: 20). Analysis in the current study therefore aims to reflect that the social activities under investigation are rooted in, and living, through ventilation practices and their connections (Schatzki et al. 2001).

Schatzki's definition of practices as 'embodied, materially mediated arrays of human activity centrally organised around shared practical understanding' (Schatzki et al. 2001: 2) places the emphasis in this research on a *collective*, rather than *individual*, understanding of ventilation. While Schatzki emphasises that practices are 'collective possessions and accomplishments sustained through interaction and mutual adjustment among people' (Schatzki et al. 2001: 6) he nevertheless recognises the role of the individual:

> The skilled body commands attention in practice theory as the common meeting point of mind and activity and of individual activity and society. (Schatzki et al. 2001: 2)

However, by emphasising the *practice* as the unit of analysis, rather than the *performer* of the practice, i.e. de-centring the subject, Practice Theory takes the focus away from the personalities of the actors involved (Shove 2017: 3). Schatzki asserts that the practice, not the individual, is 'the site of the social' (Schatzki 2002: 123), i.e. the source of action. The ontological nature of a practice is, however, the subject of debate, which questions 'in what sense do practices exist?' (Galvin and Sunikka-Blank 2016: 65). Shove and Pantzar (2007) and Hui and Spurling (2013) attribute 'careers' to practices and the capacity to 'recruit' individuals. However, Shove and Pantzar note that they 'have not gone as far as to attribute agency' to practices (2007: 166) and Hui and Spurling stress that taking practices as the unit of analysis ‘does not mean we should lose sight of individual lives’ (2013: 1). Galvin concludes that ‘a practice is a *heuristic device* rather than a publicly knowable, ontologically robust entity’ (Galvin and Sunikka-Blank 2016: 65) and consequently questions the notion that a practice takes precedence over an individual.

Notwithstanding these debates, this study seeks to answer the research questions by engaging in depth with individuals, to understand *collective* ‘open-ended sets of doings and sayings’ (Schatzki 2002: 87) as well as *individual* ‘doings and sayings’ regarding the activity of maintaining ventilation performance. Despite focusing on the practice rather than the individual, it is recognised that the personalities of both researcher and research subjects will impact on the process, and a reflective approach (England 1994) is adopted in the research (see 4.2.3).

2.6 Practices as entities and performances

Practice Theory shifts the emphasis, and research focus, from ventilation action in general to ventilation ‘practices’. Reckwitz draws the distinction between ‘practice’ (in German, *Praxis),* describing human action in general, and ‘practices’ *(Praktik),* a routinized type of behaviour, ‘a pattern which can be filled out by a multitude of single and often unique actions reproducing the practice’ (Reckwitz 2002: 250). Thus, ventilation practices are continually being made and re-made, forming, changing and disappearing. Investigating features of the phenomena of ventilation through the lens of Practice Theory therefore requires these processes to be in the foreground.

The emphasis is thus shifted away from instances of individual decision making towards the ‘doing’ or ‘performing’ of social activities that make up everyday life in relation to ventilation. Individuals are not, however, rendered as ‘passive dupes beholden to the dictates of practice’ (Hargreaves 2011: 83), but regarded as skilled agents who negotiate and perform a multitude of practices throughout their daily life in relation to ventilation. The individual acts as a ‘carrier’ of the practice, which through multiple, slightly varying, repetitions in daily life undergoes incremental change.

Hence Schatzki's description of human coexistence as a 'constantly evolving nexus of arranged things and organized activities' (Schatzki 2002: 60), an unstructured pattern of social life characterised by practices that form and re-form into 'bundles' in the course of time. 'Bundles' of practices interweave and influence each other (Schatzki 2002: 71), as this study reveals in relation to the research topic of ventilation. Indeed, Shove questions whether studying practices as discrete entities may hinder the researcher in recognising, empirically and theoretically the interactions between them (Shove 2017: 4).

In this study, the interaction between practices is central to understanding what shapes ventilation effectiveness and is embedded in the research questions. Interaction between practices is taken here to mean the influence that practices have on each other as they are performed and interweave in the course of social life. This is not a mechanistic interdependence, but a variable reciprocal influence on how practices are performed, take shape and evolve. A widely framed investigation of the diverse practices that 'bundle' together, and the interrelationships between performers of the practices, will allow the research to uncover new knowledge of significant practices that exert an influence of ventilation but may be hidden.

Taking Practice Theory as the analytical framework for this study will facilitate the broad approach to the topic reflected in the research questions. Nevertheless, it is acknowledged that 'embedded motivation behind the performance of practices' (Jensen et al. 2018: 2) may not be readily observable. Spurling et al.'s iceberg analogy (Spurling et al. 2013: 8), see figure 2, neatly illustrates that the performance of practices typically consists of both 'tangible aspects that lend themselves to immediate observation, and deeper, and for the most part unobservable aspects' (Jensen et al. 2018: 2).

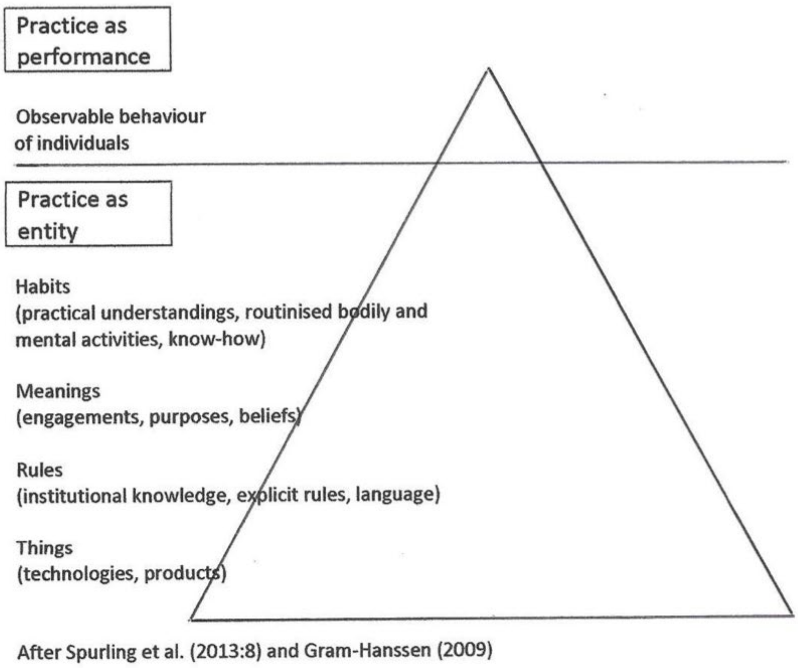

Figure 2. Practices 'iceberg'

The aim of this study is to explore not only the observable practice-as-performance of ventilation maintenance, in Spurling's words 'the observable expression of (a) social phenomenon' (Spurling et al. 2013: 8), but to understand the practice-as-entity, the 'socially embedded underpinning of behaviour' (ibid.) that is largely unobservable.

Although the concepts of performance and entity in relation to ventilation practices may be separated analytically, as illustrated in figure 2, these elements are 'fundamentally connected and mutually configuring' (Spurling and Blue 2014: 6). Moreover, Spurling and Blue conclude that analysis of practices is only of value for understanding change if the iterative relationship between these concepts is fully recognised.

Jensen et al. (2018) highlight the need for a practice approach to social scientific energy research, that 'explicitly recognizes complex interactions in the social organisation of everyday life' (Jensen et al. 2018: 1). A sound evidence base in the study of ventilation practice similarly requires a broad approach, avoiding the 'dominant focus on technical data…contextualised by a narrow palette of social science knowledge (e.g. behavioural economics)' (Jensen et al. 2018: 2). Sovacool et al. (2015) concur wholeheartedly with this view, reflecting that in energy research 'more attention is paid to the hardware than to the human software behind it' (Sovacool et al. 2015: 96).

2.7 Elements of Practice Theory

Exploring through empirical research the problem of maintaining ventilation performance in low-energy homes, the approach of Gram-Hanssen to Practice Theory, emphasising the socio-technical determinants of social practices, will be followed (Gram-Hanssen 2008, 2009). Gram-Hanssen's extension of the definitions of a social practice espoused by Schatzki and Shove make her work particularly relevant to this socio-technical study as discussed next. Four components that Gram-Hanssen (2009: 54) defines as holding together a practice, evolved from Schatzki's later work, are the basis for the fieldwork and analysis:

- Practical understandings – embodied habits and know-how
- Rules – institutional knowledge and tacit rules
- Engagements – meanings
- Products – technologies and material structures

Gram-Hanssen (2010) builds on Schatzki's notion of 'explicit rules' as an element of practices, an element that is not included in Shove's definition. While Schatzki excludes tacit knowledge or implicit rules, Gram-Hanssen, in her study of heat comfort practices, includes 'cultural myths of heating systems and energy consumption' (Gram-Hanssen 2010: 177) as well as technical knowledge and rules. Gram-Hanssen's finding that householders may define a healthy indoor environment with reference variously to scientific rules or cultural myths is relevant to understanding what influences home ventilation practices.

In addition, Gram-Hanssen's view, shared by Shove, that 'things' are a constituent element holding practices together, rather than simply a result of social practices as held by Schatzki, is consistent with the socio-technical nature of ventilation maintenance practice.

A comparison of three approaches to Practice Theory is shown in Table 4.

Table 4. Elements holding a Social Practice together

Elements holding a Social Practice together		
Schatzki (2002)	Shove and Pantzar (2005) Shove (2012)	Gram-Hanssen (2008, 2009,2010)
Practical understandings Practical skills, know-how Habit Includes tacit or implicit rules	**Competences** Skill, know-how, technique Includes implicit rules	**Practical understandings** Routinised bodily and mental activities Know-how Habits
Explicit rules How to do things What is allowed and what is not	*Explicit rules not included as an element of practices*	**Rules** Institutionalised knowledge Language Tacit rules
Teleoaffective structures Desires, beliefs, expectations General understandings	**Meanings** Symbolic meanings, ideas, aspirations	**Engagements** Meaning Purposes Beliefs
Things and technologies form 'material configurations', co-produced with practices but not part of them	**Materials** Things, technologies, tangible physical entities, the stuff of which objects are made	**Products** Things Technologies

The four components described by Gram-Hanssen help to structure the research but are not regarded as prescriptive or a complete and final explanation of human activity. As Nicolini (2017) asserts, conduct is never fully determined and, moreover, practices emerge, change and fade. Nevertheless, using Practice Theory to investigate ventilation practices enables an understanding and explanation in terms of socio-material elements that is stronger and deeper than mere description.

2.8 Practice Theory and change

The changing nature of ventilation practices, through adaptation to new circumstances in everyday life as homes become more airtight, makes Practice Theory particularly attractive as the framework for this study. Exploring the changing nature of ventilation maintenance practice in low-energy homes is necessary to understand it in depth, recognising that a practice contains:

> The seeds of constant change…as people in myriad situations adapt, improvise and experiment. (Warde 2005: 141)

Indeed, Nicolini (2013) is emphatic that individual creativity in the performance of practices is not simply desirable or possible but essential, as performing a practice 'is not a mindless repetition of routines, but requires adapting to new circumstances' (Lystbaek 2018: 366).

As well as providing a framework for understanding ventilation practices, Practice Theory offers insights into how change in practices might come about. Watson (2016) contends that conceptualising real life action through Practice Theory gives a distinctive insight into explaining not just what we do, but where change may occur through changing practices. This leads him to a strong critique of the 'behaviour change' agenda, asserting that we:

> Need to understand the practices of policy and other institutions as much as of householders if we're to tackle thorny issues that are bound up in much more distributed sets of relationships between practices. (Watson 2016: no page no.)

Jensen et al. emphasise that how a particular problem, for example maintaining effective ventilation, is framed reflects 'the underlying ideas about how change can come about, as well as what kind of change may come about' (Jensen et al. 2018: 3). This is exemplified in the work of Spurling et al. (2013) who propose a theoretical framework for energy research that takes a broad-based practice perspective. They distinguish between problem framings evident in current policy interventions (i.e. innovating technology, shifting consumer choices, achieving behavioural change) and problem framings based on a practice perspective (i.e. re-crafting practices, substituting practices, changing how practices interlock) (Spurling et al. 2013: 5). Re-framing the problem of maintaining ventilation by taking a practice perspective in this research may indicate new interventions to bring about change.

Regarding intervention in practices to bring about social change, whether the practices of individuals or organisations, Galvin underlines that 'a "practice" cannot initiate a chain of causality in the classical sense of cause and effect, because only real things can do that' (Galvin and Sunikka-Blank 2016: 66). Nevertheless, a practice approach to understanding the social world may indicate interventions to disrupt the habits, contexts or materiality of a practice to bring about change.

Whatever problem framing is adopted in practice-based energy research, it is argued by Galvin and Sunikka-Blank (2016) that such research will be undermined if it does not engage with socio-economic factors. The extent to which this study addresses factors such as income, race and gender is considered in the limitations of the research at 10.4.2.

2.9 Sub-conclusion

While Practice Theory does not constitute a real description of the world, a hypothesis or predictive model, Gram-Hanssen's exposition of Practice Theory offers a fitting lens through which to explore and understand ventilation maintenance practices. This theoretical approach, focused on how people and institutions act in the real world, performing and shaping practices and bundles of practices, is consistent with the interpretivist philosophical standpoint of the research and offers a framework for achieving a deep understanding of the research topic.

The methodological choices made throughout this research (see chapter 4) seek to maximise the potential of a practice-based approach, while being cognisant of the risk of over-emphasis on description (Nicolini 2017). The analysis therefore focuses on the dynamic aspect of practices related to the maintenance of ventilation, as they are performed and interact, rather than simply describing the elements that constitute the practices. As practices only acquire meaning when taken in context (Schatzki 2002), rich description is the aim, but the analysis goes beyond this to interpret the data and answer the research questions.

Although ventilation *practices,* rather than *individuals* performing these practices, are the focus of analysis, engaging with individuals is inherent in the researcher's approach. Recognising maintenance practitioners and residents as skilled individuals in how they navigate everyday life, emphasises the *social* aspect of ventilation practices, avoiding over-emphasis on the changing *technical* aspect of ventilation as homes become more airtight.

As set out in this chapter, using a practice-based framework to investigate ventilation maintenance offers the potential for uncovering hidden practices that exert an influence on ventilation and identifying new interventions where practices are hindering effective maintenance. In the next chapter, the state-of-the-art regarding ventilation maintenance is explored, locating and refining the gap in knowledge.

Chapter 3. Home ventilation: state-of-the-art

3.1 Introduction

The broader context for this research is the housing sector's response to the reality of increasing anthropogenic climate change, in particular in the design, construction, maintenance and management of low-energy homes. This chapter sets out to review current knowledge on the impact of the increasing airtightness of homes, aimed at cutting carbon emissions, on the maintenance and operation of those homes (see methodology at 4.4.1).

This exploration confirms the gap in knowledge regarding the maintenance of ventilation and its significance, given the consequences of ineffective ventilation for residents' health. Current practice regarding maintaining and living in low-energy homes in respect of ventilation, and its policy context, is outlined, setting the agenda for the research methodology explained in the following chapter.

3.2 Environment and housing

3.2.1 Zero-carbon housing

The potential effects of climate change in the UK have been recognised by the Government for decades (United Kingdom Climate Change Impacts Review Group 1991). Following increasingly urgent warnings by a majority of climate scientists of the catastrophic impacts of climate change if global temperatures continue to rise (IPCC 2018), a target of zero greenhouse gas emissions across all sectors of the UK economy by 2050 was legislated in 2019, amending the previous legally-binding target of 80% reduction in emissions by 2050 from a 1990 baseline (Government 2008).

In order to deliver the zero target, deep cuts in carbon emissions will be required by 2030. Given that 19% of carbon emissions in the UK in 2019 came from the domestic sector

(Department for Business Energy & Industrial Strategy 2020a: 5), it is imperative that the sector understands and reduces the environmental impact of its practices.

Accepting the urgency of reducing carbon emissions in the housing stock, the UK Government plans to mandate a Future Homes Standard (see glossary), applicable to both new and existing homes by 2025. The target is a 75-80% reduction in emissions, compared to 2013 Building Regulations for new homes, as a stepping-stone to zero emissions by 2050 (Ministry of Housing Communities & Local Government 2019e).

Regardless of the source of heat, reducing heat loss from homes is essential to cut energy use, particularly as this loss adds significantly to carbon emissions while domestic heating continues to rely on fossil fuels. Achieving zero carbon emissions from homes therefore requires not only ultra-high levels of insulation, but a high degree of airtightness in the building fabric (see glossary, zero carbon homes).

As a consequence, a means of ventilation that will ensure adequate indoor air for the health of residents, without compromising the airtightness of the dwelling, must be designed and installed. In order that heat loss is minimised and healthy indoor air is available for the long-term, it is essential that effective ventilation is maintained through the life of the dwelling.

3.2.2 Airtightness and ventilation

The 2019 UK Committee on Climate Change report on housing highlighted the central role of mechanical ventilation systems in future new homes and asserted that:

> There is an urgent need for further work to ensure these systems are designed, commissioned and installed properly, and that householders are supported to use and maintain them effectively. (Committee on Climate Change 2019: 68)

Indeed, the report specifically pointed to the need for:

> Further research into how challenges in *maintaining* and *operating* them (i.e. mechanical ventilation systems) can be overcome. (Committee on Climate Change 2019: 68) (author's italics)

It appears, however, that these challenges are not yet recognised in the house building sector. Alongside the consultation document regarding Building Regulations in England (Ministry of Housing Communities & Local Government 2019e), the Government published an evaluation of ventilation in new homes built to the energy efficiency standard required in the current Building Regulations (Ministry of Housing Communities & Local Government 2019f). Only 4% of the 80 homes studied, designed with either natural ventilation or continuous mechanical extract, met the statutory guidance for means of ventilation. The report concluded though that non-compliance with required provision did not fully explain the relatively high pollutant levels found, attributing this, at least in part, to resident behaviour, such as switching off noisy fans.

However, the evaluation did not consider the practice of residents in detail and made no mention of maintenance of ventilation equipment. This gap in knowledge drives the current research, which aims to explore the ventilation of new homes built to a high level of airtightness, employing various ventilation strategies, focusing specifically on maintenance and operation from a practice perspective.

A further aspect of ventilation that is of increasing significance is its role in resilience to climate change, as considered in the next section.

3.2.3 Adaptation and resilience

It is generally accepted by the international scientific community that reducing greenhouse gas emissions will slow the rate of global warming, but will not stop this process and the ensuing climate change (UNFCCC 2017).

UK climate predictions indicate that increasing summer temperatures, more extreme weather events, and rising sea levels, are likely in this century (Met Office 2018). Smith (2010) predicted that only 'radical revision of the building regulations' (Smith 2010: 49) would succeed in achieving resilient homes capable of withstanding these climatic changes. However, despite the increasing prevalence of flooding of residential areas, storm damage to homes and overheating dwellings, it appears that the UK housing sector is slow to act to increase the resilience of homes to these changes.

It is particularly concerning that social housing organisations have apparently taken little action to improve housing resilience, with landlords mainly adopting a reactive approach, responding to issues as they arise (Sustainable Homes 2018b), especially as households vulnerable through socio-economic or health status are over-represented in social housing, which is often located in areas of low environmental quality. Indeed, research by the European Environment Agency (EEA) found that:

> Climate change can worsen poverty, and conversely poverty increases vulnerability to climate impacts. (European Environment Agency 2018: 66)

While action to decarbonise the housing stock will contribute to mitigating climate change, the effective ventilation of homes plays a significant role in ensuring resilience to overheating. The intersection of increasingly airtight homes and hotter UK summers adds significance to the effective ventilation of homes. The particular vulnerability of residents in low rent social housing to both poor air quality and overheating, as an aspect of lack of resilience, is explored in section 3.5 and informs the scope of this research.

3.2.4 Low-energy homes and housing associations

Housing associations (see glossary) manage 2.45m homes across England, just over 10% of the total housing stock (Ministry of Housing Communities & Local Government 2019b). New build dwelling starts in 2018-19 by housing associations totalled 27600, approx. 17% of starts for all tenures in England (Ministry of Housing Communities & Local Government 2019d). They have been in the vanguard in building and retrofitting low-zero-carbon homes and have long been expected by Government to pilot innovations in the housing sector to reduce carbon emissions (Department for Business Innovation and Skills 2010). The scale of low-energy new build stock in housing association ownership and plans to build over

1million new homes over the next 10 years (House of Commons 2020) makes investigation of ventilation practice in that sector significant.

Although housing associations are independent businesses, as recipients of public funding, their finances and activities are tightly regulated. The regulation framework has varied over time, currently comprising, for housing associations in England, the Regulator of Social Housing and Homes England (see glossary). The influence of regulation on housing associations is relevant to understanding practices that impact on ventilation effectiveness and is a gap in research that this study will address.

The key driver for housing association investment in energy efficiency has typically been concern about fuel poverty (see glossary). In a recent survey (National Energy Foundation 2017), 84% of housing associations rated reducing fuel poverty and increasing affordability for tenants as a motivation for investing in low-energy retrofit, whereas only 17% considered that climate change was a factor in making the investment.

Although housing association tenants may be living in energy-efficient properties, with high levels of airtightness and appropriate ventilation in place, the financial circumstances of the household could impact on ventilation practices. For example, switching off mechanical ventilation might be used as a practice believed to save electricity and heating costs (National Energy Foundation 2015). The impact of low income on residents' ventilation practice in low-energy homes will be investigated in this study.

At a time of acute housing shortage in the UK, it is unsurprising that Government policy regarding new house building is heavily focused on quantity (Department for Communities and Local Government 2017). However, given the pressing need to reduce domestic carbon emissions, tackle fuel poverty, and future-proof homes against the effects of anticipated climate change, it could be argued that focusing on quality, particularly environmental standards, is equally important (Boardman 2012; Manchester City Council 2016).

The increase in house building required to address housing shortage, at levels of airtightness that will contribute to ultra-energy efficient performance and cut carbon emissions, focuses attention on the means of ventilation in new homes and its impact on indoor air quality. This research reflects the importance of this aspect of low-energy housing in use, exploring in particular the practices of maintaining and operating ventilation in low rent homes in the housing association sector in England.

3.3 Ventilation context

3.3.1 Defining 'low-energy'

A plethora of standards defining the 'rules' for low-energy homes are commonly in use (see glossary), varying significantly between countries and, even within the UK, between different policies, regulations and databases. Terms such as 'zero-carbon' or 'zero-net energy' or 'energy-plus' can indeed be misleading, as they may exclude carbon emissions produced during construction, an increasing proportion of overall emissions over the lifetime of a dwelling. Moreover, 'rules' that relate to the operational phase of a home may include only the energy and emissions related to space and water heating, ventilation and fixed lighting (see glossary, regulated emissions), taking no account of practices associated with appliances and household activities (Williams 2011).

The research gap identified (see 1.3) relates to the ventilation of homes intended to reduce energy use through a high level of airtightness (see glossary). 'Low-energy homes' are therefore defined, for the purpose of this research, in relation to the designed airtightness, being homes with a design air permeability (airtightness of the building fabric) less than or equal to $5m^3/hr/m^2$ at 50Pa, i.e. $5m^3$ of air leakage, per hour, per m^2 of the building envelope, at 50 Pascals pressure. This defines a more airtight building than the Building Regulations currently permit, set currently at a maximum air leakage of $10m^3/hr/m^2$ at 50Pa.

3.3.2 Ventilation design practice

All homes, whether designed to be low-energy according to this definition or not, require a means of removing stale and/or moist air and replacing it with fresh air, in order to maintain a healthy indoor environment. The practice of uncontrolled ventilation has traditionally met this need, though with erratic outcomes and at the cost of losing heat through a 'leaky' building envelope. Preventing the build-up of humidity and poor air quality in dwellings requires controlled ventilation as a practice.

Building Regulations for new homes in the UK consequently specify ventilation rates (see glossary) consistent with the *designed* level of airtightness (Department for Communities and Local Government 2015). As the need to reduce carbon emissions intensifies, airtightness and ventilation requirements are expected to become more demanding (Ministry of Housing Communities & Local Government 2019a). In addition, future regulations are expected to take *as-built* airtightness into account, which may differ from as-designed, ensuring that ventilation is sufficient where airtightness exceeds the intended level.

As indicated in section 3.2.2, practices of operation and maintenance of ventilation may result in inadequate ventilation *in use* (see 3.3.4), regardless of the design strategy adopted. An understanding of ventilation practices in use, performed both by residents and maintenance practitioners, is therefore the focus of this research.

3.3.3 Ventilation and housing standards

Housing developers may, in addition to meeting the mandatory requirements, aim for accreditation under one of several voluntary schemes established to promote low-energy building standards (see glossary). Private developers' practice is to use an independent assessment of build quality mainly to promote their sustainability credentials to prospective buyers, with the objective of gaining market differentiation and commercial advantage.

Housing associations, by contrast to private developers, have been required by Government, as a condition of grant funding, to produce new homes to higher standards, which have varied considerably over time. Consequently, the airtightness and ventilation strategy of the low-energy homes selected for study varies between schemes, depending on the Building Regulations and funding conditions applicable at the time of development.

3.3.4 The 'performance gap'

There exists a well-researched 'performance gap' between energy required for homes as built and as designed, across all sectors of the housing market (Wingfield et al. 2008; Bell et al. 2010; Good Homes Alliance 2011; Tuohy and Murphy 2014; Zou, Wagle, and Alam 2019). A high-level evidence review for the Zero Carbon Hub (Zero Carbon Hub 2014) found shortcomings in practices at every stage of the construction process. A performance gap as built can be expected to lead to a performance gap in use, with consequences for comfort, carbon emissions and the building fabric.

Extensive research has also investigated the performance gap between the projected and in-use energy efficiency of new homes (Baborska-Narozny and Stevenson 2015; Coleman and Robinson 2017; Gram-Hanssen and Georg 2017; Johnston, Miles-Shenton, and Farmer 2015; Zero Carbon Hub 2014), citing, variously, the part played by design, build quality and occupant practices in creating this gap. The contribution to the performance gap made by ventilation 'things' and, in particular, their influence on maintenance practice, has received less attention in the literature.

The results of an extensive Building Performance Evaluation programme, investigating 76 housing schemes across the UK identified as 'leading edge developments where low-carbon design was a priority', concluded that homes 'rarely live up to their designers' original aspirations' (Innovate UK 2016a: 2). A critical factor identified was 'failure to recognise the importance of early design and specification decisions on the long-term performance of buildings' (National Energy Foundation 2015: 3). Through the lens of Practice Theory (see chapter 2) this could be characterised as failure to take account of the practices of those who will maintain performance in the long term. The influence on ventilation maintenance of practices leading to the performance gap are evident in this research (see 7.4.3).

3.4 Ventilation practice

3.4.1 The importance of operation and maintenance

Numerous researchers have noted the importance of correct installation, commissioning, operation and maintenance of ventilation systems (Sunikka and Boon 2003; Bone et al. 2010; Shrubsole et al. 2014; Baborska-Narozny and Stevenson 2016; Davies and Oreszczyn 2012). In particular, the extensive Building Performance Evaluation programme uncovered frequent problems with Mechanical Ventilation with Heat Recovery (MVHR) systems (see glossary), attributed at least in part to an inadequate maintenance regime, although this assumption is not explored in any depth in the evaluation reports (Innovate UK 2016a; National Energy Foundation 2015).

Indeed, research into sustainable housing in the social housing sector in five EU countries, including the UK, concluded that:

> Efforts in sustainable management are misplaced with emphasis on procuring new buildings, not on operation and maintenance. (Sunikka and Boon 2003: 1)

Further, Sunikka and Boon asserted that the operational phase ‘can play a key role in reducing the environmental impact of the social housing sector in every country’ (Sunikka and Boon 2003: 11), confirming the relevance of the current research focus to its wider context (see 1.1).

However, although there is clear evidence of shortcomings during the operational phase in housing from a range of post-occupancy research studies (Gupta, Kapsali, and Dwyer 2016; National Energy Foundation 2015; Tuohy and Murphy 2014), these pay scant attention to the role of maintenance practices in performance. A review of this literature reveals a key research gap in relation to ventilation practice.

3.4.2 Practices in maintaining low-energy homes

While it is recognised in the literature that effective maintenance is essential to sustain the performance of homes, it appears that there is little research exploring housing association ventilation maintenance strategy and practice in relation to low-energy housing stock. This is a key research gap that this study will seek to address.

Given that sustainability is driving the increasing airtightness of homes and the innovative nature of ventilation systems required in such homes, it is significant that an analysis of maintenance in social housing in NW England (Tucker, Turley, and Holgate 2014) found that sustainability and innovation were deemed the least critical factors of an effective maintenance service. The lack of research related to this topic is arguably an indication of its low priority in social housing organisations.

Innovative ventilation technologies are certainly not ‘fit and forget’ systems and require new skills for maintenance (Zero Carbon Hub 2016). While facilities managers of non-domestic buildings may have expertise in building engineering, maintenance practice in housing associations is generally more narrowly prescribed and may lack the building engineering expertise that low-energy technologies in housing increasingly require.

Kempton (2014) considers maintenance practice in some detail, but exclusively focusing on the practice of housing association asset management executives. He identifies a number of themes and recommendations, focusing primarily on asset management planning and maintenance skills. Recommendations relating to promoting appropriate resident practices include communicating the benefits of low-zero carbon technologies, providing more user-friendly manuals, and, interestingly, considering how far residents can take responsibility for routine maintenance. Inter-departmental conflict within housing associations is identified as an additional contributor to the failure of low-energy heating systems to perform as intended. Relationships within housing association related to ventilation practice are a key issue to explore in this research.

3.4.3 Practices in living in low-energy homes

Maintaining the effectiveness of ventilation is not solely a function of the maintenance practices of the building's owner. As Vlasova and Gram-Hanssen emphasise:

> Practices of living with energy-efficient technologies are at least as important as the efficiency of the technology itself when it comes to actual energy consumption. (Vlasova and Gram-Hanssen 2014: 522)

Not only do 'everyday practices and technologies co-evolve' (Vlasova and Gram-Hanssen 2014: 512), but the practices of occupants and building owners related to the maintenance of effective ventilation overlap. It seems that there is virtually no research that considers the interactive practices between housing associations and tenants in relation to sustaining the performance of ventilation in such homes in the long term. The risks and prevalence of ineffective ventilation in highly airtight dwellings necessitate a better understanding of those practices and form another research gap that will be addressed.

The practice of operating and maintaining ventilation in low-energy homes is, in effect, both for residents and maintenance practitioners, a 'bundle of practices' (Schatzki 2002), as diverse as residents' laundry practice (Menon and Porteous 2011) and housing associations' management practice (Kempton 2014). Identifying how apparently unrelated practices may support or undermine ventilation effectiveness will be integral to the research analysis, aiming to reveal new understanding of the subject.

3.4.4 Technology in use

The problems encountered in maintaining the performance of low-zero energy housing, in particular heating and ventilation technologies unfamiliar to the housing association, result in part from lack of engagement with maintainability and operability from inception of design (Frank 2013). Even simple technology may be badly designed. For example, tricklevents are commonly fitted at the top of windows where they cannot be easily reached by all residents. Not surprisingly these essential ventilation 'things' may be rarely used, intermittently obstructed by curtains or blinds, or even permanently obstructed, hindering effective ventilation practice (see figure 3). Organisational practice characterised by lack of coordination between development, maintenance and management practices may compound poor design, with potentially serious consequences for ineffective ventilation over time. Exploring these interactions forms a key part of this study.

Figure 3. Tricklevent in practice

Window frame incorporating tricklevent, with open/close control, to provide background ventilation. Background ventilation plus intermittent extract fans is one of four ventilation strategies approved in Building Regulations (Department for Communities and Local Government 2015). In practice this tricklevent is obstructed by an internal blind, kept down continuously for privacy from adjoining footpath.

Adaptive comfort theory (Nicol and Humphreys 2002) asserts that occupants will act to create and maintain the comfort they consider acceptable, using whatever opportunities are available to them. As Baker notes:

> Comfort is a holistic experience in which the interaction between people and their environment is crucial. (Baker 1996: 84)

Shove builds on this research to emphasise the importance of social practices in the creation of thermal comfort (Shove 2004), shifting the focus from individual behaviour to 'interconnected human practices' (Schatzki et al. 2001: 2).

Gram-Hanssen concludes that a future low-carbon society needs 'a more integrated perspective of how users and technology interact' (Gram-Hanssen 2013: 456).

This practice perspective is not evident in the recent analysis of an extensive Building Performance Evaluation (BPE) programme (see glossary) in the UK. The interaction between occupants and the technology in their homes is referred to in the BPE programme report (National Energy Foundation 2015) in terms of 'occupants' interference' with MVHR systems, their 'window opening behaviour' and action in 'switching off the MV units because of the noise' (see figure 4).

Figure 4. Mechanical Ventilation with Heat Recovery (MVHR) control panel

MVHR system designed to run continuously, incorporating fan typically using 22 watts. Control panel provides feedback that system is on, complying with good practice (Bordass, Leaman, and Bunn 2007). Despite low running cost (Green Building Store 2017) residents on low income may be inclined to turn the system off in order to save money, particularly if the indicator light is red, rather than green (Brierley 2015).

The implication is that residents, rather than the technology, are at fault when ventilation is ineffective, with no recognition that the practice of airing the home is influenced by the 'things' available (for example, tricklevents in an accessible position) and 'rules' for their use (for example, continuous use of MVHR raising concern about running cost).

Even where a ventilation strategy has been expertly designed and specified, assumptions made in modelling the ventilation required may well not be replicated in real life (Howieson 2014). Figure 5 shows one example, from the researcher's experience, of how planned ventilation in a highly airtight dwelling can be easily frustrated by a combination of window design and user operation.

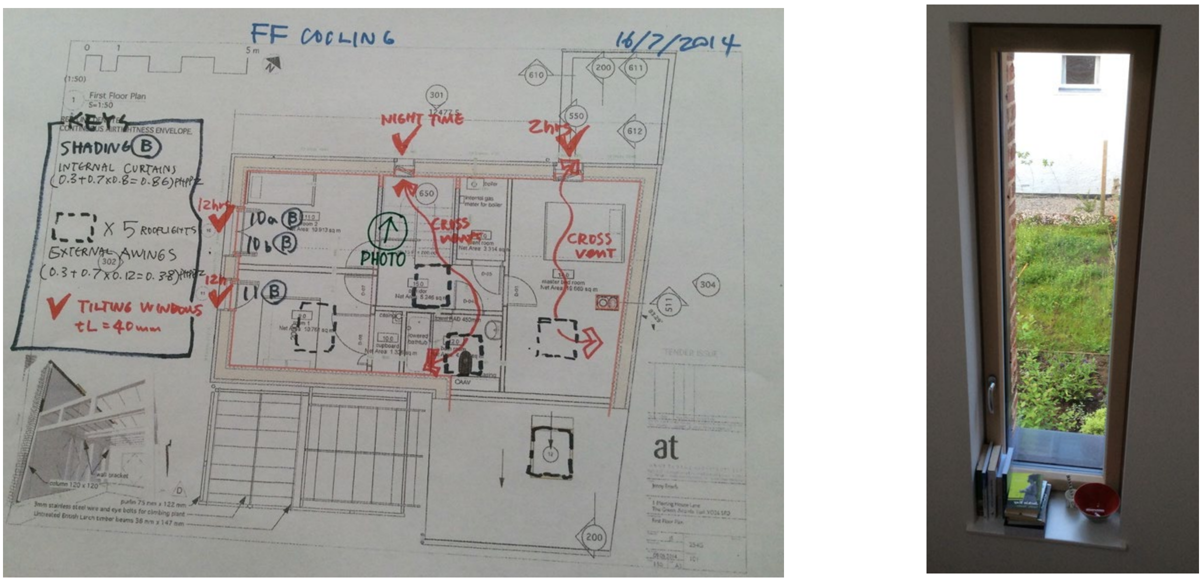

Figure 5. Ventilation as designed and as practised

Plan showing ventilation strategy for Passivhaus as designed (drawing by Junko Suetake, Anne Thorne Architects). Photo of window designed to be tilted 40mm to allow night-time cooling (direction of photo indicated on plan).
In practice, tilt mode does not provide sufficient air flow, possibly as frameless window is fitted tightly within reveal. Window therefore needs to be opened in side-hinged casement mode for cooling, but is rarely opened in practice as window opens inward and window sill is used for storage/display. Research reveals similar practices in Germany, where inward opening windows hinder government recommended 'shock ventilation' technique (Galvin 2013).

The theoretical framework adopted for this research (see chapter 2) will facilitate deeper analysis of practice in relation to ventilation technologies, as performed both by residents and by maintenance practitioners, a significantly under-researched topic.

3.4.5 Meanings and habits

There is no recognition in the BPE programme report (Innovate UK 2016b) that 'correct' operation of ventilation systems requires anything other than 'educating' occupants on the ventilation things installed and issuing instructions or rules. However, Practice Theory (see chapter 2) contends that practices are also shaped by 'meanings', for instance, a belief that opening windows is healthy; by the 'habits' of ventilation acquired in different dwellings; and by the nature of 'materials' available, such as the usability of ventilation controls.

The BPE report reflects an underlying assumption that building performance is related essentially to physical characteristics of the building fabric and services, rather than the interaction between a building and its occupants as a complex and interrelated set of practices. Indeed, research at the Salford Energy House describes the unpredictability of weather conditions and human behaviour as 'uncooperative variables' (Fitton et al. 2016: 539).

While the BPE programme report confirms the importance of the operational phase, it does not identify the key role of occupants' ventilation practices referred to by Sunikka and Boon (2003), other than in negative terms - unsurprising if a 'deficit view' of occupants is taken at the development stage, rather than an 'energy citizen' view (Williams 2012: 312).

The huge variability in household practice of heating and ventilation cannot be ignored in assessing building performance and Gill et al. conclude that:

> Human factor issues need to be addressed more adequately as standard practice in low-energy/carbon design. (Gill et al. 2010: 491)

One BPE report refers not only to 'inadequate commissioning and maintenance procedures' but concludes that:

> There are complex interdependencies that occur between the fabric, services, controls and occupant behaviour which determine actual energy use and environmental performance in dwellings. (Gupta, Kapsali, and Dwyer 2016: 237)

It is not only the meanings and habits of occupants that are relevant to effective ventilation. The practice of maintenance practitioners, and the meanings and habits that influence this practice, are barely acknowledged in the literature, yet the 'complex interdependencies' highlighted by Gupta et al. (2016) involve the practice of both parties.

This research will in part seek to understand these hidden and unexplored interdependencies, through the lens of Practice Theory, specifically in relation to the maintenance of effective ventilation in low-energy, highly airtight, low rent dwellings.

3.5 Ventilation and health

3.5.1 Air quality risks

The unintended consequences of high levels of airtightness in new homes, coupled with inadequate ventilation, despite ventilation standards being governed by the Building Regulations, are well documented (Shrubsole et al. 2014; Howieson, Sharpe, and Farren 2014). While the positive health impacts of warm, dry, homes are evidenced, reducing excess winter deaths and alleviating a range of respiratory conditions, the negative impacts of poor air quality and overheating are becoming increasingly apparent (Bone et al. 2010).

There is evidence that energy efficiency improvements in existing homes may similarly result in poor air quality and high summer indoor temperatures, where increased airtightness is not balanced by adequate ventilation (Shrubsole et al. 2015; Maidment et al. 2014). Although the current study focuses on new-build homes, where airtightness is highest, the findings will also be relevant to existing homes that are retrofitted to meet the Future Homes Standard (see 3.2.1).

Inadequate or ineffective ventilation in highly airtight dwellings may compromise indoor air quality to the extent that there are significant risks to human health. While mechanical, filtered, ventilation will limit toxins and particulates entering from the external environment, unless it is correctly balanced internally generated toxins, indicated by the concentration of CO_2 in the air, can build up within the dwelling to dangerous levels (figure 6). However, air quality is difficult to detect without monitoring devices, which are not a requirement in homes in England.

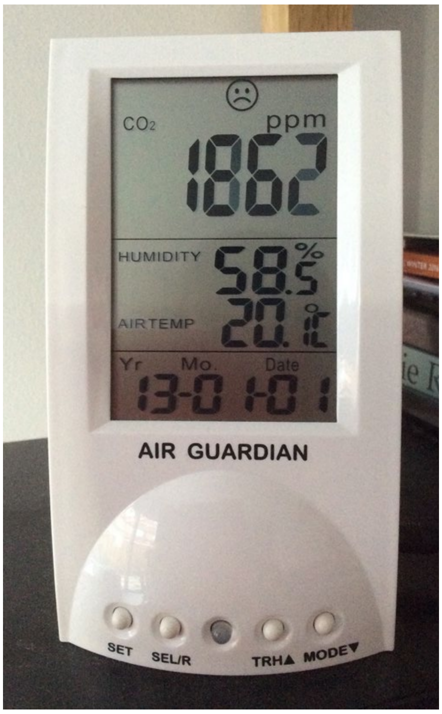

Figure 6. Indoor air quality monitor

Air quality monitor indicating raised CO_2 level following use of gas cooker in a highly airtight dwelling without increasing ventilation
Room temperature at typical level for a living room 18-21^oC (Energy Saving Trust 2017)
Relative humidity within recommended range 40%-60% (Designing Buildings Wiki 2017)
CO_2 concentration above recommended maximum level of 1000ppm (CIBSE 2011)

The presence of synthetic building and furnishing materials is known to compound this risk (Shrubsole et al. 2014). Indeed, Woolley (2016) contends that the UK construction industry has a 'head in the sand mentality' regarding the health impact of building materials, such that:

> The buildings that we inhabit…are contaminated with hazardous and toxic materials that we breathe in every day of our lives. (Woolley 2016: 1)

Woolley expresses deep concern about the widespread lack of knowledge of contaminants in everyday household products, despite their potential impact on health (see table 5).

Table 5. Health impacts of indoor pollutants

Pollutant	Sources	Health Impacts
Nitrogen dioxide (NO_2)	Heating and cooking appliances	Associated with respiratory symptoms
Carbon monoxide (CO)	Heating and cooking appliances	Lethal at high levels, potential chronic effects at low levels
Particulate matter (PM)	Cooking and aerosols	Reduced lung function and increased risk of heart and respiratory disease
Radon	Ground gases especially in defined areas	Lung cancer
Environmental tobacco smoke (ETS)	Cigarettes, cigars and pipes	Lung cancer, chronic obstructive pulmonary disease (COPD), asthma and reduced lung function
Allergens	Moulds and house dust mites	Worsening of symptoms of asthma, causation of wheezing
Volatile organic compounds (VOCs) and ozone (O_3)	Cleaning products, personal care products, paints and printers	Respiratory tract irritation, possible effects on asthmatics
Source: Houses of Parliament, Postnote 366, Nov 2010		

Shrubsole et al (2014) argue that the policy of reducing carbon emissions through increasing airtightness is not only failing, as heat is lost through random ventilation or additional energy is utilised for cooling, but is in fact widening health inequalities in the population. Woolley concurs, asserting that policies 'rigidly fixated on energy efficiency' (Woolley 2016: 1) are ignoring their health impacts.

The difficulty of evidencing a link between specific materials and illnesses is, however, acknowledged by Woolley (2016). Health research typically studies behaviours:

> Independently of the social context, in isolation from other individuals, and as practices devoid of social meaning. (Frohlich, Corin, and Potvin 2001: 783)

This approach allows epidemiologists to explain non-infectious disease in terms of individuals' characteristics or behaviour. Individuals are thus held responsible for their health status, as a result of their 'lifestyle', ignoring the impact of their housing, a belief consistent with the 'dominant paradigm of "ABC" – attitude, behaviour, and choice' challenged by Shove (2010: 1273). The prevalence of this belief, and its effect on the interrelationship between residents and maintenance practitioners, will be explored in the analysis.

Given the demographics of occupants of low rent housing, with above average numbers of elderly and disabled people, and households occupying small homes to maximum capacity, spending long periods of time in the home, the negative health impact of poor indoor air quality is likely to be disproportionate. As social housing tenants are predominantly low-income households, the cost of servicing gas cookers and changing cooker hood filters, necessary to minimise toxins in the air, may not be affordable. Moreover, the health risks of inadequate ventilation are compounded where the household includes one or more smokers, which is significantly more prevalent in social housing than in other tenures (Office for National Statistics 2019).

These factors, compounding the risks of ineffective ventilation in social housing, underpin the focus of this study on low rent homes and indicate issues that are considered in the data collection and analysis.

3.5.2 Overheating risks

While inadequate ventilation is not the root cause of overheating in dwellings, it can hinder efforts to mitigate its effects and the findings of this study are therefore relevant to understanding this increasing problem.

Recent evidence suggests that ‘around 20% of homes in England already experience overheating even during relatively cool summers’ (Committee on Climate Change 2017: 70), based on recommended maximum thresholds for summer indoor temperatures of 28^{o}C in living rooms and 26^{o}C in bedrooms. Widespread experience of indoor temperatures exceeding these thresholds during the summer heatwave in July and August 2018, and projections of future weather patterns in the UK, has raised the prominence of domestic overheating in public discourse on climate change.

Evidence to the House of Commons Environmental Audit Committee (House of Commons 2018) emphasised the vulnerability to overheating of certain building types, in particular single-aspect and top-floor flats, homes in heavily polluted, high noise areas that rely on natural ventilation, and highly glazed buildings of lightweight construction.

Despite the risks to the health and comfort of building occupants from overheating, the only reference in the Building Regulations (Department for Communities and Local Government 2014) to overheating occurs in Part L, related to fuel conservation. Approved Document L1A sets out measures to limit heat gains and losses, including day and night ventilation, with the objective of minimising energy use. There is no mention of overheating in Part F, related to ventilation, and thermal comfort is not addressed in the regulations.

Overheating, exacerbated by the effect of climate change on summer temperatures in the UK, especially in urban areas experiencing the ‘heat island’ effect (Kinnane, Grey, and Dyer 2016; Aynsley and Shiel 2017; Lomas and Porritt 2017), may increase the use of mechanical cooling to alleviate discomfort, thus perversely increasing energy use and carbon emissions (Davies and Oreszczyn 2012).

It has been predicted that ‘energy demand for domestic cooling could triple between 2010 and 2050’ (Department for Environment Food and Rural Affairs 2013: 26). In order to mitigate this demand, the Greater London Authority, in the draft London Plan, requires planning assessments to consider overheating as well as energy efficiency and has adopted ‘a cooling hierarchy that prioritises design, orientation, shading, and ventilation over mechanical cooling’ (House of Commons 2018: 29).

In its evidence to the Environmental Audit Committee, CIBSE emphasised that the treatment of overheating at design stage is fundamental in increasing the resilience of buildings to the impact of climate change. The Committee, in its conclusions, urged that:

> The health and future health of occupants should be a key priority of the building regulations, especially as severe heat events have become increasingly common since 1950 and are set to become more frequent. (House of Commons 2018: 27)

It is anticipated that effective ventilation will therefore have a higher profile in future Building Regulations, as described in the next section, reflecting increased airtightness in order to deliver buildings that are resilient to a changing climate, as well as having healthy indoor air.

3.6 Policy context

3.6.1 Ventilation in building regulations

In a sector with ‘relatively weak consumer drivers for higher environmental standards’ (RICS 2016: 43), mandatory regulations play a key role in driving house building standards. The statutory Building Regulations in England (see glossary) are therefore crucial in setting a minimum standard for new homes, including requirements for airtightness and ventilation.

Given extensive evidence of ineffective ventilation in new homes (Ministry of Housing Communities & Local Government 2019f; Mawditt 2017; Sharpe et al. 2016), proposed changes to the Building Regulations include significant changes to Part F (Ventilation) (Ministry of Housing Communities & Local Government 2019a).

Specifically, the changes would permit natural ventilation only for homes defined as ‘less-airtight’ (i.e. having a design air permeability higher than 5 $m^3/(h.m^2)$ at 50 Pa, or higher than 3 as-built). Continuous mechanical ventilation (see glossary), either extract only (MEV) or supply and extract (MVHR), would be required for all other dwellings. While the maximum air permeability would be set at 8 $m^3/(h.m^2)$ at 50 Pa, only a modest reduction from 10 in the current Building Regulations, the clear direction of travel, driven by the imperative of cutting carbon emissions, is towards more airtight homes with continuous mechanical ventilation, the focus of this study.

While it is recognised in the literature (McGill, Oyedele, and McAllister 2015; Behar 2016; Baborska-Narozny and Stevenson 2016), that practices related to the operation and maintenance of ventilation equipment can contribute to ineffective ventilation and poor indoor air quality, policy in these areas is weak. The only reference to *maintenance* in the proposed Building Regulations Part F remains that ‘reasonable access should be provided for maintaining ventilation systems' (Ministry of Housing Communities & Local Government 2019a: 14). The absence of more detailed standards is consistent with maintenance practice not being recognised in policy as significant in relation of ventilation effectiveness.

The impact of *operational* practice on ventilation effectiveness is recognised in the proposed Building Regulations through a requirement for enhanced information to householders regarding energy efficiency and ventilation in the home. However, while the proposal for a template for a user-friendly home user guide could represent an improvement on the current widely variable practice (Sharpe, Bridgestock, and Menon 2012), it is questionable whether the proposed highly technical BREL document (Building Regulations England part L), set out in Annex D of the consultation document (Ministry of Housing Communities & Local Government 2019e) would 'champion transparency' for householders as anticipated by the Government. The impact of guidance for householders on resident ventilation practice is considered in section 6.5.2.

Although Building Regulations set a baseline for housing standards, policy incentives to achieve higher standards have been weakened in the UK in recent years, despite legally binding carbon reduction targets and required compliance with the European Energy Performance of Buildings Directive (EPBD) (Department for Communities and Local Government 2013) (see glossary). The abandonment of the Zero Carbon Homes policy and the downgrading of the Code for Sustainable Homes to a voluntary code, in the UK Government's 2015 'bonfire of red tape', removed any requirement, or incentive, for the housebuilding sector to exceed the statutory Building Regulations (Committee on Climate Change 2019).

Even within the housing association sector, which had positioned itself, with Government inducements, in the vanguard of energy efficient development, this loosening of the regulations freed associations to accelerate a change in priorities, towards increasing the quantity of homes produced rather than achieving zero carbon emissions. Cutting carbon emissions from housing to achieve the legally-binding UK target of zero emissions by 2050, will, however, lead to increase airtightness requirements in the proposed building regulations and place the focus on effective ventilation.

Building Regulations are also weak in relation to noise standards (see glossary) for homes, an issue relevant to ventilation practice due to the increasing necessity for mechanical ventilation systems. Although there is evidence that noisy fans lead to residents switching off ventilation equipment (Ministry of Housing Communities & Local Government 2019f), the proposed regulations do not include a standard for noise levels or mandatory noise testing, merely a requirement that fans are ‘not unduly noisy’ (Ministry of Housing Communities & Local Government 2019e: 45). Understanding the relationship between ventilation practice and noise is a knowledge gap that this study will explore.

3.6.2 Indoor air quality standards

Despite extensive research evidencing the adverse effects on health of poor air quality in homes (RCP & RCPCH 2016; Cincinelli and Martellini 2017; Department of Health 2004) mandatory standards for indoor air quality in UK homes are not yet in place (see 3.5.1). However, increasing pressure to enact legislation in respect of polluting domestic fuels and products, and introduce guidance on indoor air quality in dwellings, led to a major consultation in 2019 (National Institute for Health and Care Excellence 2019) and pledges to act to reduce emissions at home in the UK Government’s Clean Air Strategy (Department for Environment Food and Rural Affairs 2019).

Literature exploring indoor air quality in relation to energy efficient dwellings (Howieson 2014; McGill et al. 2017; McGill, Oyedele, and Keeffe 2015; Wallner et al. 2017) has highlighted the importance of ventilation in delivering both energy efficiency and healthy indoor air. While research has explored the technical aspects of ventilation systems extensively, there is also a substantial body of literature focused on the ventilation practices of residents (Baborska-Narozny and Stevenson 2016; Behar 2016; McGill and Sharpe 2017; Sharpe et al. 2015).

Although the impact of maintenance practices on indoor air quality is acknowledged in the literature, to date this aspect has received less attention from researchers than either the technical aspects of ventilation or user practices. This is a key knowledge gap that this study addresses.

Indoor air quality is inextricably related to external air quality. The health impacts of external air pollution (Evangelopoulos et al. 2019) are a high profile concern for the UK Government and for the general public (Department for Environment Food and Rural Affairs 2019). Inequalities in the spatial distribution of pollutants are noted in the RCP & RCPCH report (2016), although it is acknowledged that the relationship with deprivation is not straightforward.

Nevertheless, housing in poor quality environments, close to busy roads with queueing traffic, railway lines with diesel trains, or polluting industries, is at risk of unhealthy indoor air unless ventilation is effective in filtering particulate matter and other pollutants from incoming air (Forrester and Rajan 2018). This risk is underlined where external air pollution exceeds legal limits, putting residents at risk if they open their windows, although it appears that this risk is no barrier to new housing development (Noor 2019). This study focuses on the ventilation of low rent housing association homes, typically located in areas of poor external air quality, making the findings particularly significant in respect of resident health.

3.6.3 Health and safety legislation

The law relating to domestic health and safety has been described as 'piecemeal, out-dated, complex, dependent upon tenure, and patchily enforced' (Carr et al. 2017). Indeed, Carr et al. assert that a cultural change is needed, such that:

> No longer should occupiers be treated as posing health and safety risks. (Carr et al. 2017: 1)

Despite the evidence of risks to health, indoor air quality and overheating are not yet reflected in health and safety legislation in relation to homes in the same way as, for example, gas safety (Brierley 2018). Nevertheless, the Housing Health and Safety Rating System (HHSRS) (Office of the Deputy Prime Minister 2006) (see glossary), a risk-based tool for evaluating potential hazards in dwellings, does include the assessment of air quality and the effectiveness of ventilation.

Moreover, the HHSRS is now the basis of legislation, the Homes (Fitness for Human Habitation) Act 2018 (Houses of Parliament 2018) (see glossary), which gives tenants new routes to remedy poor housing conditions. However, landlords are not required to remedy problems caused by 'tenant behaviour', a judgement open to considerable disagreement in respect of air quality, its causes and consequences, and the responsibility for effective home ventilation.

The impact of the absence of health and safety legislation regarding ventilation on maintenance practice is a further factor that this study investigates.

3.7 Sub-conclusion

The imperative of cutting carbon emissions from housing, in order to mitigate climate change, is well evidenced in the literature and forms the context of this research. The accelerating move towards zero-carbon homes places the emphasis in design and construction on minimising heat loss and the provision of means of ventilation appropriate for highly airtight dwellings.

As the literature reveals (see methodology at 4.4.1), expert design and construction alone are not sufficient to guarantee that low-energy homes in use will be effectively ventilated. A gap in knowledge regarding ventilation maintenance and operational practices in such dwellings is evidenced in this chapter and is the key focus of the research.

Given the leading role that housing associations in England have played in the development of low-energy housing, the gap in knowledge relating to ventilation effectiveness is particularly relevant to this sector of the housing market. As the literature reveals, the demography of social housing tenants and typical location of housing association homes increases the risk to health of poor indoor air quality and overheating in this sector. Practices in low rent housing association homes are therefore an appropriate focus for this research.

The influence of *resident* practice on ventilation effectiveness is acknowledged in the literature, although typically characterised as 'behaviour' to be changed. However, what shapes that practice, and what related practices influence ventilation, appears to be largely unexplored. This study will investigate this significant gap in understanding from a practices perspective.

An understanding of how *maintenance* practice impacts on ventilation effectiveness is largely missing in the literature, although there are indications of its significance. This study aims to fill this gap in knowledge, examining the practice from the perspective of maintenance practitioners.

The interdependency of occupant and owner practice in maintaining effective ventilation in rented homes is acknowledged in the literature. However, the impact on ventilation of interaction between resident and maintenance practitioner practices, and the impact of the interaction with wider practices within a housing organisation, are unexplored. Examining these interactions, from a practice perspective, aims to deepen understanding of their significance in ventilation maintenance.

Gaps in knowledge revealed in this literature review underpin the research questions (see 1.4), which seek an understanding of a significant issue in low-energy housing, of increasing relevance as the housing sector acts to mitigate climate change. The theoretical approach adopted, described in chapter 2, provides a practice-based framework, consistent with exploring the complexities of everyday life that underpin the gaps in knowledge revealed in this chapter. The qualitative, interpretive methodology adopted, and the multi-method case-study design selected, being fitting for investigating the research questions within a practice-based framework, are explained in the next chapter.

Chapter 4. Methodology

4.1 Introduction

This chapter sets out the methodological approach of the research, designed to investigate the knowledge gap identified in chapter 3, using the practice-based framework detailed in chapter 2.

The research takes a qualitative, interpretive approach to understanding what shapes ventilation maintenance practices in low-energy homes and its impact, focusing on the everyday practices of maintenance practitioners and residents. A case-study design is adopted, using multiple data collection methods. Analysis is carried out in two cycles of coding, followed by thematic analysis, moving from inductive to abductive reasoning.

In this chapter, the methodological approach (section 4.2) and case-study design (section 4.3) are first explained. This is followed by the details and rationale for the data collection methods employed (section 4.4) and analysis methods applied (section 4.5).

The next chapter sets out the results of the data collection, followed by analysis of the data in chapters 6 and 7.

4.2 Methodological approach and rationale

4.2.1 Qualitative

Understanding everyday ventilation practices requires the researcher to uncover in rich detail the particularities and peculiarities of how practices are performed. Observing and analysing what may seem to be 'inconspicuous routine' (Browne et al. 2014: 28) is key to this understanding. The research questions formulated (see 1.4), and the adoption of Practice Theory as the framework for analysis (see chapter 2), lead to a qualitative, rather than quantitative, approach to the investigation. This approach, described by Mason as 'characteristically exploratory, fluid and flexible, data-driven and context-sensitive' (Mason

2002: 24) is evident in a growing body of practice-based, socio-technical research (Shove 2012; Gram-Hanssen 2009; Foden et al. 2017; Strengers and Maller 2011).

4.2.2 Interpretive

In order to observe and understand 'the informal logic of actual life' (Geertz 1973: 17), the interpretive researcher is 'watching what happens, listening to what is said' (Hammersley 2007: 3). What is observable by the researcher is, however, only a partial picture of reality as perceived by an individual. This is graphically illustrated in figure 2 in section 2.6, where the visible performance of practices is depicted as the mere tip of the iceberg. 'Reading' the data, an individual's account of their experience related in an interview, for example, is always open to the researcher's interpretation, surmising what is invisible based on their own experience, knowledge and judgement.

A wholly objective reading of data is not realistic and interpretive research is therefore open to the risk of *mis*interpretation or bias. This risk is mitigated by a reflexive approach to interpreting the data, questioning the researcher's own assumptions and inferences, and considering possible alternative interpretations (May 2017), as detailed in the next section.

4.2.3 Reflexive

The researcher's own positionality in the research process, her experience and knowledge, role as a carrier of practices, and relationship vis-à-vis the participants, are considered mindfully throughout, and made visible where appropriate, aiming for Gillian Rose's ideal of 'a full understanding of the researcher, the researched and the research context' (Rose 1997: 305).

Given that the researcher in this study is grounded and experienced in housing practice, not academic theory, 'self-critical sympathetic introspection and the self-conscious *analytical* scrutiny of the self as a researcher' (England 1994: 244) is especially important. This reflexive approach 'induces self-discovery and can lead to insights and new hypotheses about the research questions', allowing the researcher to be more 'open to any challenges to their theoretical position that fieldwork almost inevitably raises' (ibid.: 244).

A reflexive stance challenges the notion that a researcher can be neutral, impersonal and detached, an omnipotent expert freed of personality and bias (Schön 1983). The researcher in this study accepts unequivocally that ‘the knowledge of the person being researched (at least regarding the particular questions being asked) is greater than that of the researcher’ (England 1994: 243).

Being conscious of the power relationship between researcher and researched, and establishing a trustful rapport in interviews, is a critical factor influencing the response of interviewees (Rose 1997). However, ‘recognising or even being sensitive to these power relations does not remove them’ (England 1994: 249). Understanding, or at least acknowledging, ‘the shaping role of our own gaze’ (Mason 2002: 177) is the aim of this researcher.

While the research draws on the researcher’s personal experience and perceptions, this is done without claiming any privilege from insider knowledge of the housing sector. Indeed, the researcher is aware that this demands greater diligence in explaining how interpretations are reached from the data in order to demonstrate validity.

4.2.4 Multi-method

Seeking to understand the *complexity* of human behaviour and experience, as the goal of social science research, suggests that adopting a number of different research methods, appropriate to the particular questions asked, is desirable. Different methods enable the researcher to explore the issue being investigated from a range of perspectives, expressed by Philip as the ‘exploration of different truths’ (Philip 1998: 262).

The differing perspectives of maintenance practitioners, housing associations and residents are all relevant to this practice-based research, but most likely to be revealed through different methods of inquiry. The institutions involved are sites of practice as much as the households (University of Brighton 2018) but present different challenges to the researcher in the collection of data. The methods applied at each stage of this research are designed to address this challenge and relate to the research questions, as shown in table 6.

Table 6. Research questions, objectives and methods

Research questions, objectives and methods					
Research questions	Question 1 What are the key practices of maintenance practitioners and residents that shape the maintenance and operation of ventilation in low-energy housing association homes?		Question 2 What shapes the interaction between bundled practices related to ventilation and how does this impact on ventilation effectiveness?	Question 3 What are the underlying themes that inform the effectiveness of ventilation in low-energy housing association homes?	
Objectives related to each question	1, 2, 3		2, 3, 4	4, 5	
Objectives	Objective 1 Explore the state-of-the-art in relation to the maintenance and operation of ventilation for low-energy homes	Objective 2 Scope typical maintenance practices of UK social housing organisations in respect of ventilation in low-energy homes	Objective 3 Investigate maintenance and operational practices in respect of ventilation in low-energy rented housing association homes, from the perspective of maintenance practitioners and residents	Objective 4 Understand how the practices of maintenance practitioners and residents, and their interrelationship, influence ventilation effectiveness	Objective 5 Develop themes from the data that advance understanding of the maintenance of ventilation in low-energy housing association homes
Methods	Literature review 4.4.1	Scoping survey 4.4.2 Focus Group 4.4.3	Case-study interviews 4.4.4 Observation and visual recording 4.4.5 Document review 4.4.6	Analysis 4.5.3, 4.5.4	Analysis 4.5.5
Summary of method	Systematic on-line search of design guidance, regs, codes, academic papers, manufacturer and product websites Discussions with designers, housing providers, maintenance experts, academics, etc	On-line semi-structured questionnaire survey of maintenance practitioners in UK social housing Focus Group follow-up to survey, with maintenance practitioners in UK social housing	Case-studies of rented English hsg assoc schemes new-build low-energy Semi-structured interviews with residents and staff Observation in residents' homes and schemes Recording in photos and video-clips Review of case-study documents	Qualitative, interpretive data analysis, using practice-based framework Two coding cycles using NVivo	Thematic analysis Additional insights from informal advisory group

The cross-checking of data from a range of methods, as shown in table 6, is one way of counteracting researcher bias, providing these different methods do not share and reinforce the same bias (Philip 1998). The integration of results from methods that add depth and breadth to the data, and explore the diversity of perspectives relevant to the research questions, makes it possible to extend and enhance the research findings (Mason 2002).

The methodological choice takes account of practical constraints in the context of the research. In this instance, the time available, financial resources, and the methodological skills and experience of the researcher are relevant considerations that have influenced a realistic choice.

4.3 Case-study design

4.3.1 Case selection

Thomas argues that case-study is not a method in and of itself but a 'design frame that may incorporate a number of methods' (Thomas 2011: 512). This allows the researcher in this case to study the complexity involved domestic ventilation in real-life, exploring *why* as well as *what* questions. The multi-method approach adopted for this study harmonises with a case-study design frame, enabling the researcher to explore 'concrete micro-level activities' (Langley and Abdallah 2011: 218) from the differing perspectives of maintenance practitioners and residents.

This case-study design involves multiple cases of low-energy housing schemes and analysis at numerous levels, within and between cases (Yin 2014). Case-study data may be quantitative, qualitative, or both, and a case-study design may be adopted for research rooted in a variety of theoretical positions. Indeed, Gerring describes the term 'case-study' as 'a definitional morass' (Gerring 2004: 342). This interpretive research focuses on qualitative data, taking a practice-based framework.

A 'replication' design, rather than a 'sampling' design, is followed for the selection of cases, as the aim is to investigate practices in detail in a particular category of housing scheme, with a range of defined characteristics, rather than to gather statistical data from a representative sample of all such schemes (Yin 2014). Rich data gathered from cases selected using a replication design facilitates *analytical* generalisation from the results, but not *statistical* generalisation to the whole population of schemes from which the cases are drawn. In other words, the value of studying individual cases lies 'not in the hope of proving anything, but rather in the hope of learning something' (Eysenck 1976: 9).

The capacity for generalisation that a large sample can offer is rejected in favour of 'the strength of a rich in-depth explanatory narrative emerging from a very restricted number of cases' (Thomas 2011: 512). In other words, this research is intensive, rather than extensive, placing cases not variables centre-stage, in order to explore the research topic.

Utilising the researcher's knowledge of the field, and following Yin's replication logic (Yin 2014), it was considered that five unique cases, each encompassing a range of 7-8 in-depth interviews, would capture the complexities and dimensions of the issues and enable sound insights to be offered, within the realities of time and resources available (Mason 2012; Yin 2013).

The five cases chosen for this research are not chosen arbitrarily but 'maximise differences on one dimension while controlling for differences on others, and ensuring coverage of perspectives within each case' (Langley and Abdallah 2011: 207). This is consistent with Eisenhardt's view that 4-10 cases are sufficient to reach 'theoretical saturation', i.e. the point where incremental learning is minimal (Eisenhardt 1989: 533). The five housing schemes selected as case-studies are drawn from a defined population of low-energy housing association schemes in England built 2005-15 (see scope and limitations at 1.4, definition at 3.3.1).

The research questions point to a design that encompasses a number of cases, taking low-energy housing association schemes with characteristics relevant to the research subject as the cases. Within each of the five cases, the data subjects are scheme residents, maintenance practitioners and other housing association staff relating to the scheme. As described by Yin, this typology is an embedded multi-case design (Yin 2014).

4.3.2 New-build housing association homes

As the required airtightness of new homes continues to rise, in order to increase energy efficiency and reduce carbon emissions (see 3.2.1), and the rate of new house building is projected to increase (House of Commons 2020), the crucial issue of ventilation in new-build homes is a timely subject for research. As housing associations have a significant role in the UK housebuilding programme and in low-energy construction, new-build housing association schemes are considered appropriate as case-studies for this research.

Although diverse in size and tenure mix, and operating in widely varying locations and environments, housing associations have a common ethos, legal, regulatory and policy framework. Housing legislation and policy differs between the four nations of the UK. In order to focus on cases with a consistent legal and policy basis, to facilitate comparison between cases and dissemination of findings, housing associations managing and developing new build, low energy schemes in England are the subject of the five case studies.

The case-study selection aimed to achieve a geographical spread across the nine English regions. The cases are widely dispersed across the country, so that the research could explore variations in ventilation practice linked to regional differences in climate or tradition. The traditional practices of individual households interviewed may of course not directly relate to the geographical location of their current home and this issue is evident in the data.

A mix of urban and rural case-studies was included as the local environment is relevant in respect of ventilation. Differences in microclimate related to the density of buildings, the level and nature of external air pollution, and perceived or actual levels of security, are all issues relevant to ventilation practices.

Associations were selected across the size range, as measured by number of rented homes in management. This factor was considered relevant to the research questions as size of operation is likely to have an impact on maintenance arrangements in general, on policy and practice regarding ventilation maintenance in particular, and on the style of relationship and communication between landlord and resident.

In the housing association sector, particular issues in respect of maintaining effective ventilation arise in rented housing, as discussed in chapter 3, where the practices of both the landlord and the resident, and the interrelationship between these, are relevant. The case-studies therefore focus on rented housing.

The financial circumstances of residents in housing association low rent homes, defined for this research as Affordable Rent or Social Rent homes (see glossary), can result in fuel poverty, even where dwellings are designed for low energy consumption, impacting on resident practices regarding heating and ventilation. Case-studies therefore focus on low rent homes and the significance of household budgets for maintaining effective ventilation is considered in the research.

4.3.3 Housing association selection

The researcher employed an effective combination of networking from experience of working in the sector and snowballing (Morgan 2012) to select the sample. These techniques are an appropriate and effective method of purposive sampling for this interpretive research.

A longlist of 18 housing associations across England, known to have low energy, new build, low rent homes, was compiled. An initial approach was made by email to key contacts in the longlist, representing a mix of size and urban/rural locations, in different regions. The researcher explained the aims and scope of the research and provided the research proposal and case-study brief (see table 7).

Table 7. Case-study brief

Case-study brief **November 2017**

Maintaining effective ventilation in low-energy rented housing association homes

- 5 rented housing schemes, managed by housing associations, in different regions of England
- Newly built in the last 10 years, with the intention at design stage of low-energy performance i.e. designed to Code for Sustainable Homes level 4 or above, Passivhaus standard, Building Regulations 2010 Approved Document F, or similar standard
- Any ventilation strategy/ventilation technology*
- Any dwelling type/construction type*
- Any resident demographic/household composition*
- Urban or rural location*
- Any size of housing association*
- Occupied for at least 3 years, with or without change of residents
- Interviews will take place with 3-5 residents, in their homes, and with housing association maintenance, development and housing management staff, and additional housing association personnel where relevant. A total of 7-8 interviews will take place for each case study, all with the specific consent of the individual
- Interviews with residents will include, where the resident agrees, a walkthrough of the home with photo/video recording of significant issues
- Case-study schemes will be agreed by December 2017, with participants confirmed early in 2018 and interviews taking place during spring 2018
- Findings will be disseminated to participants, incorporated in a PhD thesis and in related publications/presentations, including feedback to the housing sector
- All data will be anonymous and no details will be shared or published that enable individual participants or housing associations to be identified

*Selection of case studies will aim to include a range of these characteristics

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This was followed up with further approaches to others on the longlist, until a group of five interested associations, matching the desired profile, was identified. The remaining eight associations on the longlist were held in reserve, to be contacted in the event of dropouts at a later stage.

An introductory meeting with the selected key contact, and others as available, took place at each association's office. The aims of the research and purpose of the case-studies were discussed and potential schemes considered (see Appendix 1).

4.3.4 Scheme selection

Each of the five selected housing associations was asked to identify a housing scheme where they were willing for the research to take place, which matched the case-study brief (see table 7). The selection of schemes across the five housing associations aimed to represent as wide a range as possible of dwelling types and sizes, ventilation strategies, environmental standards and construction types, enabling the researcher to explore the experience and practice of housing associations and residents in different environments relevant to ventilation of their homes (Yin 2014). The case-study scheme was decided by mutual agreement taking account of all potential schemes offered by the associations.

4.3.5 Practical and ethical considerations

Identifying five housing associations within the target category, with maximum diversity in the criteria considered relevant to the research questions, required more than hard recorded data on a range of potential associations.

The willingness of associations to participate in research is a crucial factor in selecting cases and cannot be assumed. While many associations are enthusiastic about sharing their experiences and data with researchers, and happy to facilitate contact with residents, in the researcher's experience others are distinctly reluctant. The process of establishing support across the various teams and individuals necessary to explore the research questions was an essential part of the selection process.

Fear that shortcomings in performance, the association's or their own, will be exposed, can underlie staff reluctance to participate. A desire to protect residents from intrusive questioning, or a fear of generating resident complaints, may play a part. Previous experience of research projects which have made heavier than expected demands on the association, or produced outputs of little practical value to the association, will deter involvement, as evidenced in the researcher’s own experience (Connect Housing Association 2014). These potential concerns were borne in mind at the introductory meeting and addressed explicitly when necessary.

Assurances about anonymity for participants and findings was crucial, though this presents a particular challenge in the relatively small field of housing associations in England. This was especially the case in this research as it was an explicit aim to feedback learning from the research to the sector. Transparency on the aims and expected outputs of the research, and assessment of the association’s level of support for these, played an important part in the selection process, as did the re-assurance of a strong ethical process and compliance as required by the researcher’s University (see Appendix 2).

The practicalities of accessibility, time and cost also play a part in the selection. The desirability for case studies to be widespread geographically across England placed practical demands on the researcher that needed to be balanced with the resources available. The final selection of five housing associations therefore represented as wide a diversity as possible on the criteria established, within the broad category of associations relevant to the research questions, that were willing and able to participate, and practically feasible.

4.4 Data collection methods

4.4.1 Literature review

The first stage in scoping the research, having identified and broadly defined the area of interest, is a rigorous review of the available literature in order to locate and refine the gap in knowledge (Hart 1998). A qualitative systematic search approach is taken in this study, categorised by Grant and Booth (2009) as a ‘state-of-the-art review’, although this falls short of the strict ‘systematic review’ described by Aveyard that seeks to identify *all* literature on a topic, based on strict protocols and explicit inclusion/exclusion criteria (Aveyard 2014).

Keywords and their synonyms, including stemmed words, and word combinations using Boolean logic, are entered in library and internet databases to identify relevant books, peer-reviewed articles, PhD theses and other material. Bibliographies in these sources are mined for further references until the search uncovers few new items. Abstracts are first read for relevance and metrics consulted for significance. Systematic critical reading of the relevant literature is the essential foundation for the research (Cottrell 2013; University of Leicester 2018). Literature with conceptual relevance to the topic is added to EndNote online, the bibliographical management software used by the researcher.

Given the objectives of the literature research for this study, to understand maintenance practices and requirements in the subject area, grey literature forms an essential resource, accessed by internet search and direct contact with manufacturers, government websites and relevant organisations.

The gap in knowledge, and justification for this research, are evidenced through building a broad and comprehensive evaluation and picture of current knowledge and existing research. The literature review is thus the first stage in refinement of the research questions, although in practice the literature search continued throughout the project in order to keep up to date with both research findings and technical developments in the field.

The literature search was supplemented by face-to-face or email correspondence with experts in the field, including designers, housing providers, maintenance experts, ventilation manufacturers, academics and others, building on the researcher's contacts and knowledge of the housing sector and low energy design, as an informal advisory group (see table 8). This provided access to unpublished up-to-the-minute experience and opinions relevant to the research topic.

Table 8. Informal advisory group

Who?
Dispersed group of individuals with relevant expertise in low-energy housing design, development and maintenance, and connections in the housing sector, who have not been involved in the case-studies.

Contact?
Individual semi-structured meetings in person and email correspondence during literature search and towarc end of thematic analysis stage.

Purpose?
Gain further insights on the research topic and findings from individuals with relevant expertise and experience, particularly with reference to Research Question 3.
Consider the strategy and opportunities for ensuring that the research has impact in the housing sector and gather an early indication of the issues that will be encountered in disseminating the research findings.

Role	Housing association	Architect	Ventilation industry	Research experience	Sustainable housing	Link to relevant body
Partner Architecture practice		✓		✓	✓	AECB
Development director Medium-sized housing association	✓				✓	
Advisor Social housing maintenance organisation		✓		✓	✓	NHMF
Researcher Sustainable housing organisation				✓	✓	Sustainable Homes
Architect		✓			✓	Passivhaus Trust
Regional manager Ventilation company			✓	✓		
Energy Advisor Danish Bldg Research Institute				✓	✓	Danish BRI (SBi)
Architect		✓			✓	AECB
Director Environmental design company		✓			✓	

4.4.2 Scoping survey

4.4.2.1 Survey scope and population

McLafferty (2003) considers that surveys have particular value in eliciting attitudes and opinions, and exploring people's interactions, a key focus of this research. An on-line survey was used to scope the current position on ventilation in the social housing sector, specifically targeting maintenance professionals in order to directly obtain data that was not available from other sources.

The sample for the scoping survey, from the total population of those in key maintenance roles in social housing, was developed through the principal trade body representing this group, as it was not possible to access contract details of the entire population in order to apply techniques such as random or stratified sampling (McLafferty 2003). Patton (2002) refers to convenience as an acceptable selection criterion in conditions where access is difficult and resources limited (Flick 2009: 122).

Seeking direct links with maintenance professionals for this stage of the research, contact was therefore made with the National Housing Maintenance Forum (NHMF) (see glossary). The NHMF has approx. 400 members, representing around a quarter of housing associations and local authorities in the UK. The NHMF Committee was keen that the survey should cover its full UK-wide membership, including both local authorities and housing associations, as it was aware of concern about the research topic among members in both sectors. This broader base for the survey increased the potential for useful responses and was useful in relation to research question 3, which aims to identify learning from the research relevant to the wider UK housing sector.

4.4.2.2 Questionnaire development

The questionnaire design was a crucial part of the 'total survey design' (Fowler 2008), requiring several iterations of both question content and format to ensure that the questionnaire was not a weak link in the process. As Fowler points out, 'the quality of data will be no better than the most error-prone feature of the survey design' (ibid.: 7). Simple unambiguous and clear questions and a self-explanatory format mitigated the risk of a low response, which is a particular weakness of self-administered, on-line surveys. The researcher anticipated how respondents would interpret the language used and ensured that questions were relevant, taking account of respondents' time constraints (McLafferty 2003).

A combination of multiple-choice and open-ended questions was selected for this survey. Multiple-choice questions provided data on the characteristics of schemes and organisations and an overview of the individual's experience. Responses to the open-ended questions provided richer data on respondent's experience and insights. This mix of quantitative and qualitative questions provided comparable data from standardised questions, as well as enabling data on opinions and experience to be cross-tabulated with characteristics of the respondent.

Respondent details were also compared with details of the whole sample to indicate representativeness of responses, although, as McLafferty (2003) points out, non-response bias, where the experience and opinions of non-respondents differ significantly from those of respondents, could not be eliminated. Moreover, assuming that responses in a survey accurately reflected what happens in practice must be questioned, due to, for example, a 'social desirability response bias' (Robson 2002: 233). Despite these caveats, a carefully designed questionnaire can provide a simple and effective way to scope the area of concern in this study.

4.4.2.3 Pilot survey and process

Piloting a survey is essential, often revealing flaws in the questions not obvious to the researcher (McLafferty 2003). Following a pre-pilot check of the survey questions with two practitioners in the subject area, minor amendments were made. A pilot survey was conducted on a sample of ten NHMF committee members. The questionnaire proved to be far too long. As one pilot participant commented, 'the business world now communicates in short gasps' (personal email), indicating that a wordy questionnaire would not gain and keep the attention of the intended respondents.

The questionnaire was therefore halved in length, to just five key questions, four multiple-choice and one open-ended, requiring no more than 10 minutes to complete. A second pilot with ten members led to further minor amends to ensure that all possible responses were included in the multiple-choice questions. As the purpose of the survey was to give an overview of the current position, from the perspective of one group in the research, the scaled-down survey was considered adequate.

SurveyMonkey was selected as the online survey tool. The Advantage version of this tool has the capacity to analyse quantitative questions and to export data to NVivo (see 4.5.2.3) for qualitative analysis and cross-tabulation with other data. SurveyMonkey is readily manageable by the researcher and, crucially, in the researcher's experience is a survey format in regular use in the social housing sector and therefore familiar to participants. Although this tool lacks the sophisticated analytical ability required for a complex quantitative survey, it was considered appropriate in this instance.

Following the University Ethics approval for all methods (see Appendix 2), the survey was launched in November 2017, using the SurveyMonkey platform, addressing the questionnaire (see Appendix 3) and explanatory email to named individuals on the membership database of the NHMF.

4.4.3 Focus Group

A focus group of maintenance practitioners in the social housing sector, conducted as part of the scoping stage of the research, helped counter the limitations of the self-administered online survey, in particular the typical low response rate and the inability to probe responses. The interactive nature of a focus group helped to 'stimulate the respondents and support them in remembering events' (Flick 2009: 196) and thus added knowledge and insights that are less accessible through a survey alone.

In this study, the focus group complemented the survey, using the same questions. In discussions with the NHMF, it was agreed that the researcher would feedback results of the scoping survey at the NHMF conference in January 2018, in an optional focus group for conference delegates. The survey results would be used as a stimulus to prompt input from focus group participants, thus extending the range and depth of opinions and experience gathered related to the survey questions (Morgan 1988).

Although conference delegates opting to take part in the focus group were a relatively homogeneous group, all being engaged in social housing maintenance and generally in a management or director role, differences of opinion could be anticipated. Sharing experiences related to the research topic within a group representing a diverse range of social housing businesses would thus illustrate the 'dilemmatic nature of everyday argument' (Lunt and Livingstone 1996: 96).

A focus group context risks a 'false consensus' or, alternatively, group polarisation, when people in groups move towards agreement or shift towards extreme positions. The researcher therefore drew out 'socially expressed, and contested, opinions and discourses' (ibid.: 93), rather than focusing on eliciting individual attitudes. Given that 'qualitative research thrives analytically on differences and discrepancies' (Barbour 2007), such differences in results are a resource rather than a problem and 'the methodological goal should be to understand the sources of these differences' (Morgan 1993: 232).

The recruitment of participants with relevant experience and interest in the subject was straightforward, but the number and mix of participants depended on alternative options scheduled at the same time in the conference programme, and the choices made by individual delegates, rather than on research design. The focus group was required to fit within a one-hour session, at a time and place determined by the conference organisers.

Notwithstanding the drawbacks, adapting the focus group protocol to this situation enabled the researcher to access rich data, at low cost (Flick 2009: 200). As Lunt comments, there can be many difficulties in the conduct of research, 'some of which are not solved by design, but by careful practical conduct' (Lunt and Livingstone 1996: 93).

4.4.4 Case-study interviews

4.4.4.1 Interviewee selection

The rationale for conducting case-studies in this research was to build an understanding of the issues in rich detail through the particularity of specific examples, with differing characteristics, in a variety of contexts (Yin 2013). An ‘information-oriented selection’ (Flyvbjerg 2006: 230) of interviewees was therefore made, reflecting factors identified as relevant to the research topic and providing a basis for analysis within and between the case studies. Strategic selection of cases in this way enabled a small number of cases to yield deep, context-dependent, knowledge (ibid.). A total of 35-40 interviews in total, spread as evenly as achievable across the five case-studies, was considered to be manageable in practice, with the potential to encompass a diverse range of homes and households.

Across the five case-studies, selection of residents was designed to capture the experience and practices of a wide range of households, varying by age, household composition, ethnicity, health/disability, and length of occupancy, to explore what impact these factors may have on ventilation practices, although individual schemes may be restricted to a specific age group or household type.

The case-study schemes varied in size and dwelling types. The larger schemes included a mix of dwellings, giving the opportunity to select residents with experience of a range of dwelling types, whereas the smaller schemes offered less variety. Nevertheless, across the five case-studies it was possible to select interviewees with experience of a range of dwellings and explore what impact the dwelling type may have on ventilation practices.

At each case-study scheme all residents in low rent homes, with limited exceptions, were contacted by letter, drafted by the researcher and sent under the housing association letterhead, inviting volunteers to participate in the study. A selection was made from those volunteering, to maximise the mix of household characteristics and dwelling types. Residents were excluded from the invitation only where, in the opinion of the housing association, personal circumstances would make interviewing inadvisable or impractical, such as a history of violence or known serious ill health.

Taking part in the study could have led interviewees to modify their responses. While it was not possible to eliminate this known phenomena, the Hawthorne effect (Payne and Payne 2004), interviews included observation (see 4.4.5) as well as listening, in order to capture what residents actually did in relation to ventilating their homes, as well as what they say they did.

Not all members of each household participated in the interviews. This added a further variation as responses reflected the experience and practice of the interviewee, which did not capture the full picture for a multi-person household. This dimension was explored with interviewees in such households, whether or not all members of the household participated in the interview.

Key housing association personnel were identified at the planning meeting, comprising a core group across all the case studies, and additional interviewees dependent on the specific structure and job responsibilities within each association.

The core group of staff interviewees at each scheme were selected post-holders in the maintenance team, who had detailed knowledge of the scheme and current responsibility for day-to-day services to residents. Staff interviewees in the neighbourhood/housing management team and development team, ideally an individual involved in the scheme at development stage, were also sought for each scheme. The specific post-holders varied between associations, due to different structures and responsibilities applying and, in the case of development, changes in personnel during the time elapsed since scheme completion. In one association a Quality Manager was also identified as a key post-holder in relation to the case-study scheme.

4.4.4.2 Interview planning

A planning meeting at the association's office was scheduled for each case study, ideally including the key personnel from maintenance, neighbourhood/housing management and development teams (see Appendix 1). This gave the opportunity to discuss scheme maintenance and management issues relevant to the research and raise initial queries arising from the review of documentation requested (see table 9). Any missing documents were requested at this stage.

Table 9. Scheme documents requested

Priority	CORPORATE
	Association's vision and values
	Development strategy
*	Maintenance Strategy
*	Corporate policies and procedures related to energy efficiency, sustainability, housing standards, service monitoring, quality standards
*	Structure diagram for the Association
	SCHEME DEVELOPMENT
	Key personnel – Association's project manager, architect, M&E consultant, contractor
*	Project responsibilities diagram
*	Contract type
	Project timeline and phasing
*	Location plan/site layout plan
*	Scheme mix by unit type/tenure
*	House layout plans, including intended furniture layout
*	Scheme specification, including standards specified for energy efficiency and airtightness
	Heating and ventilation layout plans and technical spec
*	Construction type, including window/door details
*	Revisions during development stage to brief, plans, specification
*	Ventilation equipment product information, installer instructions, maintenance instructions, user instructions
*	Airtightness test reports
	Energy Performance Certificate
	Maintenance responsibilities during defects period/post defects period
	SCHEME HANDOVER
*	Home User Guide
*	Handover procedure
*	Tenant Handbook
	Repairs Handbook
*	Key personnel involved in handover
	SCHEME POST-OCCUPANCY
*	Association maintenance schedule for ventilation equipment
	Ventilation incidents/action during defects period, extracts from maintenance log
*	Ventilation incidents/action post defects period, extracts from maintenance log
	Monitoring data on energy use, humidity, air quality, other environmental factors
*	Scheme reviews/resident satisfaction surveys
*	Instructions/advice to residents regarding operation/maintenance of ventilation
*	Instructions/advice to residents regarding condensation, damp, mould
	Key personnel post-occupancy

A visit to view a void dwelling at the case-study scheme, with an association officer, was requested if available, providing a useful opportunity to become familiar with the layout, heating/ventilation and features of the home and scheme before interviewing residents.

Appointment times were agreed with residents and confirmed, by phone, text or email. Two prompts were sent, one week and one day before the appointment. A reserve group of residents who had volunteered to take part was identified, to be contacted in the event that any interviewees were unable or unwilling to continue their involvement. It was not proposed to offer incentives or rewards for participation in this study as the commitment for each resident was voluntary and consisted of one short interview only.

In order to ensure the safety of interviewees, they were advised that the researcher would show photo identification on arrival. Safety arrangements were also implemented for the researcher. Interview addresses and times were provided to a contact person, enabling the researcher to text that person at the start and end of each interview.

4.4.4.3 Interview format

Resident interviews took place in the resident's home, at a mutually convenient time. Written information about the research and a copy of the consent form was provided to the resident in advance and the opportunity given to raise queries before the interview took place. When the resident was fully satisfied with responses to any queries they had, they were asked to sign the consent form.

Case-study interviews were semi-structured, recognising that new perspectives and issues would more readily emerge in a more conversational, unstructured section of an interview (Gillham 2005; Kvale 2008). In order to capture the specific circumstances and context of each interview, structured questions were included in the pre-prepared interview plans, while people's stories would provide rich sources of data (see Appendix 4).

Interviews were expected to last about 30 minutes and were recorded in hand-written notes and audio-recording, using a small unobtrusive voice recorder. The researcher sought to understand participants' practices by gaining knowledge beyond what was verbalised and by recognising that language is not a neutral carrier of meaning. Listening to what was *not* said, and being open to non-verbal communication, was an integral part of the interview process (Mason 2002).

Interviews with association staff were conducted at their place of work, at a mutually convenient time. The same interview protocol was followed for staff as for residents. Interviews followed a pre-prepared semi-structured question plan, tailored to the interviewee's job role (see Appendix 5 Interview guide for maintenance practitioners).

4.4.5 Observation and visual recording

The discrepancy between what people *say* in interviews and surveys, and what they actually *do* in practice, is a long-known and well-researched phenomenon (Robson 2002: 310). In order to capture participants' 'doings' as well as 'sayings', the elements of a practice according to Schatzki (2002: 14), resident interviews included observation of residents' actions during a home walkthrough. The walkthrough followed a pre-prepared guide (see table 10), informed by study of the property documentation. Where possible, relevant features of the home and actions demonstrated by the resident were recorded in photo and video-clip formats, using a small digital camera.

Table 10. Home walkthrough guide

QUESTIONS	OBSERVE PHOTO VIDEO
How well does ventilation work here? Any particular issues? How/when do you ventilate in here? How do you boost if needed?	Feel of room Windows open/closed Heating Fans
Do you open windows here? How often? How easy? Anything stops you? Do you use tricklevents?	Window type Catches Obstructions Tricklevents
Any condensation or damp? Where? When? How long?	Crowded furniture etc Under door gaps
Bathroom extract?	Working Clean
Kitchen extract? Cooking amount? Cooker hood? Filter?	Working Clean Cooker hood type
Laundry wash & dry. Where? How?	Tumble dryer vent Outside line
Ventilation controls. Where? How? Who?	Type of controls Complexity, usability
Maintenance of ventilation? Filter change?	Filters
All in house agree on temp and vent? Who takes charge?	

As interviews involve recalling events, or action taken, after the event, accounts are subject to the accuracy of a participant's memory. For this reason, Hitchings considers that interviews can only ever provide 'an unsatisfactorily washed out account of what previously took place' (Hitchings 2012: 61). Indeed, everyday practices may be so habitual that people overlook significant aspects when recounting daily activities to an interviewer (ibid.). The intention of observing residents' actions in respect of the research topic, in their homes, is to use 'domestic spaces and materials to frame conversations about what happens, where and why' (Tweed et al. 2014: 5), not relying on memory.

Observation by a researcher as a resident carries out everyday tasks does not guarantee, however, that these will be performed ‘as they naturally occur’ (Flick 2009: 225), due to the unquantifiable influence of the act of being observed on the resident. Similar to the effect on interview and survey responses, actions may be distorted by a desire by the individual to present themselves in a good light, described by Robson as the ‘social desirability response bias’ (Robson 2002: 310).

Notwithstanding these criticisms, observing how residents interact with their physical environment contributes to understanding how individuals act as ‘carriers of practices’ (Reckwitz 2002), including how they manage to ‘amend the contextual rules through improvisation’ (Hitchings 2012: 63).

The methodological approach of this study does not come close to the sensory ethnography described by Pink (2015). Nevertheless, elements of visual ethnography, through the medium of photos and video clips, are employed. In addition, sensory observations while interviewing and observing, in residents’ homes and around the schemes, are recorded in the researcher’s contemporaneous notes.

The method for recording activities by photo or video is not, however, self-evident. The researcher’s focus is inevitably selective (Flick 2009) and shaped by both ‘spatial editing’, i.e. choosing what and how to record, and ‘temporal editing’, i.e. choosing when to start and stop recording (Tinkler 2013: 6). Notwithstanding obtaining informed consent in advance, the intrusion of recording equipment, and unknown impact of the process on the participant, could not be eliminated entirely, although it was minimised (Flick 2009).

A process of self-reflection after each interview was an integral part of the interview method, captured in contemporaneous notes. These recorded how the intersubjective dynamic shaped the interview, and action taken to counter potential bias, and provided secondary data to assist interpretation.

Further secondary data was gathered by observation in and around the case-study housing schemes, using a site checklist (see table 11), and by taking photos of relevant external features of the schemes. This data enabled details recorded in interviews to be cross-checked against the reality on site.

Table 11. Site observation checklist

Site Checklist ***Attach site plan and location plan*** ***Observations – note on checklist, indicate relevant issues on plans*** ***Photos – take photos, indicate position/direction on plans***		
Day/date of visit		
Time		
Weather		
Scheme name		
Address/ postcode		
Housing assoc		
		NOTES
EXTERNALS	Windows/trickle vents Doors/porches Extract/intake vents Ventilation cowls Solar PV/Solar Thermal/other renewables Indicators of damp – gutters, downpipes, walls, DPC, ground level Well maintained/neglected	
SCHEME	Orientation Exposed/sheltered Open/shaded Overlooking/privacy issues Clothes drying space Well maintained/neglected	
LOCATION	Urban/rural Built up/open Residential/commercial/industrial/agricultural Main road/side road/cul-de-sac Safety issues Air pollution sources – dust, dirt, pollen, smells Noise sources Security issues Radon area – postcode check at www.ukradon.org	

4.4.6 Document review

Understanding the case-study schemes, and the interrelationship between the housing associations and residents involved, was assisted by the detailed study of plans, documents and records relevant to the research questions. These ‘standardized artefacts…in particular formats’ (Wolff 2004: 284) are not, however, bias-free, objective records. Mason cautions that documents are always ‘constructed in particular contexts, by particular people, with particular purposes, and with consequences – intended and unintended’ (Mason 2002: 110), information that is not always overt in the document itself.

A critical reading of documents considered the context, authors, purpose and consequences. Particular attention was paid to the ‘institutional intentions’ (Flick 2009: 257) of the case-study documents: the picture they are designed to paint, the messages they are intended to convey, the processes they reveal. Indeed, Flick considers documents as ‘communicative devices rather than as containers of content’ (ibid.: 261).

In this study, documents were used as a supplementary source of data, contextualising interview statements and observations. They assisted by clarifying and corroborating, or indeed contradicting, data from other sources, but could not prove the accuracy of interviewee statements (Flick 2009; Mason 2002).

A checklist of requested documents (see table 9) was discussed with each case study housing association at the planning stage, to identify the availability and source of each item. Available documentation, in hard copy or digital format, including text and non-text documents, such as plans, was collected and studied prior to interviewing participants. Documentary data on the scheme - the ventilation strategy, intended operational requirements and maintenance regime, and advice to residents, for example - inform the interviewing and observation, enabling the stated intentions of the scheme to be compared with actual practice.

4.5 Analysis methods

4.5.1 Data preparation

4.5.1.1 Capturing participants' own words

Rendering spoken data into text enabled the researcher to 'create durable and analysable records of otherwise transient phenomena' (Krippendorff 2013: 82). Throughout the analysis, the researcher aimed to follow Hammersley's dictum to think 'not only *about* one's data, but also *with* and *through* the data, in order to produce fruitful ideas' (Hammersley 2007: 168). Transcription of recorded data in this study captured the 'substantive content or topic of talk' (Roulston 2013: 299) and prepared the data for analysis.

Interviewees' words were recorded in the transcripts using standard orthography, without editing. The interviewer's words were omitted except where necessary to summarise a question or describe an extralinguistic action, pointing to a specific item for instance. Where included, the interviewer's words were identified and did not form part of the coding or analysis. The detailed transcription conventions necessary for linguistic, conversational or discourse analysis were not considered necessary in this study. The focus of the transcripts is the words spoken, rather than the way they are spoken or non-verbal vocal or non-vocal behaviour (Braun and Clarke 2006).

4.5.1.2 Selectivity, bias and reconstruction

Although interviewees' responses are recorded in their own words, it is recognised that 'you can't assume that a person's words are a transparent window' (Roulston 2013: 2). Knowledge gained from interviews is inevitably partial and imperfect. Analysis therefore reflected this, cross referencing interview data with secondary and context data (see 4.5.5.2).

Kowal and O'Connell remind the researcher that 'all transcription is in principle selective and entails the inevitable risk of systematic bias' (Kowal and O'Connell 2013: 4). They add that lack of experience in transcription may compound this risk. These risks were mitigated by testing the transcription process at the pilot stage, with the supervisor checking for accuracy and bias and advising on technique. Cross-checking data in transcripts against other data, such as records of home observation and photos, provided an additional opportunity to detect and correct inaccurate transcription.

Recognising ‘the necessity to *know* one’s data’ (Hammersley 2007: 162), transcription was carried out by the researcher in person. Repeated listening to the audio-recordings was undertaken, to eliminate as far as possible the ‘deletions, additions, substitutions and relocations’ that frequently lead to ‘creative unconscious reconstruction’ by the transcriber (Kowal and O'Connell 2013: 8). Further clarification was obtained direct from the audio-recording as necessary during analysis.

As a novice transcriber, the researcher recognised the need to overcome ‘over-learned habits regarding the use of well-formed structure in written language’ (Kowal and O'Connell 2013: 10), in order to remain true to the interviewee’s voice. This risk was mitigated by repeated listening to the recording and correction of the transcript until the written text was a faithful record of the words spoken.

4.5.1.3 Anonymising the data

The ethics of anonymising data are contested, regardless of the practical obstacles to achieving this outcome. Baez (2002) argues that anonymity leaves underlying power structures unchallenged. He challenges the ‘convention of confidentiality’ (Baez 2002: 35) from the standpoint of transformative research, asserting that ‘secrets in the context of oppression foreclose the possibility of an agency that will resist it’ (ibid.: 55). In defence of his position, Baez challenges the view that honest disclosure by participants depends on a promise of confidentiality, arguing that this is engendered by trust in the researcher.

A more nuanced view is put forward by Moore, accepting that anonymity is ethically right but suggesting that a ‘paternalistic notion of protection’ (Moore 2012: 331) leads to exaggeration of the anticipated harm to participants from lack of anonymity. She argues that anonymity can be preserved, without compromising the integrity and future use of data, through 'a shift from paternalism to a feminist ethic-of-care' (ibid.: 338).

Participants in this study were assured of anonymity, though care was taken not to give unrealistic guarantees (British Sociological Association 2017). Given the small field of social housing in England, changing identifiers to the extent required to eliminate *all* chance of housing associations and schemes being recognised, and thus indirectly leading to interviewees being identified, could have distorted data to the extent that analysis becomes meaningless and future use of the data is precluded (Saunders, Kitzinger, and Kitzinger 2015).

Informed consent was sought in advance from all research participants, offering anonymity and giving individuals the option of anonymised material being retained for future use. Codes are used in place of real names for all participants, places and organisations involved, retaining the ability to cross-reference data but ensuring that participants cannot be readily identified.

4.5.2 Coding

4.5.2.1 Attributing meaning

Transcription prepared the data for analysis using coding methods, firstly to understand the data inductively, without pre-coding, and secondly to interpret the data abductively with reference to theory. This approach broadly follows Kvale's process of 'meaning coding', 'meaning condensation' and 'meaning interpretation' (Kvale 2018: 210).

Hammersley emphasises that 'underpinning the process of analysis is the necessity to *know* one's data' (Hammersley 2007: 162), in all its richness and diversity. Coding, in the context of this qualitative analysis, is essentially a process of attributing meaning to raw data, as interpreted by the researcher through 'researcher-generated constructs' (Saldana 2016: 4), to facilitate further analysis. Codes of a word or short phrase, determined by the researcher, were used to assign a 'summative, salient, essence-capturing and/or evocative attribute' to each portion of text (ibid.: 3).

However, coding is not simply a means to manage and manipulate the data but also enables the *'breaking open'* of the data (Bazeley 2013: 72). Systematic coding not only provided an important infrastructure for later searching and retrieval, but constituted an integral part of the analysis, enabling the researcher to be 'surprised and excited and informed by nuances in the text, but also stand back and see the whole, and where that whole fits in a larger whole' (Bazeley 2013: 68).

4.5.2.2 Coding cycles

In order to *know* and *break open* the data, coding was carried out in two consecutive stages, applying different coding techniques at each stage (see table 12). Repeated coding cycles enabled the researcher to aggregate the plethora of initial topics into a more manageable number of categories and thus identify more easily the major themes or concepts in the data (Richards 2013).

Table 12. Analysis methods

Analysis methods					
Section	Stage	Data	Aim	Method	Reasoning
4.5.3	First cycle coding	Interview transcripts Focus Group transcript Survey data	Meanings: Capture meaning or topic of each segment of text in a word or short phrase	Descriptive Coding to build up a library of codes representing topics/ideas/concepts, without pre-coding Create codebook	Inductive
4.5.4	Second cycle coding	Codebook from first cycle Supplementary data	Understanding: Identify patterns, themes and linkages in the codes Classify codes into categories and sub-categories Build map of themes and sub-themes	Pattern Coding to create categories and sub-categories by assembling and re-assembling codes Test and refine categories with reference to additional data, theoretical framework, literature, researcher's knowledge Identify provisional themes	Inductive Abductive
4.5.5	Thematic analysis	Provisional themes from second cycle Supplementary data	Interpretation: Answer research questions through thematic analysis of data, with reference to theory and literature	Thematic Analysis to finalise themes with reference to data, theoretical framework and literature Seek additional insights from informal advisory group Write up analytic narrative for each theme, supported by data extracts and 'stories'	Abductive

First cycle coding methods are relatively simple and direct, enabling the researcher to understand and label or index the contents of the data in ways appropriate to the research design and questions. Descriptive Coding (Saldana 2016: 87) was used for the first cycle in this study in order to capture inductively the meanings in the data without preconceptions.

Second cycle methods build on this initial stage, using the coded material to classify, categorise, conceptualise and integrate the data. Pattern Coding (Saldana 2016: 209) was considered an appropriate method for the second cycle, being consistent with the research aim and theoretical framework.

Analysis thus progressed from capturing meaning at the initial stage, to understanding and interpreting data at the later stages, seeking patterns, themes and linkages within the data and relating these to the research questions and the theoretical framework adopted. While the process in general shifts from openness to selectivity (Flick 2009: 307), Saldana points out that coding cycles should not be regarded as strictly separate stages, linear in time, but as an iterative process. Analysis in this study reflected this, being a recursive process, moving back and forth throughout the phases (Braun and Clarke 2006).

4.5.2.3 Tools for qualitative data handling

The use of CAQDAS (Computer Aided Qualitative Data AnalysiS) software is increasingly the norm for researchers. While the electronic coding capability of CAQDAS has ‘the potential to turn qualitative research into a rigid automated process that neglects the role of human interpretation and reflection’ (Kelle 1995), the use of CAQDAS software in this analysis, involved manual rather than electronic coding. This harnessed the capacity of IT for recording, sorting, matching and linking, thereby greatly enhancing the data handling process and opening up new ways of seeing the data (Bazeley 2013; Basit 2003).

NVivo 12 for Mac was selected as the CAQDAS software, facilitating concurrent coding, annotating and recording reflections on the data, and enabling links to be made within the data (Lewins 2007). While NVivo cannot replace the interpretive role of the researcher, its search and query capability enabled analysis to encompass the whole corpus of data. The validity of the analysis depends, however, on skilful coding. For example, respondents expressed similar ideas in different ways, using multiple synonyms, which needed to be identified and aligned by the coder. NVivo's functionality was considered appropriate for the research methodology and enabled the quantity of data collected to be analysed in the time available.

4.5.2.4 Countering subjectivity

Whereas electronic coding on its own presents the risk of coding becoming an unthinking automated process, manual coding is open to subjectivity on the part of the coder. Charmaz emphasises that meticulous coding 'helps you to refrain from imputing your motives, fears, or unresolved personal issues to your respondents and to your collected data' (Charmaz 2003: 94). Sipe and Ghiso assert that 'all coding is a judgement call' and that it is unavoidable that we bring 'our subjectivities, our personalities, our predispositions, our quirks to the process' (Sipe and Ghiso 2004: 482).

Subjectivity has been countered in this study by paying rigorous attention to coding the material 'in line with what is happening within the text' (Flick 2009: 330). Concentrating on the text, rather than preconceptions (Bazeley 2013: 72), initial coding was an iterative process, involving reading and re-reading texts exhaustively.

In order to counter the inevitable subjectivity and tendency to be selective, coder consistency was tested at the outset. Co-coding one text was considered sufficient to strengthen credibility of the findings in thematic analyses (Richards 2013; Sutton and Austin 2015). In this study, one interview transcript was independently coded by the researcher, her supervisor and a third-party familiar with coding but with no connection to the research. The differences and similarities in coding were discussed, with adjustments identified and made in the coding technique and interpretation of the text to ensure credibility.

Details of each code created in the first cycle were recorded in a codebook, and similarly details of categories identified in the second cycle in a category file, not only to provide a check for consistency for the researcher and supervisor, but also for external auditors or later researchers using the data.

4.5.3 First cycle coding

4.5.3.1 Descriptive Coding

In this study, Descriptive Coding (Saldana 2016: 87) is used for the first cycle of coding, in order to capture inductively the meaning of the text in a concise format, in preparation for further analysis. Kvale (2018) describes this approach as 'meaning coding', using descriptors of one or two words as precise 'identifications of the *topic,* not abbreviations of the *content.* The topic is what is talked or written *about'* (Tesch 1990: 119).

Building up a vocabulary of codes from the data, without imposing *a priori* categories, enabled the researcher to explore and interpret meanings in the raw data without 'forcing a structure on the data' (Flick 2009: 314), given that a theoretically driven analysis 'may obscure the view of the contents rather than facilitate analysing the text in its depth and underlying meanings' (ibid.: 328). The coded meanings extracted from the texts were then explored to identify themes and patterns at the next stage of the analysis.

4.5.3.2 First cycle coding process

Using the coding facility in NVivo, each text (interview transcripts, focus group transcript and text responses to survey Q5) was considered in turn, identifying and describing each topic that arose by a code of a single word or short phrase, between one and five words. Using only short codes allowed for a level of differentiation between topics at this stage, while retaining conciseness and distinctiveness. Texts were read and re-read, line-by-line, and coded exhaustively until all text was coded, adding new codes or adding material to codes already created (see Appendix 6 First cycle coding example).

Each segment of text coded was long enough 'to provide sufficient context without clouding the integrity of the coded passage by inclusion of text with a different meaning' (Bazeley 2013: 72). Taking too small a section of text would result in coding that is shallow, whereas coding too large a section would generate unreliable results, in both cases compromising its validity (Krippendorff 2013).

The coding process avoided selectivity on the part of the coder, eschewing ‘cherry picking’ from the texts. Systematic and exhaustive coding was critical to the validity and reliability of the research, as ‘thin descriptions and unconvincing analyses derive from cursory reading and inadequate acquaintance with the data’ (Hammersley 2007: 162). Krippendorff similarly proposed that ‘no unit may be excluded because of a lack of descriptive terms’ (Krippendorff 2013: 132). Accordingly, the researcher coded the data exhaustively.

4.5.3.3 Coding multiple meanings

Given that ‘social interaction does not occur in neat, isolated units’ (Glesne 2011: 192), some segments of data suggested ‘multiple meanings that necessitate and justify more than one code’ (Saldana 2016: 80). Miles advised that assigning more than one code to a segment of data is warranted if a segment is both descriptively and inferentially meaningful’ (Miles 1994: 66).

Saldana cautions, however, that simultaneous coding should be used sparingly, as this may ‘suggest that there is no clear or focused research purpose and thus a clear lens and filter for analysing the data’ (Saldana 2016: 81). In this research, multiple coding of a segment of data was used where it was assessed by the researcher that this captured fully the speaker’s meaning.

4.5.4 Second cycle coding

4.5.4.1 Pattern Coding

A second cycle of coding provides a bridge between initial extraction of meaning in the ‘bread and butter’ codes created inductively in the initial stage, and abductive interpretation of the data at the thematic analysis stage. This intermediate stage of the analysis, understanding the data, requires both inductive and abductive reasoning. The style of coding described as Pattern Coding (Saldana 2016: 209) is employed in this study to develop initial themes from the first order codes, a process of categorising and grouping codes that creates ‘a sort of meta-code’ (Miles 1994: 69). The definition of categories, creation of sub-categories, and reassignment of data between categories, proceeds from examination of similarities, differences and linkages within the data.

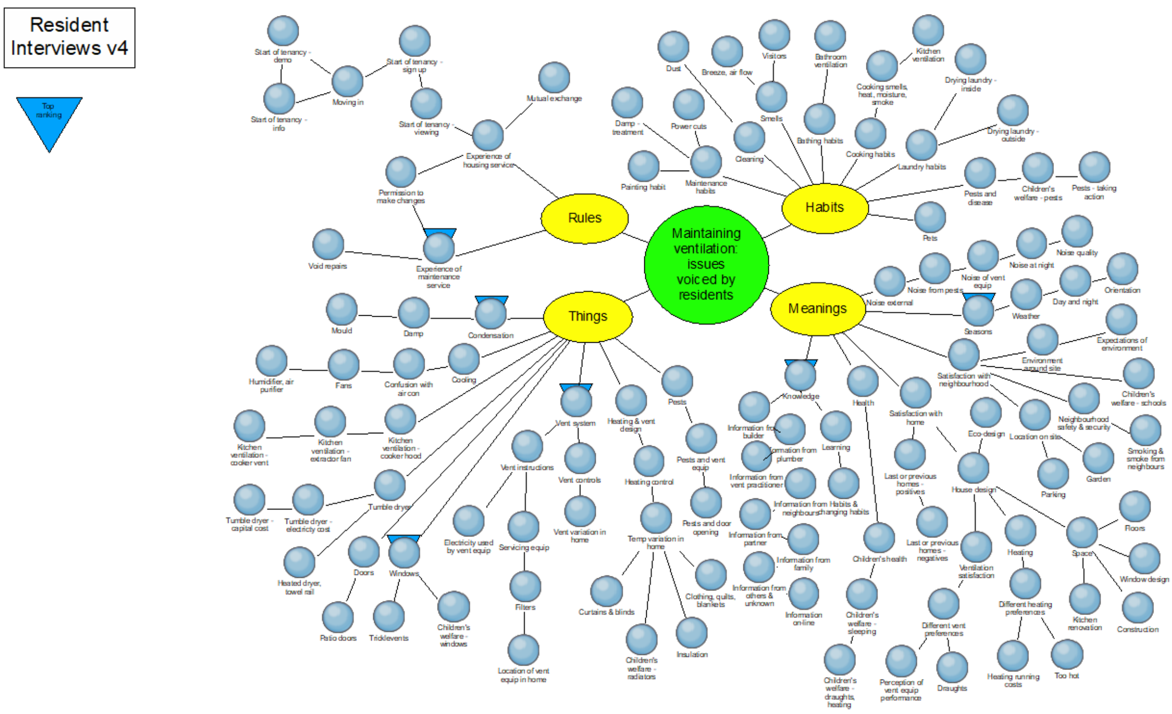
The process used to create the initial ‘meta-code’ in this study is derived from the constant comparative method, as detailed by (Grove 1988). Although this method is normally aimed at the development of grounded theory (Glaser 1967; Lincoln 1985), the iterative process involved in developing initial themes and categories was considered applicable in this research, before abductively refining the categories and themes with reference to Practice Theory.

4.5.4.2 Second cycle coding process

In the second cycle of coding, once the meaning codes were grouped into provisional categories and themes, initially ‘according to the researcher’s intuition’ (Grove 1988: 275), an iterative process followed, involving continuous movement back and forth between building categories and sub-categories inductively from the codes, and abductively testing the categories and the relationships between them in relation to Practice Theory, the literature and the researcher’s knowledge (see table 13).

Table 13. Second cycle coding example

Second cycle coding example: descriptive codes from resident interviews, patterns related to components of practices (Gram-Hanssen, 2009)



This iterative process stopped when all codes had been categorised and a discernible pattern emerged, although there were inevitably codes and categories that did not readily ‘fit’ the pattern. Braun & Clarke express this succinctly as: ‘when your refinements are not adding anything substantial, stop!’ (Braun and Clarke 2006: 92).

This pattern building process led to the provisional identification of themes, informed by utilising NVivo for cross-tabulating data and creating charts, as well as the researcher’s active role in identifying themes and linkages.

4.5.4.3 Data that does not ‘fit’

Although the coding of texts is not in itself an analytical method, by incorporating memo writing this process allows the researcher to move ‘beyond thick description to a microanalysis of their data' (Hutchison, Johnston, and Breckon 2010: 289). Memos are used, in particular, to reflect on data that does not appear to 'fit', text with unclear or multiple meanings, codes that are hard to categorise, or relationships that are difficult to understand. In such cases memos indicate the need to check the source material or contemporaneous field notes for meaning and context, and to cross-reference sources of data. The aim of analysis is to channel 'the diversity encountered in texts to the possible answers to a research question' (Krippendorff 2013: 362). However, rich data from diverse sources inevitably reveals contradictions and inconsistencies. Far from regarding unexpected data as problematic, a 'lack of "cooperation" of texts often stimulates new insights and opens unanticipated turns' (Krippendorff 2013: 374).

4.5.5 Thematic analysis

4.5.5.1 Relating themes to case-study data

As Braun and Clarke (2006) assert, themes do not 'emerge' from the data passively, but only through the active role of the researcher: identifying, testing, selecting, or rejecting, material in the data through abductive reasoning. This interaction between the researcher, the data, the theory and the literature is critical at the final stage of analysis, as 'if themes "reside" anywhere, they reside in our heads from our thinking about our data and creating links as we understand them' (Braun and Clarke 2006: 80).

The themes identified were examined firstly in relation to the coded case-study data. Comparisons were made within and between the five case-studies and between the subject categories (residents, maintenance practitioners, other housing association staff) to determine the prevalence, significance and characteristics of each theme and sub-theme for each data set. Prevalence in this regard is measured by the *presence* of codes related to each theme in a data set, i.e. in how many interviews with residents are there codes related to this theme, rather than the *number* of times the codes appear in the data set.

A simple counting of frequency of codes could 'diminish the essence of qualitative data', as it is primarily concerned with generating precise, in-depth meanings (Hewitt-Taylor 2001:

41). For instance, the number of times a particular item is mentioned in a set of interviews may indicate that the item is greatly significant to a small number of interviewees, rather than widely recognised (Braun and Clarke 2006: 82). Nevertheless, the significance of particular items was relevant and numerical data was cross-referenced with characteristics of participants and cases to understand the nature of that significance. In order to understand the context and nature of a theme in relation to a data set where it appeared, all coded extracts in the data set related to that theme were examined, with reference to the transcripts, recordings and supplementary data where further clarification is needed.

One of the common misunderstandings about case-study research, countered by Flyvbjerg (2006), is that case study narratives are difficult to summarise. In contrast to conventional wisdom among researchers, Flyvbjerg regards a 'thick' and hard-to-summarise narrative not as a problem, but as 'a sign that the study has uncovered a particularly rich problematic' (Flyvbjerg 2006: 237). As the value of a context-rich and detailed case-study can be lost by over-summation (Peattie 2001), Flyvbjerg recommends telling the story of the case in all its complexity and diversity. Following Flyvbjerg's advice, the analytic narrative for this research is supported by case stories, capturing a 'nuanced view of reality' (Flyvbjerg 2006: 223), with all its contradictions and ambiguity.

4.5.5.2 Using secondary data

Cross-referencing the coded extracts and themes with supplementary data – contemporaneous reflections/field diary, site observation and home walkthrough notes and photos, documents, index data for cases, focus group and survey – adds further depth to the context and greater understanding. Coding of all data in NVivo enabled statements by interviewees to be cross-checked with supplementary data and compared by characteristics of the interviewee, property and landlord. This facilitated analysis of the differences and similarities between data sets, adding richness and complexity, particularly where data sources were contradictory. Deepening understanding of the themes and sub-themes identified in the data, supported by data extracts and contextual data, enabled the thematic map to be refined and defined, in preparation for answering the research questions.

4.5.5.3 External insights

At this stage of the thematic analysis, an exercise to seek external views on the research process and findings was introduced. Hewitt-Taylor (2001), highlights the complex balance of power issues to consider, and the question of how to handle disagreements between researcher and participants, but concludes that such feedback contributes to, although it does not guarantee, the trustworthiness of qualitative research.

Although external constraints in 2020 precluded face-to-face meetings, a small number of informal discussions took place with experts in the field to 'sense-check' the findings and gather additional feedback (see table 8 in section 4.4.1). In addition, given that research question 3 aims to identify what can be learnt from the study that is relevant to housing providers, discussion with relevant professionals provided ideas for knowledge transfer.

4.6 Sub-conclusion

The methodological approach of this research has been selected as fitting for an investigation of the everyday practices of ventilation maintenance in low-energy homes. It is a methodology rooted in the researcher's interpretive philosophical stance. This investigation is achieved in a qualitative study, using multiple methods of data collection, with case-studies of five new-build housing association schemes at its centre.

The data collection methods were designed and implemented with reference to the research questions and objectives, as set out in table 6 (see 4.2.4). The selection of case-study housing associations (4.3.3), schemes (4.3.4), and interviewees (4.4.4.1) reflected specific characteristics relevant to ventilation maintenance and ensured that the data collected was rich in content, as indicated in the results in chapter 5.

Analysis of the data followed a three-stage process, set out in table 12 (see 4.5.2.2). The reasoning flows from inductive coding at the first stage, to understand the data without preconceptions, through to abductively drawing out themes from the categorised codes. The researcher has engaged throughout in a 'constant interplay between data and ideas', whereby ‘ideas are used to make sense of data, and data are used to change our ideas’ (Hammersley 2007: 159) in order to answer the research questions.

Using the practice-based framework adopted (see chapter 2), an analysis of the data regarding the ventilation practice and perspectives of residents is set out in chapter 6. A similar analysis for maintenance practitioners follows in chapter 7. From this analysis, two key themes emerge, which are discussed in chapters 8 and 9.

Chapter 5. Results

5.1 Introduction

This chapter reports the results of data collection using methods of investigation detailed in chapter 4, setting out the range and characteristics of the data which is analysed in chapter 6 (resident data) and chapter 7 (maintenance practitioner data).

Data collection took place between November 2017 and June 2018, comprising an on-line survey and related focus group with maintenance practitioners in the social housing sector, and five case-studies of recently built, low-energy, rented housing association schemes (see methodology at chapter 4). The survey and focus group together form the scoping stage of the research, with the case-studies constituting the core of data collection.

The primary and secondary data collected, designed to explore the research questions, is set out in table 14. The following sections of this chapter detail the results of the data collection.

Table 14. Data collection

Data stage	Scoping		Case Studies	
Data subjects	Maintenance practitioners in the UK social housing sector Survey population 409 Focus group population c.500		Staff in five housing associations in England involved in the case-study schemes 17 staff invited	Residents in low rent homes in five recently built, low-energy, housing association schemes in England 106 residents invited
Data sources	On-line survey 34 respondents	Focus group 17 participants	Interviews, documents, observations, photos 16 staff interviewees	Interviews, documents, observations, photos 18 resident interviewees
Primary data	Survey responses Q5, free text	Focus group recording	Interview recordings	Interview recordings, including home walkthroughs

		Focus group transcript	Interview transcripts	Interview transcripts, including home walkthroughs
Secondary data	Survey responses Q1-4, multi-choice	Researcher's notes on focus group		
			Fieldwork notes	Fieldwork notes
			Scheme documents	Scheme documents
			Site observation notes	Site observation notes
				Home observation notes
			Scheme photos	Home photos/videos

5.2 Scoping survey

The first stage of data collection comprised an on-line survey of maintenance practitioners in the UK social housing sector, carried out in November 2017. The full membership (409 individuals) of the National Housing Maintenance Forum (NHMF), the professional trade body for this group, formed the survey population, representing a mix of housing associations, local authorities and Arms-Length Management Organisations (ALMOs) (see glossary). Approx. one-fifth of all UK local authorities and one-quarter of all UK housing associations are in membership of the NHMF, with a wide geographical spread. The survey population was therefore considered to include an acceptable range of experience within the sector for the purpose of a scoping survey. Although the response rate was low at 8.3% of the survey population, the 34 responses received provided valuable initial insights into the practice and opinions of this key group in relation to the research (see methodology at 4.4.2, survey database and respondent characteristics at tables 15, 16 and 17).

Table 15. Survey database and respondents: organisation type

		Invites		Responses		Responses as % of invites
		No.	%	No.	%	%
Local authority		121	30	7	21	5.8
Housing association		275	67	27	79	9.8
Other		13	3			
Total		409	100	34	100	8.3
Local authority breakdown						
	LA	88		5		
	ALMO	24		2		
	TMC/TMO	9				
		121		7		
Other breakdown						
	Procurement consortia	6				
	Surveyor/ consultant	3				
	Contractor	2				
	Military org	2				
		13				

ALMO	Arm's Length Management Organisation
TMC	Tenant Management Company
TMO	Tenant Management Organisation

Table 16. Survey database and respondents: location

		Invites		Responses		Responses as % of invites
		No.	%	No.	%	%
England regions						
	NE	14	3.4			
	NW	44	10.8	5	14.7	11.4
	Y&H	18	4.4	3	8.8	16.7
	East Mids	17	4.2			
	West Mids	36	8.8	4	11.8	11.1
	East	38	9.3	6	17.6	15.8
	SE	55	13.4	5	14.7	9.1
	SW	34	8.3			
	London	84	20.5	5	14.7	5.9
England		340	83.1	28	82.3	8.2
Scotland		24	5.9			
Wales		27	6.6	2	5.9	7.4
Northern Ireland		17	4.2	4	11.8	23.5
Jersey		1	0.2			
Total		409	100.0	34	100.0	8.3

Table 17. Survey database representativeness

	No.	%
Proportion of all local authorities included in survey database		
Total no. LAs in UK (May 2017)	**418**	
No. (%) of all LAs included in survey invites	**88**	**21%**
Source: Local Government Information Unit (LGIU)		
Proportion of all housing associations included in survey database		
Total no. HAs in UK (Oct 2017)	**1130**	
No. (%) of all HAs included in survey invites	**275**	**24%**
Source: Membership data from websites of housing association federations in four UK nations (NHF, SFHA, Community Housing Cymru, NIFHA)		
Cross-reference to database of developing housing associations in England		
Total English HAs developing (July 2017)	**247**	
No. (%) of these included in survey invites	**158**	**64%**
No. (%) of these included in survey responses	**15**	**6%**
Response rate for this group	**9.5%**	
Source: National Housing Federation (NHF) database of members currently developing and/or planning to develop		

Although housing associations comprise only 67% of the NHMF's membership, 79% of survey responses came from this group, an over-representation compared with respondents from local authorities. However, the content of responses did not appear to differ significantly between organisational types.

The NHMF represents maintenance practitioners across the UK. Respondents were spread unevenly across the English regions and the UK nations and did not reflect the geography of NHMF's membership, with no responses from NE or SW England, the East Midlands or Scotland. The small number of responses and uneven spread precluded a meaningful comparison between regions.

Given that the core of the research related specifically to housing association schemes in England, rather than the UK-wide social housing sector, the NHMF's membership database was checked against data from the National Housing Federation (NHF) (see glossary), the trade-body for English housing associations. This revealed that nearly half of the survey responses came from housing associations in England that are currently developing and/or planning to develop, the group most likely to have experience of low-energy new-build homes. The survey respondents were therefore considered a relevant population to scope the research topic.

Following a pilot survey and amendments to the draft survey design (see methodology at 4.4.2.3), the final survey questionnaire contained five questions: four multiple-choice tick-box questions and one open-ended question requiring a descriptive answer in free-text format (see survey questionnaire at Appendix 3).

The open-ended question, Q5, was as follows:

> In your view, what are the three biggest problems, and the solutions, for social landlords in maintaining effective ventilation in rented homes?

All but one of the 34 respondents answered this question, almost all using short phrases, or sometimes single words, only occasionally expanding on their answer (see responses to survey Q5 at Appendix 7). Nevertheless, the totality of responses provided a useful snapshot of opinions on the research topic from maintenance practitioners in the social housing sector, which were explored more fully at a subsequent focus group at the NHMF annual conference.

The responses to the open-ended question above were analysed in relation to the elements of Practice Theory defined by Gram-Hanssen (2009), adopted as the theoretical lens for this research. Secondary data, from the four multiple-choice survey questions, informed and expanded the analysis where relevant (see responses to survey Q1-4 at Appendix 8).

The survey responses indicated that maintenance practitioners feel ‘outside the loop’ of the design and construction of new low-energy homes, merely ‘inheriting’ whatever design, installation or commissioning faults occur. The handover process appears to be minimal, leading survey respondents to argue that ventilation maintenance practice needs to be integrated in a continuous housing process, from briefing to occupation.

Respondents placed responsibility for damp and mould on residents' habits or 'lifestyles', discounting ventilation maintenance as a cause, and expressed frustration that resident education had little effect on their ventilation practices.

A further theme in the responses was the desire for standardised ventilation systems across the stock for ease of maintenance, although there was acceptance that this would result in sub-optimal ventilation performance.

These insights from survey participants provided an indication at the preliminary scoping stage of key themes for further investigation in the focus group and case-studies.

5.3 Focus group

Approx. 500 maintenance practitioners, i.e. every delegate at the National Housing Maintenance Forum (NHMF) Annual Conference, held in Birmingham, 23-24 January 2018, were invited to explore the research topic, in a one-hour focus group (see methodology at 4.4.3). Questions in the November 2017 on-line survey were used as a framework for discussion (see survey questionnaire at Appendix 3). The 17 participants were self-selected, opting to participate in the focus group in preference to other conference workshops running at the same time. Participants were predominantly in manager/supervisor roles in housing maintenance, employed in a mix of housing associations, local authorities and Arms-Length Management Organisations (ALMOs), geographically spread across the UK (see table 18).

Table 18. Focus group participant characteristics

Focus Group 23 Jan 2018			
Participant number	Job title	Region	Organisation type
F1	Maintenance Officer	SW	HA
F2	Projects Manager	NW	HA
F3	Social Housing Sales Manager	UK-wide	Ventilation manufacturer
F4	Property Supervisor	West Mids	ALMO
F5	Asst Repairs Manager	West Mids	ALMO
F6	Maintenance Inspector	NW	HA
F7	Senior Building Surveyor	SW	Local authority
F8	Property Surveyor	East	HA
F9	Head of Asset Management	West Mids	HA
F10	Stock Data Manager	NW	HA
F11	Area Sales Manager	UK-wide	Ventilation manufacturer
F12	Director	UK-wide	Building consultancy
F13	Tenant Services Manager	East	Local authority
F14	Advisor	UK-wide	Trade body
F15	Repairs & Maintenance Manager	East Mids	Local authority
F16	Executive Engineer	N Ireland	Local authority
F17	Executive Engineer	N Ireland	Local authority
ALMO Arm's Length Management Organisation			

Participants' responses to the questions, and their wider comments relevant to the topic, as expressed in the focus group, were analysed in relation to the elements of Practice Theory defined by Gram-Hanssen (2009) (see focus group transcript at Appendix 9).

Focus group participants, considering the same questions as survey respondents, broadly confirmed the key themes indicated in the survey. Again, the lack of joined-up thinking within housing organisations was cited as problematic in relation to ventilation maintenance. Inadequate, or absent, handover or briefing evidently contributed to a failure to carry out regular servicing.

Participants expressed a reluctance to engage with unfamiliar ventilation technology, preferring to use standard equipment and parts, even where this compromised ventilation performance.

Friction between maintenance practitioners and residents regarding the cause of ineffective ventilation was evident, although the assertion that resident 'lifestyle' was the overriding cause was challenged by some participants.

The focus group discussion confirmed that understanding what shapes ventilation maintenance practice and how it impacts on the effectiveness of ventilation in low-energy homes requires investigation of wider housing practices as well as resident practices related to ventilation.

It was evident that the relationships between housing practices, and between maintenance practitioners and residents, are key to understanding the topic, and that handover practice for new homes, typical maintenance practices and beliefs about the cause of ineffective ventilation, are all significant factors in ventilation maintenance. These insights were taken into account in planning the range of interviewees and scope of the case-study interviews.

5.4 Case-studies

5.4.1 Housing associations

The five housing associations selected for the research represented a diverse range on each of the characteristics considered to be relevant to the research questions (see methodology at 4.3.2). This diversity enabled exploration of a wide range of experience of residents and maintenance practitioners within a small number of cases (Flyvbjerg 2006) (see table 19).

Table 19. Housing association characteristics

Case-study housing associations					
Housing association	**A**	**G**	**H**	**L**	**R**
No. of rented homes in management	1100	400	4300	54000	46000
Operating regions	Y&H	SE	E, London, SE, SW	London, SE	East, E Mids, London, NE, NW, Scotland, Y&H
Part of a group structure	No	No	Yes	Yes	Yes
Development managed in-house	Yes	Yes	Yes	Yes	Yes
Maintenance arrangements	In-house team + local contractors	In-house team + local contractors	In-house team + regional contractors	Contracted-out to independent company	Contracted-out to company within group structure
Y&H Yorkshire & the Humber					

The size of the case-study associations, measured by the number of rented homes in management, ranges from 400 to 54000 homes, with the five associations including both independent organisations and those which are part of larger groups of associations. The three larger associations operate multi-regionally and provide market housing for rent and sale, as well as homes for Affordable and Social Rent (see glossary), while the two smaller associations have a more limited geographical footprint and range of tenures. The case-study housing associations operate in regions spread geographically across England and Scotland, although all schemes selected are located in England.

All five selected associations continue to manage at least part of their new home development programmes in-house, with varying arrangements for contracting and procurement, influencing the association's control over design and quality (see table 19). Each association was asked to identify a housing scheme developed in-house in the last 15 years, including homes let at social or affordable rents, designed to a low-energy standard higher than the minimum required by funders or the Building Regulations applicable at the time (see definition of 'low-energy' for this research at 3.3.1). Schemes completed prior to

2005, pre-dating introduction of the Code for Sustainable Homes (see glossary), were considered unlikely to achieve the level of airtightness specified in this definition of low-energy and were therefore excluded from the selection.

The selected associations manage property maintenance in a range of ways, and indeed have varied the arrangements with contractors from time to time. None provides a full maintenance service in-house, using directly employed operatives for all maintenance jobs, although the three smaller associations all retain some in-house maintenance services. In all cases, maintenance work not carried out in-house is delivered through arrangements with one or more external contractors (see glossary, repairs and maintenance service).

5.4.2 Housing schemes

The schemes selected as case-studies are each in a different region, representing five of the nine administrative regions of England (see figure 7) and comprise a mix of scheme sizes and locations in order to maximise the variety of experience relevant to the research questions.

Figure 7. Location of case-study housing schemes

While some of the schemes included a limited range of house types and sizes, being designed to meet particular housing needs, across the five case-studies a mix of sizes and types was achieved, as shown in table 20.

Table 20. Scheme characteristics

Scheme	A	G	H	L	R
Total homes in scheme	19	12	8	78	46
House type mix	Houses	Houses	Houses	Flats + maisonettes	Flats + bungalows
No. of bedrooms	3 and 4 bed	1, 2, 3, 4 bed	2 and 3 bed	1, 2, 3 bed	1 and 2 bed
Intended lettings	Large families in local multi-ethnic population	People with connection to local area	People with connection to local area	General needs	People aged 55+ downsizing from family houses
Tenure mix	Social rent	Social rent	Social rent (6) + shared ownership (2)	Affordable rent (40) + rent/buy (27) + shared ownership (11)	Affordable rent (34) + supported housing project (12)
Location	Urban	Rural	Rural	Suburban	Suburban
Region	Y&H	SE	SW	London	NW

Although three of the schemes included a mix of tenures, residents interviewed were all renting homes at social or affordable rents.

The five case-study schemes (see figures 8-12) comprised:

- 2 smaller schemes in rural villages in the SE (scheme G) and SW (scheme H), both built on greenfield 'rural exception sites' as affordable housing for local people. In scheme H, 25% of the homes are for shared ownership.
- 1 urban scheme (scheme A) on a brownfield site in an inner-city location in Y&H (Yorkshire & the Humber). This scheme provides large family houses at affordable rents to meet the needs of the local multi-ethnic population.
- 2 larger suburban schemes in London (scheme L) and the NW (scheme R), both on brownfield sites.
- Scheme L is high density, reflecting the pressure for affordable homes in London, providing a mix of 1-3 bed homes for general needs. 50% of homes in this scheme are for shared ownership.

- Scheme R is lower density, providing smaller affordable rented homes for people aged 55+. This scheme is in the midst of a 1930s estate consisting entirely of family sized houses, many occupied by older single people or couples.

Figure 8. Scheme A

Figure 9. Scheme G

Figure 10. Scheme H

Figure 11. Scheme L

Figure 12. Scheme R

5.4.3 Dwellings

The case-study dwellings, completed 2005-15, were all designed to achieve an environmental standard (Code for Sustainable Homes or EcoHomes) (see glossary) higher than funders or the Building Regulations in England required at the time (see comparison of standards table 21). These standards indicate a designed level of airtightness within the low-energy definition used for this study (see 3.3.1), however specific airtightness or energy performance targets were not available. As higher levels of airtightness will become essential as all new homes are required to meet more demanding energy efficiency and carbon emission regulations, exploring the maintenance of ventilation in the case-study homes has relevance for all future new build homes.

Table 21. Comparison of standards

Scheme	Build completion date	Environmental standard	Standard required by funder HC/HCA	Standard required by Building Regulations
G	2005	EcoHomes Excellent + (approx. Level 4)	EcoHomes Very Good (approx. Level 3)	2000 Bldg Regs pre-date CfSH (below Level 1)
H	2011	Level 4	Level 3	2010 Bldg Regs 25% uplift on energy perf in 2006 Bldg Regs = Level 3
L	2012	Level 4	Level 3	
A	2012	Level 5	Level 3	
R	2015	Level 4 +	Level 3	2013 Bldg Regs 44% uplift on energy perf in 2006 Bldg Regs = Level 4
Level refers to the Code for Sustainable Homes (CfSH), launched 2006, withdrawn 2015				

The four schemes completed in the period 2011-15 all aimed to achieve Level 4 or 5 of the Code for Sustainable Homes (CfSH). At that time the minimum standard for new homes funded by the Homes and Communities Agency (HCA) was Level 3, equivalent to the 2010 Building Regulations. Revisions to the Building Regulations in 2013 subsequently raised the standard required to equate to Level 4.

The scheme completed in 2005 was included as a case-study in order to capture experience in an earlier exemplar of low-energy housing, designed to exceed the EcoHomes Excellent standard, equivalent to CfSH Level 4. At that time the Housing Corporation (predecessor to the HCA until 2008) required schemes to achieve EcoHomes Very Good, equivalent to CfSH Level 3, a significantly higher standard of energy efficiency than required by the 2000 Building Regulations.

Since the withdrawal of the CfSH in 2015, and in the absence of higher energy efficiency standards in HCA funding requirements, there has been little incentive for housing associations to aim for standards above the Building Regulations minimum, currently equating to CfSH Level 4.

5.4.4 Ventilation systems

The five case-study schemes adopted a range of ventilation strategies and systems (see glossary), giving the opportunity to explore the practice of residents and maintenance practitioners encountering different technologies. Heating systems, and on-site energy generation, also varied between the schemes. Table 22 summarises the property characteristics of each scheme (see glossary for details of ventilation systems). Table 23 details the equipment installed at each scheme.

Table 22. Property characteristics

Scheme	A	G	H	L	R
Date of build completion	2012	2005	2011	2012	2015
Environmental standard	Code Level 5	Above EcoHomes Excellent	Code Level 4	Code Level 4	Above Code Level 4
Construction	Off-site timber frame	On-site timber frame	Off-site timber frame	Off-site timber frame	Off-site timber frame
Ventilation type	Room vent Extract fans + tricklevents	Whole-house vent MVHR	Whole-house vent PIV + tricklevents	Whole-house vent MVHR	Whole-house vent MVHR
Heating type	Gas combi-boiler	Gas combi-boiler	ASHP	Gas combi-boiler	Gas combi-boiler
Energy generation	Solar PV		Solar PV		Solar PV in bungalows
House types	Houses	Houses	Houses	Flats + maisonettes	Flats + bungalows

Code Level	Code for Sustainable Homes
MVHR	Mechanical Ventilation with Heat Recovery
PIV	Positive Input Ventilation
ASHP	Air Source Heat Pump
(see glossary)	

Table 23. Heating and ventilation equipment

Heating and ventilation equipment					
	Scheme				
	A	G	H	L	R
Gas boiler	**Worcester Bosch Greenstar Si**	**yes**	-	**Vaillant**	**Johnson & Starley**
ASHP	-	-	**Mitsubishi Ecodan Monobloc**	-	-
Extract fans	**yes**	-	-	-	-
Tricklevents	**yes**	-	**yes**	-	-
MVHR	-	**Vent-Axia**	-	**Nuaire MRXBox95**	**Heatrae Sadia Advance**
PIV	-	-	**Nuaire Drimaster**	-	-
Solar pv	**C21e Tile integrated**	-	**yes**	-	**yes**
Heating controller	**Worcester Bosch Weather Compensation Controller FW100**	**Danfoss**	**Drayton**	**Honeywell**	**yes**
TRV	**Drayton RT414**	**yes**	**yes**	**yes**	**yes**

Scheme A utilises the simplest form of ventilation of the five case-study schemes, having intermittent mechanical extract fans in the kitchen, operated by a manual switch next to the cooker (see figure 17 in 6.2.1), and in bathrooms, operated by the light switch. All windows have tricklevents to provide background ventilation, with a manually operated open-close mechanism (see typical example at figure 13). Although the simplicity of this system was praised by the maintenance manager (see 7.5.5), its capacity to handle the ventilation needs of a large household in the highly airtight dwelling was questioned by one resident (see 6.2.1).

Figure 13. Tricklevent operation

Schemes G, L and R have whole-house mechanical ventilation, with different makes of Mechanical Ventilation with Heat Recovery (MVHR) unit (see table 23). This system controls the fresh air inflow and exhaust air outflow through concealed ducts in the building. Vents extract warm stale air from the kitchen and bathrooms and supply filtered fresh air to the living room and bedrooms. An air-to-air heat exchanger in the MVHR unit allows the outgoing house air to precondition the incoming outdoor air. Changing filters at 3-12 month intervals is recommended by the manufacturers in each case to ensure the efficient operation of the system. The practicability of filter changes in the three schemes with MVHR units (see typical examples at figure 14) was clearly dependent on the location and accessibility of the units (see figure 27), although this was not the only factor at play in the maintenance of these systems (see 6.5.4 and 7.5.3).

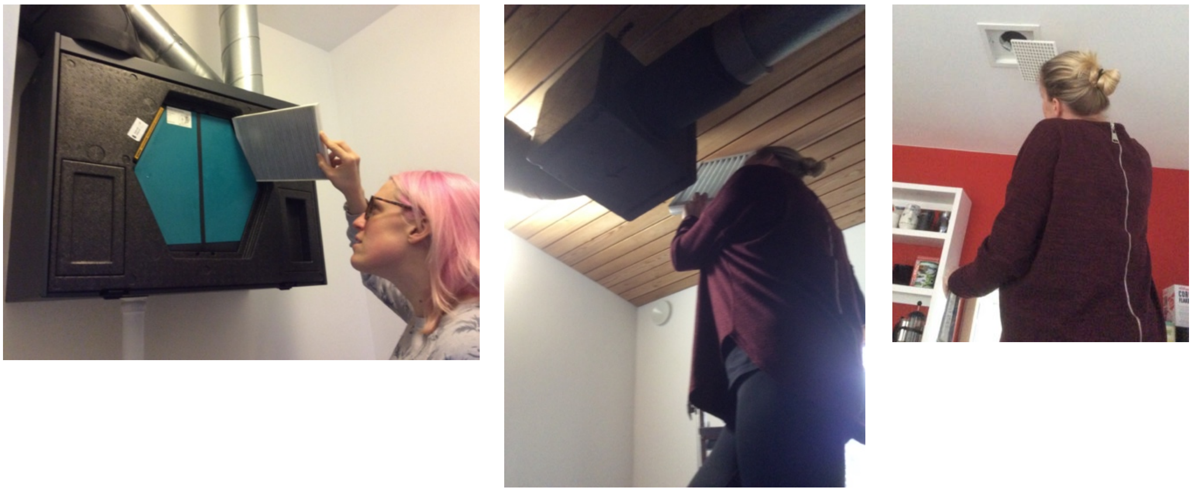


Figure 14. Accessibility issues for changing MVHR filters

Scheme H also has whole-house mechanical ventilation, but in this case utilising a Positive Input Ventilation (PIV) unit, a system that gave rise to contrasting experiences for residents interviewed (see 6.5.1). The PIV unit is fitted in the loft (see figure 15), supplying filtered unheated fresh air to the dwelling through a diffuser in the landing ceiling (see figure 16). The manufacturer recommends that filters are changed every five years. PIV is a supply-only ventilation system, with stale air escaping through air leakage points in the house and no heat recovery. In scheme H, designed to a high level of airtightness, manually-operated tricklevents are also fitted to provide background ventilation.

Figure 15. Positive Input Ventilation (PIV) unit in loft

Figure 16. Diffuser for PIV unit on landing ceiling

5.5 Case-study staff

5.5.1 Selecting staff

Data collection from the five case-studies included interviews with selected staff at each housing association. The first stage in the case-studies, after identifying the five housing associations willing to participate in the research, was a planning meeting with the key contacts at each association, held in March-April 2018 at the associations' offices. Case-study schemes were identified at these meetings and the process for selecting and interviewing residents and staff was agreed (see planning meeting checklist at Appendix 1).

One or more maintenance staff were interviewed at all five case-studies, as well as a combination of development, housing management and other staff, enabling ventilation maintenance practice to be explored from different viewpoints within the housing association. The span of staff roles, and job titles, varied considerably between associations, depending on organisation size and history, and individual skills and experience, and many staff had held a range of different roles during their careers, at this and other housing organisations. Experience of the research topic over a long period of time, with a range of responsibilities in different organisations, was reflected in the interview responses (see table 24).

Table 24. Staff interviewee characteristics

Case-study staff interviewees					
Interviewee No.	Sex	Current role	Years in current role	Years with this housing association	Involved with devt of case study scheme
AS1	F	Maintenance	12	32	Yes
AS2	M	Hsg management	10	17	No
GS1	M	Development	20+	20+	Yes
GS2	F	Development	1	20+	Yes
GS3	M	Hsg management	10mon	10mon	No
GS4	F	Maintenance	2	2	No
HS1	F	Hsg management	8	15	No
HS2	M	Development	11	11	No
HS3	M	Maintenance	8	8	No
LS1	M	Maintenance	5mon	5mon	No
LS2	M	Development	14	14	Yes
RS1	F	Maintenance	2mon	40	No
RS2	M	Hsg management	10	15	No
RS3	M	Maintenance	1	15	No
RS4	M	Maintenance	8	8	No
RS5	M	Quality man'ment	5	5	Yes

Current role					Years in current role		
	No.	% of all staff interviewed	% in role female			No.	%
Maintenance	7	44	43		Under 1	3	19
Development	4	25	25		1-5	4	25
Housing management	4	25	25		6-15	8	50
Quality management	1	6	0		Over 15	1	6
	16	100	31			16	100
31% of staff interviewed had been involved in development of the case-study scheme							

5.5.2 Interviewing staff

Staff were interviewed, at their places of work in the association’s head office, regional or local office, in April-June 2018 (see methodology at 4.4.4.3).

Interviews were semi-structured, based on a series of questions specific to each staff role (see interview guide at Appendix 5 and anonymised interview transcript at Appendix 10, both for maintenance staff). In practice, interviewees expanded beyond the pre-planned questions, adding valuable insights related to the research questions.

A total of 16 staff (2-5 in each case-study) were interviewed, in 15 separate interviews ranging in length from 13-70 mins (average 34 mins). Two staff chose to be interviewed together, which proved unexpectedly productive, enabling staff to compare and contrast their experience of the case-study scheme. Only one pre-arranged interview was cancelled at short notice, due to urgent work matters arising for the staff member concerned.

In four housing associations, interviews took place with the staff member responsible for instigating and/or developing the case-study scheme, one of whom was subsequently responsible for maintenance of the scheme following a change of post. In two of these schemes, developed specifically to pilot low-energy or low-carbon housing technologies, staff responsible for evaluating the schemes in use were interviewed. The experience and insights of these staff, and of staff currently responsible for maintenance of the case-study schemes, provided rich data relevant to the research questions.

By contrast, housing management staff interviewed appeared to be less knowledgeable in relation to the ventilation systems of the homes they managed, indicative of their lack of involvement in the handover of new homes and highly significant in relation to communicating ventilation practice to future tenants.

It was noted that 31% of staff interviewed were female, compared with 67% of residents interviewed, a significant difference that reflects the typical mix of housing association staff in property-based roles and the above average proportion of female heads of households in housing association rented homes (Women's Budget Group 2018). However, 43% of the staff in maintenance roles interviewed were female, whereas women are underrepresented in the maintenance workforce as a whole, comprising only 1% of trade operatives (Mears Group PLC 2017). Analysing the impact of sex, or other personal characteristics, on the research topic may be a useful area for further exploration but is beyond the scope of the present practice-based study.

5.5.3 Document review

A request was made for a range of documents (see documents requested at table 9) related to the association, the scheme, maintenance and management of the properties (see methodology at 4.4.6). Although all the associations were willing to provide documents to the researcher, the process of obtaining these was slow, requiring several reminders, and it was evident that some key documents requested could not be located (see table 25).

Table 25. Scheme documents provided

Case-study scheme documents					
	Scheme				
	A	G	H	L	R
Structure diagram	✓	✓		✓	
Property schedule	✓		✓	✓	
Scheme layout	✓	✓	✓	✓	✓
House plans	✓	✓	✓	✓	
Heating layout plans			✓		
Code or EcoHomes certificate	✓				
EPC			✓		
PV test certificate	✓				
Airtightness test report			✓	✓	
MVHR test certificate				✓	
TRV data sheet	✓				
Heating controller instructions	✓				
Boiler instructions	✓				
PIV instructions			✓		
ASHP instructions			✓		
MVHR instructions				✓	✓
Home User Guide	✓	✓	✓	✓	
M&E spec		✓			
Architectural spec		✓			
Scheme brief					
Standard brief			✓		
Tenant Handbook			✓		
Repairs Handbook			✓	✓	
Welcome Pack example					✓
MVHR servicing letter					✓
Condensation/mould advice		✓	✓	✓	
POE report/presentations		✓		✓	

There was no consistent pattern in the availability of documents, whether related to the date or size of the scheme, size of association, or time staff had been in post. Somewhat surprisingly, the two associations that had undertaken post-occupancy reviews were no more able to access relevant documents. It is suggested that this indicates inadequate data recording systems and explains why some staff interviewed clearly lacked information about ventilation systems essential to their work. Indeed, one resident showed the researcher a Home User Guide for her home that staff were unable to find.

All the associations confirmed verbally that the case-study scheme brief specified a target environmental standard (Code for Sustainable Homes or EcoHomes) but none could provide a copy of the brief. Furthermore, only one association could locate documentary evidence confirming that the standard had been achieved. While other documents available for some schemes, such as airtightness test reports, Home User Guides, etc., were used to corroborate interview data and the researcher's observations, the intended detailed triangulation of data across the case-studies was not possible from the random documentation available.

5.5.4 Scheme observation

During the fieldwork week at each location observations around the case-study scheme and its neighbourhood were recorded, in order to check interview data and documents. A site checklist was used as a prompt to ensure any issues relevant to ventilation practice at the scheme were noted (see anonymised site observation notes at Appendix 11). The notes were supplemented by photos (total 40).

5.5.5 Wrap-up meetings

Each fieldwork week concluded with a one-hour 'wrap-up' meeting with the key contacts at the housing association, in which anonymised general feedback was provided by the researcher and staff were given the opportunity to comment on this and add any further information they considered relevant to the study. This feedback was welcomed by staff at all the associations, although some of the findings were clearly unexpected. Indeed, at one scheme staff were dismayed that the association was apparently unaware of the maintenance requirements of ventilation systems that had been specified after detailed consideration at the development stage. No further information of significance regarding ventilation practice was added by staff at the 'wrap-up' meetings.

At one scheme, two potential health and safety issues observed were reported back to the association, as agreed with residents, for the housing association to action in line with their policies. One issue related to the location of a cooker directly in front of an openable kitchen window, creating a hazard when opening the window for ventilation. The other issue was unrelated to ventilation.

The feedback meetings provided the associations with real-time knowledge about their schemes as a result of participation in the research, although it is not known whether any reflection or action took place as a consequence.

5.6 Case-study residents

5.6.1 Selecting residents

The selection of resident interviewees commenced at planning meetings held at each association with key contacts (see Appendix 1). The aim was to select interviewees, at each scheme and across the five case-studies, who covered a range of household, dwelling and ventilation types relevant to the study. Residents were not chosen to be *representative* of a particular group, but to include *diverse* characteristics and experience, aiming to capture the widest possible range in the number of interviewees selected.

Housing management staff at each association sent an invitation letter and information about the study, drafted by the researcher, to all residents in low rent homes at the scheme, excluding only those known to be particularly vulnerable or on the housing association's risk register. The five schemes included 111 social or affordable rent tenancies. 5 residents (at 2 schemes) were excluded by the associations, with the remaining 106 residents receiving an invitation to participate.

Residents willing to participate then contacted the researcher to arrange an interview during the fieldwork week. Where necessary, association staff followed up the invitation to encourage residents to respond prior to the fieldwork starting. This process ensured data confidentiality, as the researcher had no access to residents' contact details until they volunteered to participate.

Self-selection by residents avoided the risk that staff might 'cherry-pick' residents to take part in the research but did not guarantee that the desired diversity of household and housing characteristics would be included in the interviewee group. However, the selection of diverse schemes, and issuing the invitation to participate to all residents at each scheme with only justifiable exclusions, achieved a broad mix of characteristics in the group in terms of household size and type, length of occupation and letting type, age and sex of interviewee, disability or ill-health in the household, smoking status and pet ownership, all characteristics considered to be relevant to the topic (see table 26).

Table 26. Resident interviewee characteristics

Case-study resident interviewees										
Inter-viewee No.	Sex	No. in h'hold	Household type	Property type/no. of bedrooms	Ventilation type	Letting type	Years living in this home	Disability or ill-health in h'hold	Pet	Smokers
AR1	M	6	Multi-adult	House/4	Extract fans + tricklevents	First let	6	Yes	No	No
GR1	M	1	Single older adult	House/2	MVHR	Mutual x	10	Yes	No	No
GR2	F	2	One adult + child(ren)	House/1	MVHR	First let	13	Yes	Yes	No
GR3	M	6	Two adults + child(ren)	House/4	MVHR	Mutual x	3	Yes	Yes	No
GR4	M	3	Multi-adult	House/2	MVHR	Mutual x	5	Yes	No	No
GR5	F	3	One adult + child(ren)	House/2	MVHR	Mutual x	8mon	Yes	Yes	No
HR1	F	4	Two adults + child(ren)	House/3	PIV + tr'vents	First let	7	Yes	Yes	Outside
HR2	F	2	One adult + child(ren)	House/2	PIV + tr'vents	First let	6	Yes	Yes	Outside
HR3	F	5	Two adults + child(ren)	House/3	PIV + tr'vents	First let	7	Yes	No	No
HR4	F	5	Two adults + child(ren)	House/3	PIV + tr'vents	First let	7	No	No	No
LR1	F	6	Two adults + child(ren)	GF Maisonette/4	MVHR	First let	6	Yes	No	No
LR2	F	4	One adult + child(ren)	GF Maisonette/3	MVHR	Re-let	3mon	No	Yes	Inside
LR3	F	2	Couple younger adults	GF Flat/2	MVHR	First let	6	Yes	Yes	No
LR4	F	2	Multi-adult	GF Maisonette/3	MVHR	First let	6	No	No	No
RR1	M	2	Couple older adults	GF Flat/1	MVHR	First let	2	Yes	Yes	No
RR2	F	2	Couple older adults	Bungalow/2	MVHR	First let	3	Yes	No	No
RR3	F	1	Single older adult	Bungalow/2	MVHR	First let	3	Yes	No	Inside
RR4	M	2	Couple younger adults	FF Flat/2	MVHR	First let	3	Yes	Yes	No

Household size	No.	%
1	2	11
2	7	39
3-5	6	33
6+	3	17
	18	100

Household type	No.	%
Single older adult	2	11
Couple older adults	2	11
Couple younger adults	2	11
Multi-adult	3	17
One adult + child(ren)	4	22
Two adults + child(ren)	5	28
	18	100

Child 0-18
Younger adult 19-59
Older adult 60+

Letting type	No.	%
First let	13	72
Re-let	1	6
Mutual Exchange	4	22
	18	100

Years living in this home	No.	%
Under 1	2	11
1-3	5	28
Over 3	11	61
	18	100

67% of residents interviewed were female
83% of households included one or more adults or children with a disability or ill-health
50% of households had pets (6 dogs, 2 cats, 1 both)
22% of households included smokers

At two schemes (G and L) the selection process identified 4-5 residents willing to be interviewed and dates and times were agreed in advance of the fieldwork week in each location. At two schemes (H and R), only 2-3 residents were identified in advance. In these cases, additional interviewees were recruited during the fieldwork week, being neighbours or relatives living at the scheme, who were contacted by the researcher on site, using a ‘snowball’ recruitment technique. At one scheme (A), only one resident was identified in advance. It is likely that language barriers in this multi-ethnic neighbourhood deterred some residents from taking part. It was not possible to recruit further interviewees by door-knocking on site at this scheme as the housing association was not willing to divulge which residents had already refused to participate or should not be approached by the researcher.

5.6.2 Interviewing residents

A total of 18 interviews with residents took place, in April-June 2018, across the five case-study schemes, with one week dedicated to the fieldwork at each scheme. A pilot interview took place prior to the fieldwork in order to test the format and practicalities of recording an interview and walkthrough. Minor changes were made to the interview guide as a result, rephrasing the questions.

Interviews took place in residents’ homes, each interview lasting 25-50 mins (average 39 mins). A project information sheet and consent form were sent to interviewees with confirmation of their interview date and time. At the start of each interview the study was explained and the interviewee was asked to sign the consent form, in accordance with the University’s ethics requirements. No queries were raised by interviewees and consent forms were signed in all cases.

Across all five schemes only two pre-arranged interviews were cancelled by the resident at short notice, due to other priorities arising, resulting in 18 completed interviews, with a diverse range of households (see resident interviewee characteristics at table 26). Another adult in the household was present in nearly half the interviews and participated in the discussion to some extent, adding different viewpoints and experience of the topic.

All interviewees were willing to talk about their experiences and practice regarding ventilation, both in their current and previous homes, at different stages of their lives, thus extending the range of circumstances reflected in their responses. An interview guide was followed, although discussion frequently ranged outside the pre-planned questions when residents expanded on their experience relevant to the topic. Audio-recorded interviews were later transcribed verbatim (see interview guide at Appendix 4 and anonymised interview transcript at Appendix 12, both for resident interviewees).

Household types and sizes reflected the purpose and location of each scheme, so although the mix across the five case-studies constituted a diverse group of residents, the group did not necessarily reflect the average figures for housing association homes. The proportion of female interviewees at 67% was broadly consistent with the 57% female ‘household reference persons’ (see glossary) in social rented housing (Women's Budget Group 2018). However, the proportion of households consisting of single adults with children was not typical of social housing, with only 22% of interviewees being in this category, whereas the figure for all social housing is 40% (Chartered Institute of Housing 2018). The range of household types and sizes nevertheless suggested a suitable variety of experience among residents in relation to the research topic.

The length of residence in the current home ranged from three months to 13 years. Given that four of the schemes were completed in 2011-15, the 72% of residents who had been the first tenants was as expected, and indeed there had been only one re-let in these schemes. By contrast, only one original tenant was interviewed at the scheme completed in 2005, all others being mutual exchanges. This range captured a variety of experience, both in the lettings process and in usage of ventilation systems over time.

The proportion of interviewees reporting at least one member of the household suffering long-term illness or disability is far higher at 83% than the average in social housing of nearly 50% (Chartered Institute of Housing 2018), reflecting the lettings priorities of the case-study associations. This is a characteristic not only of residents in scheme R, designed for people aged 55+, but of interviewees across all the case-study schemes, and reflects health issues for children as well as adults in the schemes. It was evident that many homes in the case-study schemes had been designed, or later adapted, to improve physical accessibility and usability. The impact of ventilation on indoor air quality, and its implications for the health of residents, was less visible but nonetheless a significant issue, discussed in chapter 6.

Interviewees were asked about smoking habits in the household, given the relevance of this issue to air quality and health. 22% of households included smokers, half of whom only smoked outside, which is less than the average of 31% for social housing (Office for National Statistics 2019). Of greater concern to residents in relation to ventilation appeared to be the cannabis-smoking habits of their neighbours.

The relevance of pet-ownership to ventilation practice was also explored with residents, half of whom had pets. The experience of the case-study interviewees, particularly those who owned dogs, indicated a link between pet-ownership and practice in airing the home which is considered in chapter 6.

5.6.3 Home walkthroughs

Following a series of structured questions, residents were invited to show the interviewer around their home, expanding on their answers, indicating ventilation facilities and equipment and how they used these, and adding further details which they regarded as relevant to keeping their home well aired (see methodology at 4.4.5). At the same time, the interviewer noted observations of the home, using a pre-prepared guide, to provide contextual data. Observations were recorded in written notes (see anonymised home walkthrough notes at Appendix 13) and in photos and videos (see 5.6.4).

Inviting interviewees to show the researcher around the home received a mixed response. One resident declined, explaining that a baby was asleep upstairs, and two others were unwilling to show bedrooms. Others, by contrast, showed no hesitation in walking with the interviewer through the whole house, ignoring the privacy of other adults in the house in one instance, despite the researcher’s assurance that the walkthrough was entirely optional. Unstructured discussion while walking around the house was audio-recorded as part of the interview and added valuable new information, as well as clarification of points made earlier in the interview.

Although residents were willing to indicate the controls for ventilation systems, none were willing to demonstrate how they operated these. It was evident that some residents did not use or did not understand the controls; instructions by the housing association not to touch the controls were paramount for some residents. This is discussed in chapter 6.

Interviewees were more willing to show the researcher how windows were operated, although several were unclear whether or how windows could be locked securely while open for ventilation. Tricklevents were fitted in two schemes (A and H) but it appeared that these were rarely used and in one case the resident was unaware of their purpose. This is discussed further in chapter 6.

5.6.4 Photos and videos

It was planned, with the resident's consent, to record some features of the property relevant to ventilation in photos and to take video clips of residents demonstrating how they ventilated their home. However, photography, and in particular the attempt to make short videos of residents operating controls, was of limited success. In several cases, the walkthrough was accompanied by young children and the resident did not have free hands to demonstrate, in addition to evident lack of knowledge of the controls or reluctance to touch the equipment. The researcher's inexperience in photography and video in this situation exacerbated the lack of success in using this method of recording. Nevertheless, the photos and videos taken (125 photos; 11 videos, length 7-65 seconds) provided useful data to compare with residents' verbal responses to interview questions.

5.7 Sub-conclusion

Across the two stages of data collection – scoping and case-studies – a total of 85 individuals contributed to the research. The scoping survey (34 respondents) and related focus group (17 participants) provided insights and opinions on the research topic from UK social housing maintenance practitioners, a key group in seeking to answer the research questions. Data collected at the scoping stage was valuable in highlighting key issues for this group to pursue in the case-studies and explore in the wider context of the practice of residents and housing association staff.

Five low-energy, low rent schemes, developed and managed by housing associations in England and completed in the period 2005-2015, were identified as case-studies, encompassing a range of characteristics in order to capture a breadth of experience related to the research topic. Interviews with 18 residents and 16 housing association staff, from maintenance and other teams, captured a rich variety of experience regarding ventilation, while focusing on low-energy, recently built, low rent homes. Case-study interviews were supplemented by the study of documents and observations by the researcher.

Participants in the survey and focus group, and residents interviewed, were self-selecting, within a purpose-designed brief to ensure a diversity of experience. Staff interviewed were selected according to the role within the housing associations. This approach was successful in collecting experiential data from individuals with a wide range of household, property and housing association characteristics. While the data is not intended to be statistically representative of all circumstances relating to the occupation and maintenance of low-energy, low rent homes, it encompasses sufficient diversity to reflect typical practice in maintaining ventilation in such homes.

Supplementary data was collected through requests to housing associations for relevant documents, the researcher's observations, and photos/video clips of the case-study homes. Although it was not possible to obtain all the documents requested, due to lack of availability rather than any resistance to sharing these, and the taking of photos/video clips was limited, the supplementary data available proved an informative means of checking the primary data. Cross-referencing data from the survey, focus group and interviews, with documents and observations, added depth of understanding and informed the data analysis (see chapters 6 and 7).

Chapter 6. Analysis: Resident practice and perspectives

6.1 Introduction

The objective of this chapter is to explore, understand and explain how the practices of residents, and their interrelationships with maintenance practitioners and other housing association staff, influence ventilation effectiveness in low-energy rented homes. Data collected from five case-studies and from the scoping stage (see methodology in chapter 4 and results in chapter 5) is analysed and structured using the four components of practices defined by Gram-Hanssen (2009), analysing the data in relation to habits, meanings, rules and things. In the sub-conclusion, observations are made on key findings in this analysis, which are discussed more deeply in chapters 8 and 9 (see theoretical framework in chapter 2).

6.2 The influence of 'habits'

6.2.1 Cooking habits

Cooking habits are a key influence on indoor air quality and can strongly influence ventilation habits too. Interaction between cooking habits and ventilation practices significantly influenced the everyday experience of the residents interviewed. The frequency of cooking varied widely among interviewees from none at all to 'we're cooking pretty much all the time' GR3. Cooking smells and steam were problematic in relation to ventilation for households who cooked frequently, for example:

> The whole accommodation gets all the smells. You cannot use your clothes unless you take it outside for some time. Sometimes, when she's cooking vegetables or making bread. Sometimes the whole house is full of humidity. Open the window, but still we get all the windows wet. AR1

Although it was observed that this resident used the extractor fan boost and opened the kitchen window, these actions were not adequate to expel the quantity of moisture produced by cooking every day for a household of six adults, using the hob-based style of cooking observed (see figure 17)

Figure 17. Standard-size kitchen extractor over large cooker (scheme A)

Indeed, this interviewee called for greatly increased ventilation power:

> Ventilation fan like a restaurant is needed. This is very small for a big house. It's for a bathroom, not for a kitchen. AR1

Ventilation was experienced as a particular smell, noise and humidity problem where the house had an open-plan design or the kitchen was particularly small, both typical of low rent housing association properties. One interviewee pointed out that heat and smells rise, so that the whole house is affected where the living area and stairs are open-plan:

> Whatever's cooked down here you can smell upstairs, quite specifically you can smell it more upstairs than in that room (open-plan living room). It does go up, it does linger. GR3

Small separate kitchens can also cause ventilation difficulties. For one resident, despite using the MVHR boost facility:

> The ventilation could be better in the kitchen as well, because even though the windows are open, if you're cooking, something's boiling, the cupboards, and inside, are wringing wet. So I don't think that's very good. I don't know if it's because it's such a small space. LR4

Poor ergonomic design of kitchens hindered opening windows in some cases. One resident had found a way to deal with this:

> I can't reach it. I have to stand on a stool. I did mention that to them when they came to do the snagging. That's why the stool's there, so that I can stand on the stool to open and close it. LR4

However, this may not be physically possible or a safe option for others, restricting use of the window for ventilation.

Inadequate extraction, even when the boost function is used, was regularly mentioned, for example:

> The system is not strong enough to, you know, you're cooking and it's not taking everything away. GR4

Cooker extract hoods were not generally provided in the rented properties studied. In the researcher's experience, housing associations may be reluctant to install cooker hoods due to their added risk and responsibility, and the workload and cost of replacing filters. There were examples in the case study houses of filters clogged with grease. One resident, who had installed a cooker hood herself, appeared to be unaware of the need to clean or change the filter. Another interviewee was surprised that the housing association did not install these in all properties, given that the association is aware of the need for ventilation:

> This wasn't put in when we were here, which to me is a ridiculous notion. Bearing in mind that X clearly have a problem with damp in some of their homes and they say to us if you're boiling a pan, open your windows, do this, do that, do the other. We just thought that actually, if you're cooking in a kitchen, you really should have an extractor over your cooker to suck out any moisture that's in the air. HR4

However, this resident had resorted to taping up the extract vent on the outside to stop it rattling in windy weather (see figure 18). She hastened to confirm, possibly to reassure the researcher rather than reflecting reality, exemplifying the Hawthorne effect (Payne and Payne 2004), that ‘I untape it obviously when I’m cooking. I go outside and untape it’ HR4.

Figure 18. Taped-up extract vent (scheme H)

It appears that the provision and maintenance of the means of ventilation does not always allow for typical cooking practices, with evidence of undersized extract fans and no cooker hoods (or clogged filters), and inaccessible kitchen windows thwarting residents’ preferred means of ventilation.

6.2.2 Laundry habits

Although drying laundry is an essential household activity, it appeared that the habits of the residents interviewed interacted with ventilation in unplanned ways. The assumption of designers/developers that clothes will be dried outside was dismissed by interviewees on the grounds of unpredictable weather, even in summer:

> We do use it (outside line) on a Saturday when we're here, but I work and don't get in until gone seven normally of a night, and by then it's dark out there and you start getting the bugs out there, and it might have rained. So normally we keep the washing in in the summer, unless we're here. And also if people have barbeques, can't be doing that either. It smells of that.   LR4

Shared drying areas for flats were criticised by some interviewees, with one resident in a first-floor flat reporting 'it just doesn't feel like my garden' RR4.

Tumble-dryers are not considered to be financially viable for everyday use by low-income households, with interviewees preferring to use drying racks, radiators or heated towel rails instead.

Some residents acknowledged that indoor drying on racks or radiators was an unsatisfactory solution, resulting in dampness where ventilation was inadequate. One large household used a mix of tumble-dryer, racks, radiators and towel rails, but found:

> Because the downstairs bathroom doesn't have any windows it's quite damp as it is, to dry it (laundry) in there is not ideal but there's not really anywhere else you can put it, it's the best place to put it.   GR3

Another interviewee knew that his habit of drying clothes on the radiators was not ideal:

> Yes I am naughty, I do put them on the radiator.   RR4

Several interviewees bemoaned the lack of thought given to drying laundry in the design of their home. One opined that this lack of thought was due to architects not being responsible for doing their own laundry.

The laundry drying problem can be exacerbated by the use of low-spin washing machines, typically cheaper versions bought by low-income households. One resident found:

> Since we got a new washing machine, because I didn’t realise how bad our old one was, so it took two days to dry the clothes simply because the washing machine wasn’t spinning them that well. Now if I hang these upstairs they’re dry by the end of the day. HR3

The experience of residents interviewed clearly evidences the need for ventilation in highly airtight homes to take account of the normal, everyday practice of drying laundry, as well as questioning assumptions about the affordability of drying practices.

6.2.3 Cleanliness, health and fresh air

The need for ventilation was acknowledged, but the effectiveness of mechanical ventilation systems was questioned by some residents. One interviewee commented:

> I mean we’ve got a ventilation system but, to be fair, I don’t think it’s that effective. It’s on permanently, only because they told us not to turn them off, but they do produce more dust, I find. And I’ve got one of the newer systems too. GR2

While an MVHR system increases air movement, potentially causing the redistribution of any dust that is present, the misconception that the system ‘creates’ dust proved common. This led some interviewees to regard the ventilation system as a health risk. In the opinion of one interviewee, his wife’s chronic breathing problems were worsened by the ventilation system:

> The only thing I can think is, the other room is not that bad, is that roof, the loft, isn’t done fully out properly and there’s dust coming through that one (vent). RR2

In fact, in this particular property, the MVHR system had been installed in the roofspace but the ducting had not been fitted correctly to the fan unit. It is therefore possible that dust in the roofspace had been sucked into the ductwork. Although the faults had been remedied, this resident continued to believe that the system was the cause of an abnormally dusty environment in his home.

Another held that living in a house ‘creating dust’ was actually causing health problems for his family, including children:

> I would definitely say, since we moved here people have developed apparent allergies, it's all dust and air, breathing specific, just a series of kind of rashes which, you know, nobody had before.   GR3

He concluded that the root of their problems must be the house itself, its construction materials or services. However, the brief for this scheme had specifically required non-toxic materials to be used and the housing association did not accept that the house was the cause of health issues for the family (see section 3.5.1 on indoor air quality and health).

Some pet-owners, particularly those with dogs, habitually opened the windows and doors. As one resident explained:

> Because I have a dog, I just like to have fresh air in the house all the time so then when people come in they always say, well we can't ever smell that you've got a pet, and I think it's because the windows are always open.   GR5

The dog-owners interviewed did not trust the mechanical ventilation system in their homes to extract these odours and relied on window opening, despite the loss of heat that this causes. It appeared that these residents were less concerned about over-ventilation than the risk of visitors being able to detect dog smells. The impact of pet-ownership on the effectiveness of ventilation in low-energy, airtight homes clearly needs consideration by designers.

The presence of children in the household can have a similar impact on ventilation habits, potentially compromising the effectiveness of mechanical ventilation, as one interviewee described:

> Quite often when the kids are running in and out it (back door) could be open for hours on end in the day, in, out, in, out, can you shut the door please! Really it's just everyday life, it's doors and windows open in here, willy-nilly, all day long.   HR2

Another, however, was wary of leaving external doors open in order to protect her children from rats in the vicinity:

> So that would be the other thing, about leaving my patio doors open because of the rats, because we have a rat nest under the shed, so that's the only thing would put me off leaving doors open unattended, especially with the children down there. LR2

The risk of vermin and insects entering the house was a concern for interviewees in all five schemes, both in relation to opening doors and windows and to mechanical ventilation systems. In order for ventilation to remain effective, this concern needs to be considered in designing the means of ventilating the home. There is also evidence in the interviews that residents may not use windows for natural ventilation and may switch off mechanical ventilation at the same time if there is no protection from vermin and insects, such as window flyscreens or meshed intake vents, built into the means of ventilation.

The smoking habits of neighbours can impact on the practice of ventilation. One resident considered that the MVHR system drew the smell of cannabis ('pot') into the house:

> A couple of mornings we've come in here and it stinks of pot. And that's no windows or doors open. And we've also had the smell of smoke in here before, as if something's burning, and it has come through them (the vents). LR4

Ventilation habits are evidently shaped by pets, children, pests and neighbours' habits and whole-house ventilation systems are judged by residents in the light of their deep-rooted concerns about cleanliness and health. The design and maintenance of means of ventilation therefore need to ensure that systems can cope with these factors and take into account the risk of vermin and insects.

6.2.4 Do-it-yourself habits

Interviewees revealed considerable inventiveness in ventilating their homes in their preferred ways. One resident chose to open doors and windows but did not like bugs entering the house. He therefore made flyscreens for the windows, as DIY filters that solved the problem:

> It's just a simple way of doing something. If they (the housing association) just passed it on to other people, I don't know why they don't, it would make their lives easier instead of people complaining.   GR4

The housing association instead advised residents to use the mechanical ventilation system as intended and did not support this alternative option.

Alterations were not always so benign, as for instance when one resident altered the kitchen extract vent on her MVHR system, thereby unintentionally allowing greasy air to enter the ducts:

> The cover's been taken off there (vent) because of the problem with the smoke alarm, so it doesn't get affected so much. It sucks more so it helps with cooking. LR3

The design of this small wheelchair-accessible flat assumed that the kitchen door would be closed to contain cooking smells, but the two wheelchair-using residents found this impractical so altered the vent instead. The MVHR fan at this property, kept continually on the boost setting, was exceptionally noisy, indicating that it was working harder than intended to extract air through dirty ducts, not that it was extracting air at a higher rate as the resident assumed.

Few of the residents interviewed had adopted the new habit of regularly changing filters in their ventilation systems. One interviewee carried this out with reluctance, due to awkward high-level access to the MVHR unit:

> I clean the filters every 3 months, which is a pain.   GR2

Residents can be resourceful in solving problems with ventilation, although not always encouraged to do so, and sometimes with unintended consequences. However, the relatively simple DIY task of changing filters appears to be positively discouraged by the typical inaccessible location of the ventilation units.

6.2.5 Summary: the influence of 'habits'

The variations in residents' habits in respect of everyday household activities, such as cooking and laundry, can significantly impact on ventilation practice in ways apparently unforeseen by designers of the home. The ventilation design strategies underestimated the ventilation needs in kitchens and ignored the realities of drying laundry. The impact of pet-ownership on ventilation practice and the realities of daily life in households with children also appeared to be overlooked in ventilation design. The ventilation needs arising from commonplace, and entirely predictable, household activities and circumstances, appeared to fall outside the design parameters of the ventilation system, whatever means are provided.

Consequently, instead of relying on installed ventilation technology, residents will typically supplement this, or replace it, with natural ventilation as a habit. When the mechanical ventilation system does not appear to be effective, the resident may simply lose confidence in the technology, switch off the system, and turn to natural ventilation. This loss of confidence will be exacerbated where equipment is excessively noisy, or perceived to be causing or aggravating health problems, spreading dust or facilitating pest infestations.

The residents interviewed had a tacit understanding of changes that would improve the effectiveness of ventilation, shown through their assessment that more powerful kitchen extract fans are required, as well as reachable kitchen windows and cooker hoods fitted as standard. However, they did not feel that their knowledge was valued.

While some residents took steps themselves to overcome obstacles to ventilation, solutions arising from do-it-yourself habits were discouraged by housing associations. Considering the long-term costs of ineffective ventilation on residents' comfort and health, on the building fabric and on energy use, it is arguable that ergonomic design at the outset would indeed be cost-effective.

The underlying reason for failure to act on the experience of residents, or take note of research findings, appears to be an emphasis on the technical expertise of design professionals, allied with short-term cost appraisals, rather than taking into account the tacit knowledge of residents, and research expertise, and adopting a holistic long-term approach to scheme appraisal. The lack of post-occupancy evaluation and absence of a feedback loop is added evidence of this mind-set in the majority of the case-study associations.

The ventilation habits of many interviewees can be traced to direct personal experiences, in the past or present, as related by residents quoted in this section. However, a deeper awareness of the need for fresh air in the home could also be implicit in the responses, an influence on practice rooted beyond direct personal experience, discussed further in chapter 8.

6.3 The influence of 'meanings'

6.3.1 Experience of previous homes

It is important to consider the historic practices that individuals bring with them to their new homes, 'social practices ordered across space and time' (Giddens 1984: 2). As Hargreaves (2011) comments:

> As individuals pass through life, they come into contact with, get recruited to, have 'careers' within, and occasionally defect from a wide variety of different practices. (Hargreaves 2011: 83)

Moreover, it is not only previous practices that people bring with them into their new low-energy homes, influencing their heating and ventilation practices, but embodied experience reaching back into childhood (Hansen 2018), as one resident described:

> That's how I've always felt, even when I was little, I always remember because I used to have my bedroom windows open, my Mum used to have to turn my radiator off because they would all be having to have the heat and I would have to have the cold and windows open, because I like fresh air. That's why we couldn't share a room, I'd freeze my sisters out. HR1

After living in a cold, damp, draughty home, the priority for one resident was affordable comfort, rather than a detailed understanding of the ventilation system, as she explained:

> Being truthful I don't know (how it works) but being a housing association I find that alright, but if I was to own the property, then I think I would look into it a bit more, does that make sense? It's not mine to touch per se, you know, I just sort of leave it. HR3

By contrast, another resident, with a lifetime's experience in the building trade, had endured freezing conditions in an Airey house (see glossary) before moving to a recently built low-energy home, but was highly critical of his newer property, declaring that:

> You get all these weird designers today, and come up with all these brilliant ideas, they should be shot really, a lot of them. They shouldn't be allowed on a building site. GR1

He declined to use the ventilation system, considering it to be:

> Some big thing that they've got upstairs, some new-fangled idea they got. GR1

Consequently, he experienced significant condensation and damp in the property (figure 19).

Figure 19. Condensation damage on bedroom window sill, MVHR switched off, windows kept closed to conserve heat (scheme G)

The beliefs of other residents regarding their homes were more nuanced. This interviewee was ambivalent when comparing his present and previous homes:

> The last house we lived in was pretty cold, pretty damp, more or less. But it was like moving into an airless, stuffy, yes, it was noticeable. I blame this house but I could be completely wrong. GR3

This household had moved into the property 10 years after it was built, during which time maintenance seems to have been erratic. It is possible that the MVHR filters were dirty, allowing a build-up of impurities, creating a stuffy atmosphere. However, windows were regularly used for ventilation in this house, which would normally mitigate the effect of the MVHR system under-performing.

The experience of living abroad, where ventilation practices may be quite different, adds to the diversity of historic influences on practice, as this resident explained:

> In Germany what would happen we'd just open this (front door) and the back door. Because it's a door it'd just blast the whole place through. GR3

Previous ventilation practices and embodied meanings of fresh air clearly influence residents' current ventilation practice.

6.3.2 Attitudes to eco-friendly new-build homes

Resistance to new-build homes was evident among the residents interviewed, as one declared, 'I love old houses, I don't like new-builds' RR3.

A dislike of new homes led to reluctance to use the ventilation system for this resident:

> This is the first new build I've had, with that sort of system. I would prefer an old house, by miles, there's no two ways about it. They're built better. That system (MVHR) is the most stupid thing I think that's ever been invented. LR1

Scepticism about eco-friendly features in the case study homes was widely expressed:

> It's just where they use these stupid ideas, this eco stuff. It's like the light bulbs that were in here, you couldn't buy them, you didn't know where to go and buy them when they blew, so I had to have them changed to ordinary bulbs. GR1

The belief that eco-friendly design is not suited to the UK was also expressed by two interviewees:

> It seemed like a good idea at the time, let's get it in, it's used in Scandinavia, they have no problems with it, lovely, it's going to work here. Not quite so! HR4

A preference for older homes, combined with negative attitudes towards environment-friendly features, clearly presents a double challenge to the acceptance of new, highly airtight, low-energy homes, with mechanical ventilation systems, despite their potential to provide warm, dry homes with low running costs.

6.3.3 Household finances

The case-study homes were all designed to reduce energy use for heating. Many interviewees referred to the benefit of low running costs and it was evident that the financial costs and benefits of features of the house were finely weighed by residents. This was unsurprising given that low income households constitute a high proportion of housing association tenants (House of Commons 2019).

However, the costs and benefits of running a ventilation system are not self-evident. The fear of high electricity bills may drive residents to switch off the system, believing that opening windows will be equally effective and cost-free. Evidence on the comparative energy costs of naturally and mechanically ventilated homes is inconclusive, with in-use costs being dependent on temperature required in the home, the extent of ventilation control exercised by the occupant, and the local climate, among other factors (Sassi 2013).

One resident was not convinced by advice that relying on the MVHR system would be cost-effective:

> I mean they tell you to have the ventilation system, sorry, the recovery system, on 24 hours a day but you're talking, that's running electricity. GR4

It is evident from the case-studies that highly airtight, mechanically ventilated, low-energy homes may still result in under-ventilation and under-heating where financial precarity drives decisions on energy use.

6.3.4 Security and noise

The desire for security influenced residents' ventilation practice, regardless of location. This household did not trust the window security latches (see figure 28 in 6.5.5) and only felt safe to use windows for ventilation when the house was occupied:

> It's a very dangerous area. Someone should be at home all day. So far we do not have problems, personally, but some of the mischievous people are jumping from

> one accommodation to the other…Even if I could see them I can’t run after them because of my mobility. So anyhow it is not safe in general.   AR1

Feelings of insecurity were exacerbated by house design. Opening windows at night, to purge heat from the building in hot weather, is not an option for some residents, as these interviewees explained:

> So you can reach my bedroom window, if you was able to get up onto the glass panel it’s easy, my bedroom window’s just there. If you know how to stand on it properly you could stand on the bins. I just watch too many scary movies I think.   LR4

> I lived in the worst street in X and I felt safe there, because of the layout of the house I was in. But here being on the ground, seems so much more vulnerable, you know. RR3

One interviewee who considered that the mechanical system produced dust, exacerbating a serious chest complaint, did not feel there was any alternative due to security concerns:

> It’s of a night when you breathe in because, I’ll be honest, I don’t sleep with the window open, because of being a bungalow on the ground. It’s not a very nice area really.   RR2

Overlooking houses, security cameras or the presence of a dog enhance security and affect ventilation practice:

> Oh yes, I leave my back door open when I’m out. I’ve got a dog though, haven’t I, so no-one’s going to, you know.   GR5

However, a ventilation strategy for highly airtight homes needs to build in means of ventilation that provide security in order to be effective in the long-term, through changes of occupancy.

Environmental noise evoked widely differing responses among case-study residents. Whereas one resident, in a rural scheme, was deterred by traffic noise from opening her patio door for ventilation:

> If I'm sitting in here in the summer, in the evening and I've got the telly on, I sometimes have to shut the door just so I can hear it. It's more like the lorries and the tractors, it's not so much the cars, it's just the bigger vehicles. GR2

this did not concern her neighbour:

> We have them (windows) open all the time. We're not bothered you know. We have the traffic going up and down all the time…It's just noise, it's just noise. GR4

One resident kept windows closed at night to deaden the noise of freight trains, using the MVHR system for ventilation as intended, but still found this sound intrusive:

> They're nice looking (the windows), but I think they could have been triple-glazed. Because even sometimes I go upstairs and I think G has left her bedroom window open because the train sound is so near, but it's not. LR4

The dilemma between opening windows and doors for ventilation and closing them to prevent unwanted noise appeared to be generated more often by conflicting music preferences, as these residents commented about their neighbours:

> We've got a noisy next-door neighbour, so that would stop me opening that window and that door, yes. Terrible taste in music and a hot tub, this combination. Ironically in the summer, when it's hot and you want the door open, what you have is someone listening to '90s dance music loud in the hot tub. GR3

Ventilation reliant on opening windows may prove inadequate when residents are fearful of their security, find environmental noise intolerable or where neighbours' aspirations regarding noise are in conflict. Greater consideration of these issues, particularly in the design of windows, could make a significant contribution to effective ventilation.

6.3.5 Summary: the influence of 'meanings'

Resident engagement with unfamiliar means of ventilation in a new low-energy home appears to have its roots as much in people's life experience, motivation to adopt a sustainable lifestyle, financial concerns, and feeling of security, as in their understanding of the ventilation strategy and technology in the home.

Ventilation practice that has evolved in a typical draughty, older UK dwelling, and the tacit knowledge built up over a lifetime of heating, cooling and airing a variety of homes, is not instantly transferable to a highly airtight property with heating and ventilation technology that works in a very different way. While communicating an understanding of the systems is essential, in formats and at times that will assist engagement by new residents, the experience of residents interviewed suggests that current ventilation practice is rooted in meanings regarding fresh air associated with life experience in older homes.

Given the increasing public discourse on climate change, and on the need to cut carbon emissions and future-proof new homes, a shift in attitudes is likely to ensue, although some people will continue to resent any change in habits that this will require. As Sassi (2013) comments:

> People are seldom motivated to question the models offered by society which portray a cool life of leisure free from the limitations of socks and jumpers and even less likely to adopt sustainable behaviours without being incentivized through psychological, economic or other means. (Sassi 2013:74)

The financial precarity of low-income households appears to lead some residents to place effective ventilation at risk, through switching off ventilation systems combined with not opening windows in cold weather to avoid heat loss. This ventilation practice is seemingly driven by the perceived cost of the power used by a system such as MVHR and the belief that exercising manual control of ventilation, through window opening and closing, the use of curtains and so on, is a more effective way to control costs than the use of automated technology.

Using windows and tricklevents for ventilation requires know-how, as does controlling a mechanical ventilation system. While the relative costs of the ventilation options in terms of energy use may be perceived rather than actual, evidence from the resident interviews is consistent with research findings that any means of ventilation may compromise indoor air quality if it is not operated and maintained correctly (McGill and Sharpe 2017).

The influences on ventilation practice in low-energy homes appear to extend beyond occupants' experience, motivation and financial concerns. It is evident from the residents interviewed that their feelings of security strongly impact on the use of windows for ventilation, particularly affecting the ventilation of ground floor bedrooms at night. Although security latches were built into windows in some of the homes studied, allowing these windows to be left open securely for ventilation, in practice this did not engender confidence to do so for some interviewees.

By contrast, when residents described their immediate surroundings as neighbourly, particularly where homes overlooked each other, they expressed greater confidence in keeping windows and doors open, allowing more options for effective ventilation, particularly in warm weather. These findings suggest that the influence of neighbourhood security, real or perceived, on ventilation practice should not be overlooked.

Individuals' direct experience of different homes and neighbourhoods clearly contributes to the 'meanings' or beliefs that shape their practice of ventilation. However, the 'meanings' attached, for example, to different types of dwelling, the relevance of action to mitigate climate change, or the perception of neighbourhood security, appear to have deeper roots, in societal or cultural perceptions that influence practices in a less tangible sense than definable experience, a theme developed in chapter 8.

6.4 The influence of 'rules'

6.4.1 Lettings process

A housing association's lettings practices, whether letting newly-built homes to the first tenants or re-letting homes that subsequently become vacant, shape the opportunity for the prospective tenant to learn about the ventilation facilities in their new home (Foulds 2013). Although this is particularly necessary in a low-energy home with a ventilation strategy and equipment that may be unfamiliar to a prospective tenant moving from an older property, it appears that, in the case-study schemes, this is frequently a missed opportunity.

The priority for a prospective tenant may simply be to secure a home, any home, with little time to think about the details of the property. As one interviewee, who was offered a newly built low-energy home, expressed it:

> We were fed up of the building where we were living, because it was a temporary house, so we were rushing just to change, regardless of the advantage or disadvantage that we would face. That was a very old house. AR1

Given the high demand for homes, and the housing association's need to minimise rent loss, the lettings practice may only allow housing applicants a cursory visit to the property and require a quick decision to accept or decline the tenancy, with no certainty of a future offer if the property is declined. For one resident, applying for a re-let property, this decision had to be made on-the-spot:

> I viewed the property on the Tuesday, so I came here, very briefly, five minutes, looked around, and he said do you want it and I said yes definitely, and he said right, come to my office tomorrow to get all the paperwork. LR2

In this case, no information was given to the resident about the MVHR system in the house:

> I just got the tenancy agreement, my keys, and then that was it really. No-one even told me it was there or what it was or how to use it. LR2

Unsurprisingly, this tenant was not using the MVHR, and still confused about how to ventilate her home, when interviewed three months after moving in.

Whereas one resident at this scheme, who had moved in as the first tenant of the new scheme, received a visit from the housing association's development team to explain the MVHR system, tenants moving in subsequently did not. After the 12-month defects liability period, the development team was no longer involved with the scheme and it appears that the lettings team, that signed-up new tenants, did not pass on details of systems in the properties to residents. Moreover, in this association, the maintenance service was contracted to an external company, played no part in the induction of new tenants, and indeed had no involvement in the scheme until after the defects liability period.

It is clear from the 'Welcome to your Home' booklet issued by another association in the study that the emphasis in communication at this stage is on the tenant's responsibilities, particularly payment of rent, rather than on how to use the home effectively. The booklet contained no mention of ventilation.

The mutual exchange process (see glossary) adds to the risk that new residents lack information about their home. It is the responsibility of the outgoing tenant to pass on details to the incoming tenant but this does not always take place, leaving the new resident with inadequate, or even wrong, information about systems in the house. The housing association generally plays no part in inducting the incoming resident, as explained by one interviewee:

> They only vet you (in mutual exchanges) to see whether you're good people and all the rest of it and so you're happy to move in.   GR4

The new resident may then find ventilation equipment in the house that they have no knowledge of, possibly faulty, with no instructions:

> The system was never working properly, but they never said nothing, so obviously we had to deal with that, thinking what's that?   GR4

6.4.2 Repairs process

Housing associations invariably categorise repairs by timescale for completion, publishing a summary of repairs in each category. Timescales will typically vary from 4-24 hours for 'emergency' repairs that threaten health and safety, to 5-7 days for 'urgent' items and 21-28 days for 'routine' repairs. Of the five associations studied, only one refers to extractor fans or ventilation systems in its detailed schedules of repairs. Indeed, this association categorises repairs to kitchen or bathroom extractor fans, and treatment of severe mould or dampness, as urgent, to be completed within 7 days.

No reference was found in any of the associations' documentation for new tenants or website pages about repairs regarding changing filters in ventilation systems, although all five have systems that require filter changes in their housing stock. Indeed, the officer at one housing association tasked with arranging visits to service MVHR systems was frustrated that lack of any reference to this requirement made it more difficult to persuade residents to make, and keep, service appointments. By contrast, gas servicing, which is a legal requirement for landlords, is highlighted at the time of signing-up a new tenant, although gaining access can still be problematic.

Repairs to ventilation equipment thus appear to have a low priority for housing associations in the case study schemes. Noisy MVHR systems at one scheme led to some residents abandoning their use when repairs did not solve the problem. Getting to the root of the problem may take many attempts, during which time residents become increasingly frustrated with the housing association and with the ventilation system, as one interviewee described:

> Turning it off and turning it back on again is a quick-fix solution, you are not addressing the real problem. So he came out. On about the fifth attempt, I phoned X and said you need to get somebody out who knows what they're doing because these clowns clearly haven't got a clue what they're doing. So they did. HR4

At worst, residents give up trying to get repairs done and may stop reporting ventilation problems, as in this case:

> To be honest, there's thousands of things you could report to X but they, it's like praying for rain in the desert. There's no point. GR3

The slow response to repair requests seems to be compounded by the difficulty of evidencing ventilation problems. One resident commented, regarding air quality: 'It's such an intangible thing, to us, I wouldn't waste my time' GR3, and another felt that: 'I need to show evidence…because they're so hard work to get them to come here and do anything' LR2.

Residents' dissatisfaction is compounded when they do not just feel disbelieved, as this interviewee complained: 'They seem to think that you don't know anything, and I do, and yes, they fob you off' LR4. Indeed, residents may be held responsible for the problem, as when one reported a damp problem:

> They said 'No, it's nothing to do with the bathroom, it's something you've had up there, you've spilt water or something' they come out with. GR1

Whatever the root cause of problems that arise, delays in servicing and repairing ventilation systems can result in a deterioration in air quality, affecting residents' health. Poor maintenance can also lead to damage to the building fabric and higher costs for the housing association:

> The original company said they were not liable for the machine being in disrepair because the housing people hadn't kept up their side of the arrangement by maintaining them, which I think is why I've had so much problems, to be honest. And still to this day they do not maintain them. LR1

> The manufacturer had not come out because the warranty had expired, it had a two-year warranty and it had expired. So that's how long they'd left it. And so they had to get a new system. RR3

Given the complex interactions between building physics and human action in the creation and persistence of damp in homes, a resolution of the problem requires attention to, and understanding of, both aspects by the parties involved:

> Moisture risk is a human as well as a technical issue. (May and Sanders 2016: 6)

6.4.3 Housing management

Residents' experience of the 'rules' set by their housing associations in the case-study schemes is characterised by inconsistency on the part of the associations. Interviewees reported a high level of staff turnover, with new staff changing what is permitted and advice to residents, as in this case:

> Because they've changed their housing managers, they're on their third one in five years since we've been here, it don't seem that, they've all got different ideas. I don't know whether they've got different ideas or because they go, 'Well there's no money, we can't do this, we can't do that'. GR4

Guidance on ventilation from housing officers appeared to vary from general advice, unrelated to the specific property, to apparently random 'rules'. One resident in a house with MVHR reported damp in her home and received generic advice over the phone:

> They just say, 'It happens, it just happens in all homes'. All they'd say is 'Keep a window open'. But that's not always feasible to do. LR4

There could be many reasons for the damp but without proper investigation it is unclear whether this advice was appropriate.

Another interviewee recalled a new housing officer giving seemingly ad hoc advice:

> Then one time there was, 'Oh you can't reverse on your drive, because when you start up the exhaust fumes hit the house and go into the windows'. It was like, 'Where are you getting these ideas from?' GR1

The apparently random advice from housing officers may indeed be due to inconsistency of knowledge or training, particularly where staff turnover is high and information systems may be inadequate. However, there may be changes in internal policy or externally driven requirements that have not been communicated clearly, or at all, to residents.

Residents wishing to alter their homes at the case-study schemes require the housing association's permission, although the factors that will be considered in each case are not always clear. Beyond basic compliance with planning and building regulations, and health and safety requirements, there appears to be no further guidance for staff or residents of the associations studied. Consequently, the 'rules' on alterations appear to vary between the associations and between residents at the same scheme.

Given the lack of awareness of ventilation among housing staff, it is not surprising that the effect of alterations on ventilation does not seem to have been considered. One resident had enclosed an external pergola on all sides to create a conservatory (see figure 20), thereby partially obstructing air flow through the ground floor and exacerbating the difficulty of dispersing cooking smells. The only condition made by the housing association was that the structure should not be altered:

> He says 'That's fine, so long as you don't add to the wall, you know, if you don't start drilling the wall'. So nothing is attached to the wall outside, it's all sort of freestanding. GR1

Figure 20. Pergola designed to be open but later enclosed on all sides (scheme G)

In another case, perversely, a resident was refused permission to install a cooker hood, although others at the scheme had done so and found this helped with kitchen ventilation:

> We're actually not allowed cooker hoods. We were told we weren't allowed them. GR2

In one scheme, a resident was allowed to divide the living room to create a fourth bedroom:

> That's a stud wall, but normally this used to be the front room. I can't be bothered to move. Initially this was an L. They were fine with that. LR1

However, it appeared that no change was made to the ventilation system to accommodate this alteration, which created a poorly ventilated bedroom and a much-reduced living-room for a large family.

6.4.4 Landlord-tenant relationship

The quality of the relationship between landlord and tenant is likely to exert a critical influence on the ventilation experience of residents. In the interviews with case-study residents, little reference was made to the legal relationship that exists. However, interviewees recounted examples of attitudes of housing association staff towards residents that they found unacceptable. One resident felt that staff do not listen to residents regarding ventilation systems:

> They don't listen to what people are saying to them, you know, so when they do the next build, they're putting the same systems in. And you wonder, if that's not the right system that they've put in, if you've got problems with this here, why are you doing it there? It's just going to continue. GR4

The perception that the housing association is incompetent to fix a ventilation problem and/or indifferent to the resident's experience, triggered a formal complaint in some cases, as in this instance:

> I've been all the way through, round and round in circles. I've been to the Ombudsman about it, because I've had, like I say, the same problem six years in a

> row. To me, it's ridiculous, someone should have managed to fix the ruddy thing by now.   LR1 (see glossary, Housing Ombudsman Service)

Another resident spoke about the time and energy that it took to get a satisfactory response:

> It was only when I went through complaints, even going through complaints there was nothing happening, until I wrote my complaint to the Director. It was a last ditch attempt really, I didn't know what else to do.   RR3

In this case, it was found that the resident had experienced many months of extremely high humidity in a newly built property, where the MVHR had been fitted incorrectly. It was the housing association's slow processes and seeming reluctance to act that caused as much distress for the tenant as the uncomfortable living conditions:

> I've only really decided to stay here in the last four months, you know, because it was so stressful. It was me, it was me being neurotic, but it was not getting anything done, not being able to find a way through the problem with the ventilation. It was major, but I'm alright now.   RR3

6.4.5 Summary: the influence of 'rules'

The lettings practices of housing associations, and the practices of housing applicants in finding a home to rent, form a bundle of practices that influence the practice of ventilation in the tenant's new home. The landlord's practice is partly driven by a desire for quick lettings (ideally, coinciding with handover for new homes or with no void period for re-let homes), in order to minimise rent loss and respond to the urgent demand for homes. This speed of letting allows only minimal time for signing-up a new tenant and housing association practice typically prioritises establishing rent payment and emphasising the tenant's responsibilities, rather than highlighting features of the home and their use. Explaining the ventilation system in the property is not generally within the remit of the lettings team and, indeed, they may have no information about the system or may not appreciate the significance of the information they have.

The practice of finding a housing association home, on the other hand, may be equally influenced by a desire for speed on the part of the applicant. The urgency of moving in, often to alleviate a critical housing situation, will influence the new tenant's practice at the time of letting. It is evident from the resident and staff interviews that the practice of home heating, and the practice of payment for energy, are dominant for tenants at that point in time, but not the practice of ventilation.

The implications of these bundled practices at the point of moving into a new home are that residents may receive little or no advice or information about ventilating their low-energy home and may find ventilation equipment in the home that they know nothing about, with inadequate, or no, instructions for its use. Where the new resident has moved in through a mutual exchange, they may indeed be given wrong advice or instructions by the outgoing tenant.

However, it is evident from residents' accounts of their ventilation practice that establishing new habits, to reflect the design and ventilation systems of a low-energy home, is not achieved simply through awareness of the systems and instructions. Even among residents interviewed who had received a thorough induction into their home at the start of their tenancy, there was a range of interaction with the ventilation systems installed. The timing, frequency, depth or format of the induction received may have influenced their subsequent practice, but it appears that ventilation practice is strongly rooted in habit and meaning for these interviewees.

Residents' practice in airing their homes clearly interacts with the landlord's practice in maintaining the means of ventilation. It is evident that housing associations do not generally regard ventilation as a health and safety issue, even in highly airtight homes where mechanical ventilation is installed to ensure healthy air quality, leading to categorisation of ventilation repairs as non-urgent by most of the associations studied. Moreover, evidence from interviews with housing association staff (see chapter 7), indicates that some associations do not implement the regular servicing regime, including the essential changing of filters, recommended by ventilation equipment manufacturers. Maintenance practice thus becomes reactive, dependent on awareness of, and response to, ventilation problems arising.

Given the variable practice of ventilation performed by residents, and the intangible nature of indoor air quality, identifying and reporting problems with ventilation is evidently inconsistent. Reporting appears to be affected, moreover, by the degree of confidence that residents have in their landlord's response to such reports, built on past experience.

The combined practices of reporting ventilation problems and responding to such reports thus create the potential for faulty fans, clogged filters, inaccurate calibration, blocked tricklevents, and so on, to lead to ineffective ventilation and declining air quality. Compounding this risk, faulty mechanical ventilation may become excessively noisy, inducing the resident to switch off the system altogether.

Although the identification of ventilation equipment problems or the detection of poor air quality, per se, may be unreliable triggers for action, the visible consequences such as dampness and mould growth are more likely to lead residents to report problems to their landlord. A combination of under-heating and under-ventilation may be the direct cause of damp, but there is commonly dispute whether this situation results from the practices of residents or of landlords. It appears that the relationship between housing associations and residents is sometimes one of mutual desire to apportion blame. While this stance may be fuelled by fear of the financial, legal and reputational consequences of being held responsible for damage to health and property caused by damp and mould, a blame culture obstructs the search for the root causes, and remedies, for this intractable and common problem.

The bundle of practices that influence ventilation effectiveness in low-energy rented homes includes the landlord's practice regarding alterations to its properties. Designing homes to allow for flexibility in use, and physical alterations when needed, is highly desirable, given the lifespan of buildings, the diversity of households that will occupy the home, and the changes in lifestyle over time. Indeed, such flexibility and adaptability was a specific requirement in the brief for at least one of the case study schemes. However, while the house designs met this brief, it is not clear that the ventilation strategy took into account potential future alterations. Taking ventilation into account when making changes, as well as designing for adaptability, could contribute to effective ventilation practice in the long term.

Housing associations’ practice of communication, both within the case-study associations and with residents, appears to negatively influence both the practice of maintaining ventilation equipment and residents’ practice of ventilating their homes. Residents’ reported experiences of minimal initial information about ventilation systems in their new home, inconsistent advice from housing officers, and unhelpful responses from repairs call centres, suggest that communication practice at some associations is not founded on good knowledge of the association’s properties, robust information systems, and effective staff training at all levels across the association, particularly critical where staff turnover is high.

6.5 The influence of ‘things’

6.5.1 Ventilation systems

The low-energy homes studied in this research presented new residents with ventilation systems that were, in four out of the five cases, unfamiliar to them (see property characteristics at 5.4.4). In all five cases, homes were significantly more airtight than typical homes in England, although the design and ventilation systems of the homes varied between the schemes. Through the practice of ventilation, evolved over time and performed daily in older, less airtight homes, residents encountered a new physical environment. The physical environment, and other material objects not specifically identified as ventilation products, influenced the ongoing evolution of practice as residents performed the practice day-to-day to keep their new homes aired.

The two whole-house ventilation systems (see glossary) installed in the case-study homes, MVHR (in three schemes) and PIV (in one scheme), both attracted a range of criticism from interviewees. While both systems are forms of continuous controlled ventilation, allowable in the Building Regulations for new homes, they operate in quite different ways, which have major implications in terms of residents' experience.

Residents with MVHR systems reported concerns about draughts, dryness and noise, leading to adjustments in day-to-day practice such as:

> We've changed the bed round that many times to try to get my wife out of the draught, so I'm nearer to it now than we were before. RR1

> Open the windows, which obviously means then it messes with the heating, so we're in a no-win situation…There is a kind of airlessness, that you're kind of gasping to get out of the house. It's a godsend when it's the summer when you can have the windows open. GR3

> One day I turned it off, not to be funny just to sort of get a bit of a rest, because I remember the neighbours saying, from somewhere round here, her children couldn't get to sleep, so she turned it off. LR3

This interviewee subsequently turned the MVHR on again, after finding that condensation quickly formed. Although this particular system was so noisy that it could be heard clearly on the interview recording, the resident found that eventually:

> I sort of feel like I've adapted. It becomes the sort of noise that's always been there and it works OK. I manage to fall asleep OK. LR3

Noise may be excessive in MVHR units that are under-sized, possibly a result of cost-cutting at the development stage, or where the system is not correctly calibrated at the commissioning stage, or inadequately maintained.

Some interviewees had experienced extended problems with their MVHR systems, from building handover in a number of cases. One resident who had endured a leaking system for six years concluded:

> I wouldn't rely on that thing (MVHR system) in any way, shape or form. It's a nonsense, because what possessed them? LR1

Intermittent faults in the MVHR system led another resident to question the quality of the equipment installed and, unusually among the residents interviewed, to take a long-term view of the system:

> Even the engineer said they all need replacing because they've only got a life expectancy of a certain amount of time, and if you've got them going 24/7, everything breaks down…I know you put a cheaper one in to start with, but long term, if they put the better ones in to start with they'd last the house's lifetime. I know it's all about money and that, but long term it's very different. GR4

Confusion between an MVHR system and air-conditioning was reported by some interviewees. One resident was unsure what type of system she had, and having looked into the maintenance requirements of air-conditioning, she was concerned whether her MVHR system constituted a health risk. This was compounded by fear that the rats infesting her home could enter the ducts and spread disease:

> I know that it takes in air and lets out air and it's all internal but because the rats are inside the building, inside the walls, and obviously this ventilation system works upstairs and downstairs, it makes me think I don't really want to risk it. LR2

Despite the evident problems with MVHR systems, some interviewees who used the system installed, and altered their day-to-day actions to mitigate the difficulties experienced, were satisfied with the outcome:

> Definitely we notice we've got no damp anywhere, that's worth it. GR3

Similarly, interviewees with PIV systems installed reported both positive and negative experience. One resident who did not understand what the PIV system was, but left it running continuously, reported:

> We've never had a problem with damp here. I know it's that because my son's eczema cleared up within six months of living here. HR1

However, another resident, on the same scheme, had disconnected the PIV after finding:

> It just blows absolute ice-cold air out of it, constantly 24 hours a day, and it's not like just a little bit, it literally gushes out.   HR2

The same problem had been resolved in a neighbouring house, although this had taken five years to achieve, resulting in the resident concluding:

> We're very happy with how it's heated and ventilation, I don't have an issue with it at all, we don't have condensation.   HR4

One of the case-study schemes did not have whole-house ventilation systems, houses being ventilated instead by one extract fan in each bathroom and kitchen and tricklevents in windows. For one resident, this arrangement posed problems in balancing the heating and ventilation, which he ascribed to the construction of the house:

> This is just like cardboard, the walls…Nobody can understand unless someone lives inside the house, because it looks beautiful, but it is just (indicates external walls), the bricks are just decoration, just a covering, so that's why it gets cold and hot at the same time.   AR1

House construction unfamiliar to the resident, in this case a highly insulated timber-frame building faced with brick, appeared to negatively influence the residents' experience of comfort, and ventilation practice, even though the ventilation strategy was simple and familiar. This indicates that the practice of ventilation is influenced not only by the 'things' related to the property and its means of ventilation, but by things bundled together with habits and meanings.

Action taken by residents to remedy perceived faults in the building can thwart the ventilation strategy and create risks for the structure. On one scheme, for example, an underfloor ventilation gap around the perimeter of the houses had been blocked up by vegetation and stones to prevent mice entering (see figure 21), leading to the collapse of one timber floor, which had rotted due to lack of ventilation subsequently, and fears for similar problems across the scheme.

Figure 21. Ventilation gap around house blocked by vegetation and stones (scheme G)

Whatever means of ventilation were installed in the case-study homes, there were examples of residents taking direct action to counter the difficulties they experienced with the equipment. Switching off ventilation systems to stop draughts or incessant noise, blocking tricklevents or essential ventilation gaps to keep out insects or vermin, or opening windows to disperse cooking smells that the system could not cope with, were typical adaptations to practice, thwarting the ventilation design intention. Identifying and remedying faults in the equipment was typically slow and, in some cases, resisted by the housing association.

While some residents adapted to the faulty technology by ‘learning to live’ with a noisy ventilation system, or moving the furniture to avoid draughts from vents, rather than pursue action to correct these faults, others lost confidence in the system altogether. Thus, ventilation practice was shaped to a significant extent, in multiple ways, by the design and performance of the ‘things’ installed.

6.5.2 Guidance

The initial introduction of residents to their new home and its ventilation equipment appears to vary widely between schemes, as well as between individuals within a scheme. One resident reported receiving minimal verbal instructions, without any explanation:

> They just told us not to turn the ventilation system off and that was it, that was all we had. GR2

Another recalled receiving detailed written information, but did not appear to find this useful for future reference:

> We got given a huge, huge booklet, which I think is now actually in the attic. HR1

Receiving written information did not necessarily mean that it was understood, as one interviewee explained:

> They give you a booklet, and you read the booklet, but it don't tell you really a lot about it. It's just basic stuff, like saying keep your doors shut, keep your windows shut. A lot of it is not in layman's terms. GR4

Another resident recollected:

> I think they did give us a booklet when we moved in, but it was like in a big pile of about ten other different files so it kind of just went in the drawer, to be honest. RR4

Where an instruction booklet about the ventilation system was provided, this was generally included in a Home User Guide (HUG) (see glossary), containing a large array of information, from gas safety to local bus timetables. The HUG at one scheme consisted of a bulky and uninviting lever-arch file (see figure 22), dominated by lengthy technical documents. One resident at this scheme confirmed that she kept the guide to hand for reference but did not find the contents user-friendly. Indeed, the manufacturer's user guide for the MVHR system at this scheme ran to 50 pages and, although it was intended for a non-technical audience, it did require a moderate level of technical understanding, and not a little perseverance. In any event, the MVHR units in these properties were located in a locked roofspace, making it impossible for residents to follow the guidance in the user manual.

Figure 22. Home User Guide (scheme R)

By contrast, ‘Information about your home’ provided by another association achieved a useful level of detail, without assuming technical knowledge (see figure 23). In this case, the production of user-friendly resident guidance on the energy-efficient features of the home was part of the architect’s brief and regarded as critical to the success of the scheme. However, while the first tenants at the scheme received this information, and a detailed induction to their new homes, it appears that subsequent tenants, and indeed staff who joined the association at a later date, were unaware of the design intentions and services in the properties.

INFORMATION ABOUT YOUR HOME

Introduction

Your new home has been built with a number of features to -

- Improve comfort, convenience and accessibility
- Reduce your gas and electricity bills and reduce harmful greenhouse gases
- Reduce your water bill and conserve water
- Provide good indoor air quality and reduce pollution
- Ensure that it is secure.

ENERGY SAVING

Your home is very energy efficient. It has high levels of insulation in the floor, roof and walls, triple-glazed windows, and a high efficiency condensing gas boiler to provide heating and hot water. Low energy light bulbs are fitted to reduce energy consumption. Good size windows reduce the need for artificial lighting and a whole house ventilation system is built-in to ensure fresh air.

These houses use a fraction of the energy of typical UK houses and are much better that the current building regulations require for new homes. How much you save depends on your usage but we do not expect you will need to heat your home for much of the year and gas bills are estimated to be £1 –2 per week with normal use.

AIR AND POLLUTION

Natural building materials, paints and varnishes, for example, have been used to reduce any potential risks to health from chemicals given off into the air. We would encourage you to continue using these in future to keep the house free of toxins.

The house is designed to reduce air leakage through the construction and the hall is designed to reduce cold draughts when you open the front door. This enables an energy-efficient heat recovery ventilation system to be fitted that provides constant fresh air whilst extracting stale moist air. To benefit fully from this ensure that all window are closed when you need to use heating .

The materials used to construct your new home have been selected to reduce the amount of energy used and pollution created in their manufacture. The structure is timber rather than brick and concrete block built using cement mortar all of which require substantial energy to manufacture

Ventilation

- Your house is fitted with a heat-recovery ventilation system, which provides fresh air continuously day and night. The system extracts moist air from the kitchen, shower room and bathroom. The other rooms, living room and bedrooms have fresh air inlets. The system is controlled automatically. There is a switch in the kitchen, which allows you to boost the extract rate to when cooking. The inlets and outlets should be kept clean and unobstructed.

Figure 23. Extract from Home User Guide (scheme G)

Another association, having a high proportion of tenants whose first language was not English, included clear photos of equipment and controls in its guidebook to assist residents, customised to the specific scheme (see figure 24), although understanding of text was still needed. However, one part of this guide had been added by cut-and-paste from another document and inadvertently included contact details for the wrong housing association!

Windows

All upstairs windows are fitted with restrictor stays which prevent the window opening fully and stop children falling out. To open the window fully, open the window until it reaches the stop position and then use your hand to press the release button within the hinges (see picture below) – this will allow the window to be pushed fully open. When the window is closed again the hook restrictor stay will automatically re-latch.

Figure 24. Illustration in Home User Guide (scheme A)

Unlabelled switches clearly hindered communication, but intrusive labelling was a concern for one case-study housing association. Instructions had been provided on stickers next to switches but the maintenance manager was concerned 'it doesn't look great does it with this big sticker, do not switch off, in the middle of your living-room or something'. There are excellent examples of scheme-specific diagrams designed to communicate ventilation system instructions to residents in non-intrusive formats (Technology Strategy Board 2012), but these are the exception, not a routine practice for designers.

Neither lettings nor maintenance staff seemed to understand the ventilation system at some case-study schemes, as explained by one interviewee:

> We weren't really advised anything about it, nobody seems to know anything about the system, even the maintenance team when they come don't really know anything about it. RR1

Residents who moved in following a mutual exchange (see glossary) appeared least likely to have adequate, correct information about the ventilation system in the house. One interviewee, who did not use the MVHR installed, commented:

> She just told me don't put that thing on or you won't sleep (mutual exchange with daughter). GR1

Even if the outgoing tenant leaves the Home User Guide for the incoming tenant, this does not always provide the information needed:

> There's some kind of thing that was here that was left over from them in the cupboard that explained what the house had and where the switches were, but it never explained what they were, what they did or, so it wasn't an instruction or an explanation it was just a whereabouts. GR3

Inductions for new residents, explaining the means of ventilation in their home, were not the norm in the case-study schemes (see 6.4.1). Written guidance on ventilation systems was typically a highly technical manual that was put away by the resident and ignored. Neither lettings nor maintenance practitioners consistently offered clear guidance, leaving new residents, especially those moving in following a mutual exchange, unaware of how to operate the ventilation system, or even of its existence in some cases.

All the case-study housing associations relied on communicating details of the home to new residents in person or on paper; none offered alternative formats such as online or video (Menon and Foster 2017) as a routine practice.

6.5.3 Controls

Inadequate information at the start of the tenancy about ventilation systems installed and their operation, or indeed wrong information, as described above, evidently hindered the evolution of ventilation practice to reflect the resident's new physical environment. This was compounded when controls were unclear or, indeed, faulty. Interviewees had experience of unlabelled switches (figure 25), controls fitted upside down or sideways (figure 26), and wrongly programmed controls:

> It was so awkward because, first off, learning how to programme it, when somebody programmed it from the housing association they'd got their a.m. and their p.m. muddled up and for me it was quite complex.   RR3

Figure 25. Switches in airing cupboard, unlabelled at handover (scheme G)

Figure 26. Ventilation control fitted sideways, not matching diagram in instruction manual (scheme R)

One resident, with an unlabelled boost switch intended to increase kitchen ventilation when cooking, reported:

> We know basically nothing about it. We don't really fiddle with it. Something maybe once we might have done, but I didn't really. No, whether that's on or off or not… GR3

As this resident implied, understanding the controls at the outset is critical to engaging with the system. When the practice of ventilation has been established in a new low-energy home, whether as intended by the designer or not, there may be no incentive to make the effort to understand the controls.

Another resident was deterred from using the ventilation system, being confused by the different controls in the house:

> Is that what that's for then (boost switch)? So the switch in the airing cupboard, that says ventilation, what's that? So I don't have to touch that (heating controller) at all for that (ventilation system)? (Interviewer: No). Ah, that's good to know. I still won't use it though. GR5

This resident also left her heating programmer as set by the previous tenant as she did not understand how to change it. Instead of using the controls to meet her needs, she was in effect adjusting her use of the house to fixed settings of the heating and ventilation. Thus, a technical control system, designed to be adjustable to meet users' needs and to increase energy efficiency, had lost this capacity for this resident. Instead, she had adjusted her practices to a fixed technology, in a similar way that resident practices may adapt to the physical design of a home that cannot be altered to meet their needs. This is a clear illustration of the role of materiality in the 'temporal stitching of social practices' (Spurling 2018: 15) (see 8.2).

An alternative approach was taken by one interviewee, based on experience of the MVHR system in his home rather than the instructions given about its use. Over time, he had devised his own, affordable, ventilation strategy, using the installed system part-time, combined with window opening and the use of fans. He summarised the trial-and-error approach to ventilation taken by a number of interviewees, unwilling or unable to use the installed system and its controls:

> I think it's getting what's right for you, to be quite honest.   GR4

The controls interface between a ventilation system and resident clearly plays a crucial role in ventilation practice. Non-intuitive controls, incorrect installation or inadequate explanation, may leave the resident to adapt to the system and sub-optimal ventilation performance.

6.5.4 Filters and servicing

The continuing effectiveness of mechanical ventilation equipment requires regular changing of filters (where these are fitted) and periodic servicing. Indeed, the manufacturer's warranty may be invalidated if maintenance guidance is ignored.

After no servicing or filter changes for six years, one resident contacted the manufacturer for advice before pursuing her landlord. She found that the housing association did not have a filter change or servicing programme but expected residents to initiate action:

> When I last spoke to my housing officer about it, he said what I should do is phone up and report it as a repair. And I said 'Well it's not technically a repair'. He went 'No, you need to report it as a repair, and get someone come out and they will decide then if they're going to change the filters and what's what'. I haven't done that yet.   LR4

This approach assumes that residents understand that the system requires periodic filter changes and become aware that this is overdue, potentially through declining air quality or an increase in fan noise as the filters become clogged. However, this may not be detected or may not trigger a repair request. In that event, ventilation of the house will become inadequate over time, mitigated by whatever alternative tactics are adopted by residents to maintain fresh air.

By contrast, another housing association regularly serviced ventilation systems, even where residents had switched them off:

> I'm meant to have it on. They know I don't have it on. They're fully aware that as soon as the man went, I said 'You know as soon as you've gone out you know I'm taking out the fuse'. He went 'Yes I know you will' and he said 'Just to inform you as far as I'm concerned it's in there'. HR2

At one of the case-study schemes, some long-standing residents washed the MVHR filters themselves every 3-6 months, having established that practice when they became the first tenants at the newly built scheme. This is a cheaper, and potentially more sustainable, option than replacement that is possible with some types of filter, at least for a number of uses. Although some residents were still willing to carry out this task, it appeared to be an unwelcome chore, particularly as access to the MVHR was difficult (see figure 27). As one disabled interviewee explained:

> I get my son up there and he just does that. They're up in the little door at the top (on a mezzanine platform in the bedroom). Yes, my wife could get up there, but she won't, she'll send my son up. And then we've got an 8-year-old grandson and he'll get up there if we show him what to do. GR4

Figure 27. MVHR cupboard (blue door behind boxes) accessed from mezzanine in bedroom (scheme G)

Replacing filters appeared to be worryingly ad hoc at all the schemes studied, despite the impact on residents' health of poor indoor air quality. Indeed, one resident was aggravated that the housing association would not meet the cost of higher quality filters, to give greater protection for her child with asthma:

> I haven't got £30 to spend on filters when I have a young child. I haven't got that sort of money.   GR2

Removing and replacing the filters in an MVHR unit is a simple task, requiring less technical skill or dexterity than, for example, changing a tap washer. However, the awkward or inaccessible location of the unit prevents some residents from carrying out this task safely. Replacing the filter in a PIV unit, which is needed less frequently, requires access to the roofspace and will generally be carried out by a contractor.

The cost of replacement filters, particularly fine particle filters recommended where residents suffer from breathing-related health conditions, is significant (typically £20-£30 for a set of normal filters, at each change, at 2020 costs) and tenants expect this cost to be borne by the landlord. Indeed, none of the housing associations studied include replacement of filters as a tenant responsibility in the tenancy agreement. Although this implies that the housing association takes responsibility for filter changes, it is evident from interviews with residents that this is not always implemented. This inconsistency is explored further in the analysis of interviews with housing association staff in chapter 7.

However, some residents in the case-study schemes clearly do clean the filters in their MVHR systems regularly, even though they expect the housing association to change them when necessary. It appears that this task has become part of the ventilation practice of residents where it was expected at the initial letting of the homes, even though it is not part of the practice of their neighbours who moved in at the same time or at a later date. Although the ventilation system is the same for all residents at the scheme, it is evident that the landlord's 'rules' on tasks that tenants are expected to carry out, have changed over time. Despite this change in the rules, the practice of at least some of the original tenants has not changed, suggesting that habit, in respect of this task, now influences practice to a greater extent than rules.

Evidence from the case-study schemes suggests that the essential servicing and filter changing in ventilation equipment has not been universally incorporated into the housing association practice of maintaining ventilation in low-energy rented homes, nor into the practice of ventilating the home performed by residents. The ad hoc practice relating to filters belies the importance of this 'thing' to ventilation effectiveness and resident health.

6.5.5 Windows and tricklevents

Opening windows was regarded by many interviewees as the preferred, indeed natural, means of ventilating their home, even where a mechanical system was installed and in use. As one resident expressed it:

> I mean, in all intents and purposes, we always like a window open anyway. You know, that's ventilation, keeping all the windows, fresh air to be quite honest. In the summer we just open everything. But they say you should shut everything to keep it cool.   GR4

This resident regarded opening windows as essential to prevent damp, relating this to long experience of living in older houses:

> I mean the thing is, a lot of people tend not to, they don't open windows and doors for some reason nowadays and that's just basic. Even if you had, in an old house you've still got ventilation. I know but, you'd still open windows and that. It's a case of, if you don't air the place, then it's going to get damp, to be quite honest.   GR4

Another regarded opening windows as a healthier option for ventilation:

> I'm quite one for opening the windows and letting the breeze brush through, kind of, brush out the cobwebs. Because if you live in a house and it's so hot, all the germs and everything never gets aired out does it.   HR2

This view echoes the suspicions expressed by another interviewee that her MVHR may be spreading:

> Airborne viruses, which obviously people aren't very aware of.   LR2

This was a prescient observation, given the advent of Covid-19, which has dramatically heightened concern about ventilation systems (see 10.4.1.2).

Despite an expressed preference for ventilation by window opening, interviewees had significant concerns about safety aspects.

It appears that child-safe window locks had not been fitted at the outset to all upstairs windows in the case-study schemes. 'Child-proof' catches provided by window manufacturers were considered no barrier to a determined small child and residents at two schemes argued successfully for lockable window restraints to be retro-fitted by their landlords (see figure 28). In one case, reportedly, action was taken only after a child fell out of a window at the scheme:

> She was alright, there was no death or nothing, but it just sent me right over the edge. LR1

Figure 28. Child-proof lock retrofitted to bedroom window, original catch at bottom of frame openable by a child (scheme L)

One resident had sought reassurance from a firefighter acquaintance that a locked restraint would not prevent the fire service rescuing an occupant. Although she was concerned about being able to find the key in the event of a fire, this resident was relieved that she could safely leave the children's bedroom window open at night for fresh air.

Day-to-day ventilation practice is influenced by security fears for some residents, exacerbated by windows that cannot be locked securely with an opening for ventilation (see 6.3.4).

Even where residents had concerns about noise from traffic, trains or neighbours, they still sometimes expressed a preference for opening windows rather than closing the windows to exclude the noise and relying on the ventilation system for fresh air. One resident experienced a lot of flies around the house, being located near the scheme bin store, and suffered from hay fever when the pollen count was high. However, she still preferred to open the windows:

> I keep the blind down to prevent them (flies) from coming in…It brings in enough air but it keeps the flies out. LR2

The familiarity with window opening for ventilation among residents interviewed did not extend to the use of tricklevents (see glossary). In the two schemes where tricklevents were fitted, these appeared to be rarely used, or even understood:

> I wouldn't even have a clue how to use them. I just don't touch anything, it's a lot easier. I didn't even know what they were to be honest with you. HR1

Indeed, one resident discounted the use of tricklevents for ventilation for fear of them carrying sound unnoticed:

> The only trouble with those top things is knowing if they're open so that neighbours or that can hear your conversations, the sound sort of goes out. I'd rather open the window and know that I know it's opened than have a conversation about something that I don't want the neighbours to hear. HR3

Although there was no evidence that tricklevents had been purposely blocked, it was observed that in some cases they were obstructed by curtains.

Residents in the case-study homes typically regarded windows as the natural, normal, and indeed healthy, 'things' for ventilation, even where whole-house ventilation systems were installed. Significant concerns were expressed, however, relating to the safety, security, accessibility and location of windows, suggesting that the role of windows in the ventilation of low-energy homes is undervalued by designers. While window opening was a central part of ventilation practice for residents, the use of tricklevents was not.

6.5.6 ‘Things’ for comfort

The practice of ventilation recounted by interviewees, not relying solely on ventilation systems installed, necessitated them using a range of tactics and ‘things’ beyond the installed ventilation systems to maintain a comfortable environment.

Despite the cost and environmental impact of energy consumption, the use of portable electric fans was an everyday practice for some residents. Although fans, air purifiers and air fresheners do not draw fresh air in, indeed they add chemicals into the indoor air in some cases, they were regarded by many interviewees as a means of airing their home. One resident reluctantly discounted the use of fans on safety grounds:

> Really we should buy a fan, but we never have. But I just think they’re dangerous, I’ve got a thing about the kids putting their fingers in them. LR1

The practice of varying clothing and bedclothes was referred to by several interviewees, as an expedient to meet individual comfort preferences, which was an issue in multi-person households even where ventilation was effective:

> Two of them would constantly have them (windows) open. One, the middle girl, she’d sleep, have no blankets. There’s only really one that’d rather be warm, will just sleep in a million and one blankets and all the rest of it. LR1

In one household, where the parents preferred open windows for ventilation, a teenage son was expected to dress more warmly if he wanted to be comfortable, an example of the ‘shifting internal dynamics’ in households (Hargreaves and Middlemiss 2020: 195) that affect domestic arrangements:

> Me and my wife, we’re pretty much on the same thing. But my son, he goes, ‘It’s freezing’. Alright son, whatever. ‘Just put another jumper on, you’ll be alright’. ‘Shut the window then’. ‘No I’ll leave the window open’. Whatever. No, we’re pretty much the same really. He’s alright, he’s eighteen, he can handle it. GR4

These ‘things’ and tactics were intended to ensure comfort for different household members, however, in some cases, they unintentionally compromised air quality and increased energy consumption.

6.5.7 Summary: the influence of ‘things’

The evident inconsistency in the reporting of ventilation problems by residents, in combination with the evident inconsistency among associations in maintaining ventilation systems (see chapter 7), creates a high risk of ‘things’ in the home underperforming. Effective ventilation is thereby compromised, although this will be mitigated to some extent by residents’ action to ventilate using alternative means, principally windows and doors. However, this action is likely to compromise energy efficiency and carbon emissions, undermining the rationale for airtightness.

While windows and doors are widely regarded by interviewees as the normal means of airing the home, any barriers to their use, physical or non-physical, will exacerbate ventilation effectiveness if installed mechanical systems are not performing as intended, or indeed not functioning at all. However, window functionality appears to be a widespread frustration for residents, who cited inaccessibility of window controls, security fears and child safety among reasons for keeping windows closed. By contrast, external noise and potential loss of heat do not necessarily prevent the use of windows for all residents.

Although the evidence indicates that windows are an intrinsic part of ventilation practice, despite their shortcomings, tricklevents in windows do not appear to play a significant role in the practice. The technology of tricklevents may appear to be simple but nevertheless they are clearly not intuitive for all residents.

This suggests that window design is undervalued and overlooked by designers, with negative consequences for effective ventilation in low-energy homes, where windows are evidently a key ‘thing’ in ventilation practice for residents even where a whole-house ventilation system is installed.

6.6 Sub-conclusion

An initial analysis of the resident interviews at the five case-study schemes has highlighted the diverse range of influences on ventilation practice. The bundle of practices that impact on ventilation practice in the home, are clearly performed by residents in idiosyncratic ways, in a multiplicity of combinations. These diverse practices have evolved over time and place, shaping the demand for ventilation in the dwelling as well as influencing ventilation practice. It appears that the *diversity of influences* is not normally recognised in ventilation design and guidance.

It is also evident from the data that the parameters in ventilation design and systems in the homes studied have underestimated the *scale of ventilation demand* created by normal household activities. For example, even where residents operated the mechanical ventilation as intended, including using the boost facility, everyday cooking or drying washing often necessitated opening windows to prevent condensation, thus compromising energy efficiency.

In all the case-study schemes, there were homes where the means of ventilation provided, though operated as intended, could not cope with everyday demands. This suggests that **the design and specification of ventilation overlooks the diversity of practices influencing ventilation demand and underestimates the scale of that demand.**

The variability in ventilation practice among residents interviewed can be explained in part by habits and meanings, but it is evident from the interview data that **first, or early, encounters with novel ventilation 'things' in a low-energy home, and instructions or 'rules' given for its use, strongly influence how practice evolves** (see chapter 9). Moreover, initial willingness to adopt new practices can be easily undermined if residents receive 'mixed messages' about the 'rules' that apply.

Communication between residents and landlords regarding ventilation evolves through repeated interactions, not only at the point of letting, but in many interactions over time between residents and a changing body of individual staff within the housing association.

Residents recounted examples of both helpful and unhelpful interaction, within the same association, at the same or different times. It is apparent that **perceived inconsistency in the landlord's advice or instructions or decisions (whatever the reasons for this and however justified) had impacted on some interviewees' confidence in the technology in their homes, influencing ventilation practice.**

The regularity of occurrences where planned ventilation is operating as intended by the designer but inadequate to meet need in use also suggests that **housing associations are not hearing, or not learning from, the first-hand experience of residents and reflecting this experience as a 'rule' in the planning of new homes.** Scheme briefs and designs are generally based solely on the *technical* expertise of design professionals and, it appears, rarely seek, or take account of, residents' *experiential* knowledge. These perspectives of residents are echoed in the opinions of maintenance practitioners, who express similar frustration that their expertise is ignored at the briefing and design stage, although it appears that maintenance practitioners themselves discount the tacit know-how of residents (see maintenance practitioner perspectives in chapter 7).

While the valuing of explicit knowledge over tacit knowledge may superficially explain the exclusion of residents' experience in the design of ventilation, an interpretation of the data suggests that there are deeper influences at play shaping ventilation practices, that are beyond residents' direct experience. It is also evident from the analysis in this chapter that a diverse bundle of housing practices is relevant to ventilation maintenance. These themes are discussed in chapters 8 and 9, after the practice and perspectives of maintenance practitioners are analysed in the next chapter.

Chapter 7. Analysis: Maintenance practitioner practice and perspectives

7.1 Introduction

The objective of this chapter is to understand how the practices of housing association maintenance staff, and their interrelationships with residents and with other housing association staff, influence ventilation effectiveness in low-energy rented homes. Data collected from five case-studies and from the scoping survey and focus group (see methodology at chapter 4 and results at chapter 5) is analysed using a Practice Theory framework (see theoretical framework at chapter 2).

As in chapter 6, this chapter is structured to reflect the four components of practices defined by Gram-Hanssen (2009), analysing the data in relation to ventilation habits, meanings, rules and things. Observations are made on the key findings, leading to themes which are discussed and developed in chapters 8 and 9.

7.2 The influence of 'habits'

7.2.1 Instructions and assumptions

Problems associated with lack of ventilation were routinely assumed by staff to be the result of residents' lifestyles, even if the residents thought otherwise:

> Well, lifestyle isn't it…But trying to convince them of that, it's two different things, they don't see it, they don't see it's a lifestyle thing. (Area Housing Manager)

Frustration that ventilation systems are not operated as instructed was heightened for one interviewee from a technical background who expected that residents would readily adapt their behaviour to take account of the energy-saving features of their home:

> I don't really think they appreciate they're living in something different. I don't think their lifestyles are any different to they would be if they were living in a normal house. (Technical Services Manager)

This interviewee evidently assumed, firstly, that residents were aware that their home is not a 'normal' house, secondly, that they would 'appreciate' the benefits it offers, and thirdly, that their practice would adapt to take advantage of these benefits.

One interviewee assumed that residents had forgotten instructions given, but did not consider whether, in fact, they had received an adequate induction:

> A lot of them swore blind to me they'd never received a manual or anything…So, everybody's busy, and people forget, and so you smile and explain it again. (Development Manager)

It is evident from the interviews with residents (see chapter 6) that there are multiple reasons why instructions for the ventilation system may not be followed. Failure to engage with the system, or operate it as intended, can indicate that residents do not value the benefits it offers or that practice is driven by different priorities than staff assume. However, in assuming that residents were wilfully ignoring instructions, staff did not allow for other explanations, their habit being to issue instructions and expect that this alone would lead to ventilation practice embracing the new technology.

This assumption precluded objective assessment of problems reported, as one focus group participant reflected:

> I think that some (author: maintenance) staff are going out with the automatic assumption that it is a lifestyle issue. (Tenant Services Manager)

Residents' perceived lack of understanding of ventilation, or unwillingness to take the action required, results, in the experience of one staff interviewee, in a home where:

> You've only got intermittent ventilation, or it's dependent on people opening tricklevents and windows and things, it's really random whether you get the right level of ventilation. (Development Director)

Even where the ventilation strategy and equipment are designed to enable the 'right level of ventilation', this is based on assumptions about usage of the property and resident operation of the controls. Ventilation practice observed suggests that design assumptions may not reflect actual patterns of use and operation of equipment can be hindered if controls are not intuitive.

Drying laundry indoors, for example, was highlighted as a particular habit of residents, not always anticipated by designers, that is likely to cause condensation and damp in homes, especially during the winter months:

> There's washing everywhere, and between October and April, we've got real issues around trying to get ventilation through a building. (Development Manager)

However, designers' assumptions about laundry drying were mostly considered by residents to be impractical (outdoor drying in wet weather) or too expensive (use of tumble-dryers). The habit of staff to criticise residents for 'choosing' indoor drying, rather than staff considering the options that the design and technology of the home offer, meant that research on laundry practice and guidance on drying facilities (Menon and Porteous 2011) was largely ignored by the housing associations thereby influencing ventilation practice, with a damaging effect on indoor air quality.

Nevertheless, one housing management interviewee did accept that residents' actions may be rational if their priority is keeping warm and saving money where possible:

> Especially during the winter months, you don't want to be putting your clothes on a radiator and then open a window because it's going to get cold, so they might just put their clothes on the radiator to dry them and it's not opening the windows, and that's the condensation part. (Senior Housing Officer)

Concern about heating bills, even in homes designed for low-energy use, commonly led to underheating in the case-study schemes. In one interviewee's experience, this practice was the root cause of condensation and damp:

> The problems were arising not from the ventilation but from the non-use of the heating system: people were simply switching it off. (Quality & Value Manager)

The need to keep energy bills low was also leading to switching off ventilation systems, despite the low energy usage of the system fans (Green Building Store 2019). This was not unexpected to this interviewee, aware of the financial circumstances of typical housing association tenants:

> We have problems with people leaving switches on if they think it's going to cost them money, and that is part of working in a challenging area with people who haven't got lots of available income, and who are being very, very careful on how they monitor what they're spending. (Head of Asset Operations)

However, the habit of switching off was perceived by one interviewee as having a deeper root, fostered by residents' wider experience of technology. In his view, residents were revealing greater confidence in manual controls than in automated systems:

> It goes back to people who are living on low incomes need a lot of convincing that the technology operates in their interest. So the idea of not switching things on and off is a big hurdle to get over. (Quality & Value Manager)

Maintenance practitioners' practice appears to be influenced by a habitual assumption that ventilation problems result from residents not following instructions and failing to ventilate their homes correctly. This habit obscures understanding of underlying causes such as lack of induction for new residents or inadequate means of ventilation for typical household needs. As a result, ventilation maintenance practice addresses the symptoms but not the causes of ineffective ventilation. Understanding residents' actions from the resident's perspective appears to be the habit for some staff in the case-study schemes, but certainly not all.

7.2.2 Staff ventilation habits

Understanding the residents' perspective on the use of whole-house ventilation systems is influenced, for some staff, by their ventilation habits in their own homes.

In the case-study schemes, it appears that window opening is accepted, by both the residents and the staff, as the normal means of ventilation, rather than mechanical ventilation, as this interviewee reported:

> Whenever I go there all their windows are open…and people like fresh air I guess, at the end of the day, and you're not going to change that. (Technical Services Manager)

It was evident that some staff interviewed shared this view themselves, as one expressed it:

> Now personally I'd have the doors and windows open because you want the outside in when the weather's nice…Certainly I think it's people's nature that if it does get too hot they'll open a window. (Development Project Manager)

Indeed, one staff member, when visiting residents at a case-study scheme with MVHR installed, actively supported an alternative option for ventilation:

> I often said, well there's natural ventilation, there's nothing wrong to naturally ventilate the units. (Development Manager)

Another interviewee involved in staff training reflected on the tendency of staff to assume that low-energy homes function in the same way as their own home. In his experience, embedding an understanding of ventilation in low-energy, airtight homes, throughout the staff team, required a continuous effort to counter this tendency:

> Front line staff switch their heating on and off because they live in properties that are not state-of-the-art properties. And I don't think that message got through, in fact we had a number of meetings in this very room where we were saying to them, it's not like your home. So we need to have a constant message. (Quality & Value Manager)

Although the interview data suggests that maintenance practitioners and residents share a historic scepticism about whole-house ventilation systems (see 8.4.1), there appears to be a conflict for maintenance practitioners between their ventilation habits at home and the practices related to maintaining ventilation in low-energy homes that apply in their work. It appears that this conflict impacts on their interaction with residents, resulting in mixed messages (see 9.2.4).

7.2.3 Organisational memory and forgetting

'Forgetting' can be the experience of the housing association, not just individual residents or staff. One development interviewee regretted that the original intentions of an exemplar eco-housing scheme had been lost over time:

> Of course what happens, even in a small organisation, is the organisational forgetting. I would say what, I'll be interested to see what you find out with this, but it's been staggering how we've just managed to not keep the knowledge. It needs more systems I think. (Development Director)

This interviewee acknowledged that the habit of 'organisational forgetting' regarding this scheme, even in his own small association, meant that systems are needed to retain knowledge in businesses of all sizes.

Losing knowledge in this way hinders the induction of new maintenance practitioners into the maintenance of ventilation technologies in low-energy homes, exacerbating the shortage of appropriate skills (see 7.2.5) and holding back the evolution of ventilation maintenance practice.

Accessible and accurate information systems enable maintenance personnel to diagnose problems on site quickly. However, at one case-study association it appeared that there were no records of the ventilation systems installed:

> We asked development where they are and what units are in, so they should be able to say they're here, this is the unit that was installed and there's the commissioning sheets. They weren't aware of them, so we're finding them. (Head of Electrical Compliance)

Another interviewee referred to habitual reliance on the individual memory of housing officers, rather than information systems, in relation to informing future residents about ventilation systems:

> With the best will in the world, if we don't have a new let there for 4, 5, 6 years, a re-let, you're relying on the officer who's dealing with it to know about it, because there isn't anything on the system that would trigger, ah, we need to go and do a little bit extra now, need to educate a little bit more than just a conventional build. (Head of Housing Operations)

Maintenance teams carrying out void repairs between lettings, that may occur infrequently, would similarly be unaware of the mechanical ventilation systems in the property:

> They get involved for the void works, but again I'm not convinced that there would be a trigger within the system to flag that we need to do something differently. (Head of Housing Operations)

Without accessible, comprehensive scheme records, integrated across functions, staff turnover over time erodes the corporate memory, to the point where one interviewee found:

> It was almost a shock to some people that they (eco-homes) would be any different, because the staff had changed since the beginning. (Technical Services Manager)

Retaining the knowledge in the staff team that is essential for effectively managing and maintaining low-energy homes with new types of ventilation system, over the lifespan of the dwelling, is evidently compromised by the staff habit of relying on individual memory, without systems in place to mitigate organisational forgetting. The findings indicate that this can be exacerbated by silo working in the housing association, discussed in 9.2.3.

7.2.4 Standardisation v. diversity

Given the physical diversity of the housing stock, as well as continuing technical advances in ventilation products, the habitual desire for standardisation, frequently voiced by maintenance practitioners, is a considerable challenge in respect of ventilation systems. As one interviewee asserted:

> Standardising stock is the key to customer journey, getting it right. So basically if we standardise stock, regardless if it's a socket, a switch, MVHR, then all our operatives know what to expect in a property. (Head of Electrical Compliance)

One focus group participant explained a practical advantage of standardisation but acknowledged the impact on ventilation effectiveness:

> Your lads carry the spares on the vans and the vans are only so big, so in an ideal world you do sometimes compromise slightly in order to say actually this one product would do 90% of our needs and therefore we'll use that. (Tenant Services Manager)

In reality, however, the maintenance team will require knowledge of many different systems and products and there is a risk that effective maintenance of mechanical ventilation can be compromised by the drive for standardisation, an objective articulated both by staff interviewed and by participants in the survey and focus group. Specification of a 'standard' product, or a very limited range of products, is unlikely to meet the ventilation needs of a diverse stock.

Moreover, the habit of relying on standard products, may lead to undervaluing the need for thorough understanding of ventilation principles and practice, and underestimating the need for data systems (see 7.2.3) that facilitate the effective maintenance of diverse, purpose-designed installations.

7.2.5 Skills for ventilation

Finding contractors with the right skills and experience to install and maintain mechanical ventilation systems was considered a critical problem by this interviewee, who leads the development team of one association:

> I would say that's the biggest problem we've got as a sector, is actually having that skilled workforce, and that's across the board, design, installation and maintenance of the system. And replacement and thinking about it intelligently. So there's a lot of work opportunities there really. (Development Director)

One maintenance manager in the focus group was committed to training in-house maintenance surveyors, positively influenced by awareness of past practice:

> Another thing is that 20 years ago a building surveyor was a building surveyor, he'd been trained in all elements of building fabric, whereas nowadays a building surveyor is someone who understands the schedule of rates, understands basic maintenance, and actually it's more about how we develop and train them. (Repairs & Maintenance Manager)

Habits in both the construction team and maintenance team can result in ventilation being 'nobody's specialism'. This association experienced badly installed mechanical ventilation and concluded:

> It's nobody's, the general labour on the site or the plumber or the electrician or whoever it is that gets the job of actually putting that in doesn't necessarily understand the finer points of installing. (Development Director)

Researchers have identified a deeply fragmented skills structure across the building sector, which has 'delimited its innovative capacity' (Chan and Dainty 2007: 376). Indeed Jagger et al. have commented that the mismatch of skills with the needs of the transition to a low-carbon economy could 'critically delay elements of the transition and increase its cost and duration' (Jagger, Foxon, and Gouldson 2013: 43).

This is echoed in the experience of one association that decided to train in-house staff to maintain ventilation, after failing to procure external contractors with the required expertise, and found they had to overcome the reluctance of tradespeople, including trainees, to expand their remit to incorporate the new technology:

> We had an apprentice, he come in and he said 'I'm not happy going round with the MVHR guy', and I went 'Why?' He went 'It's not really sparking' (electrical work). I said 'Trust me mate, in ten years' time this is going to be huge and no-one will know about it and you will. So stick with it, I know what I'm doing, just learn it.' (Head of Electrical Compliance)

The habitual lack of integration between trades in respect of mechanical ventilation technology is evidently hindering the maintenance of new technologies in low-energy homes, indicating that skills and training in the wider building trade are part of the bundle of practices influencing ventilation maintenance.

7.2.6 Summary: the influence of 'habits'

Housing association staff interviewed recounted multiple problems regarding the ventilation of the low-energy case-study dwellings, often materialising as dampness or mould. The habit of staff blaming residents for poor ventilation is mirrored in the frustration expressed by some residents at the critical or dismissive attitude shown towards them by their housing association.

While maintenance practitioners may criticise the 'choices' that residents make that impact on ventilation, residents may respond that there is 'no choice' of practical and affordable options, for example for drying laundry, and a relationship of mutual frustration and disregard ensues.

The staff habit of placing their technical knowledge, albeit incomplete in respect of new technologies, in opposition to the experiential knowledge of residents is evident in the data. Ironically, the experiential knowledge of staff, from naturally ventilating their own older homes, may also be influencing the advice they give to residents living in newer homes with whole-house ventilation which requires a quite different approach.

The habitual reliance of staff on individual memory, and failure to capture that knowledge into the organisational memory, had led to 'corporate forgetting' in the case-study schemes. Maintenance practice was then unable to build on this know-how, resulting in failure to maintain ventilation systems.

Maintenance know-how appears to strongly favour standardisation of products across the stock, even though a 'one size fits all' approach is highly unlikely to deliver a 'good fit for all' across a diverse housing stock. The interests of maintenance efficiency thereby risk undermining the delivery of both low energy use and healthy indoor air.

Supporting the shift to greater diversity in ventilation 'things' by skilling and motivating maintenance practitioners to work across and beyond traditional trade boundaries, evidently presents significant challenges to established maintenance habits. However, the adoption of new staff habits, to accommodate the mainstream adoption of whole-house ventilation technology, is clearly necessary for effective ventilation in low-energy homes.

7.3 The influence of 'meanings'

7.3.1 Short term v. long term

It appears from the interviews with case-study staff that the process of developing new housing schemes places stronger emphasis on the short-term objectives of meeting specific standards (Building Regulations as a minimum, or higher voluntary standards), within the cost limits for the scheme, than on the long-term requirements of maintaining and managing the ventilation system, and protecting the health of occupants, over the life of the asset. As one interviewee highlighted:

> I'll be honest, the main push was deliver something to that code standard, not really that bothered how you get there…It did become a bit of a points exercise instead of thinking about the people who're actually going to live in them. (Head of Asset Operations)

She added: 'Maintenance cost didn't really come into it'. Although standards for new homes are driven by the ongoing need to mitigate climate change, this influence does not extend to considering the ongoing need for maintenance to ensure effective ventilation for the lifetime of the dwelling (see 8.6.1).

However, some maintenance staff expressed frustration at the emphasis on short-term 'points scoring', and chasing funding:

> They (the development team) can get some funding I think, can't they, if they install this kit initially, or they can score some points to allow the houses, I don't know how it works to be honest. I wouldn't install them personally, unless you have more

> joined-up working with development, to understand what they do, how they benefit the tenants…But at the moment that's not happening. (Senior Contracts Officer)

Indeed, one interviewee acknowledged that, with hindsight:

> We focused I think too much on the, how do we build this, the nuts and bolts rather than the user experience. Yes, and hands up, that was probably the biggest lesson we learned. (Quality & Value Manager)

Another regretted that the longer-term needs of occupants may be compromised at his housing association by its short-term reaction to a reduction in required standards, cost constraints, and changes in procurement. Responding to these changes by 'designing-out' MVHR in new schemes, specifying ventilation options that are simpler to maintain and operate, may achieve some of the association's short-term objectives, such as saving capital and maintenance costs. However, if ventilation performance is reduced, this will be detrimental to residents in the long-term.

As one interviewee emphasised, low energy bills for residents, throughout the life of the dwelling, are a key objective for her association:

> One of the big selling points of the scheme was to have these really incredibly low running costs, which is linked to your ventilation and your heating isn't it. (Head of Asset Operations)

Short-term savings in capital investment could indeed jeopardise the long-term benefit of low running costs or compromise air quality.

Although the links between ventilation, air quality and health had been evidenced long before Covid-19 emerged in 2020, the impact of ventilation on indoor air quality did not appear to be a significant issue for staff interviewed in 2018. However, one interviewee had recently become acutely aware of the issue at an external training event for building surveyors and subsequently highlighted air quality as a maintenance responsibility at her association:

> It's not something I'm particularly aware of but I was listening and thinking, this is coming, it's got to be the next thing. And rightly so, when you're talking about the impacts of air on people's health and lifespan and ability to concentrate. And when you see those sort of statistics you start to think, my goodness, how have we not thought about this before. (Technical Services Manager)

One maintenance interviewee contrasted the timescales for maintenance and development staff, expressing the view that obstacles for maintenance emanate from the practices of development staff. She explained that, as a maintenance practitioner:

> You're always thinking ahead aren't you, what happens when the building comes, whereas development people are sometimes thinking that's nice, that's pretty, there we are. I'm always thinking, if we do that no, what about cleaning that later, that won't work, the scaffolding won't reach there, I'm always thinking about things like that whereas development people aren't always. (Technical Services Manager)

Even when development people take a long-term view regarding the financial viability of a scheme, or its future strategic relevance, this interviewee believed that the detailed requirements of ongoing maintenance throughout the life of the dwelling are not generally in their thinking.

Short-term and long-term timescales are evident in both development practice *and* maintenance practice. Although all these timescales play a part in ventilation effectiveness over the life of the dwelling, the mutual dependence of practices appears to be lost in the gulf in perceptions between practitioners and obstructed by disconnections in the bundle of practices discussed in chapter 9.

7.3.2 Expertise and organisational learning

The gulf of understanding between development and maintenance teams was characterised by one interviewee as a difference in skills and outlook:

> People in development are not always very technical. Development people are a different breed I think. (Technical Services Manager)

As one focus group participant expressed her maintenance practitioner view of development colleagues:

> Development sometimes can be a little bit out on their own. (Stock Data Manager)

Conversely, a development staff member criticised the attitude of his maintenance colleagues:

> It was difficult to persuade maintenance managers to come along to demonstration sessions at the end of the scheme. (Development Manager)

Taking expert advice from outside the housing association on the ventilation aspects of a development is evidently hindered by a lack of expertise nationally:

> There are certain experts, you know, if you go to the Green Building Store and you get it done and put in and you have X doing the M&E, you know that you've got some (expert advice), but there are only a handful of these people in the country. (Development Director)

As a result, the ventilation design for one case study scheme was left to an inexperienced contractor, with disastrous results, and, with hindsight, staff acknowledged:

> I think we didn't fully understand how sensitive MVHR is. (Quality & Value Manager)

Lack of expertise on site, and changing personnel, appears to exacerbate the risk of maintenance issues arising. As one interviewee recounted despairingly:

> It evolves and it doesn't get better, is all I can say. It's a bit depressing. We think oh well we've done that, we got that 80% right, and you think the next one will be a bit better, but it turns out to be problems…We thought that was good, they've learned about it, but it's very much down to individuals. You get a particular site manager, it changes, that's the thing, and then the quality, all those things, are an issue. (Development Director)

Ironically, where a housing association has invested in a specific post or team to increase expertise and organisational learning on sustainability issues, this expertise may be lost if the investment is not sustained, due to funding pressures or changing priorities for instance. As one interviewee regretted:

> We had a lady in post that used to do it (advise staff and residents on low-energy homes) all the time. She was the energy whatever, she left in March so she went with all the knowledge. (Technical Services Manager)

The lack of systematic organisational learning clearly impacts on the evolution of ventilation practice, with each new scheme potentially repeating earlier mistakes. This was particularly surprising at one case-study that was the second of a series of three pilot schemes, testing new approaches to low-energy design. Even so, with each scheme being constructed by a different contractor, the learning from the first scheme had not been carried forward. This illustrates the impact on ventilation practice of the disconnection between housing practices (discussed in chapter 9), even where an association had set out to learn from a pilot project.

7.3.3 Disconnection or influence

The disconnection between practices was also reflected in maintenance practitioners' perception of their own position. While critical of designers and development teams for their lack of attention to the maintenance implications of ventilation technologies in new homes and failures of quality management on site, maintenance practitioners were also critical of residents' practice. It appeared that this maintenance practitioner in the focus group was frustrated not only by exclusion from the development process but also by residents' expectations:

> A lot of tenants don't want to hear that it's a lifestyle issue. They want to know what we are going to do about it not what they can do about it. (Tenant Services Manager)

This is not consistent with the powerful position of 'middle actors' able to influence change in different directions, described by Janda & Parag (2013). Nevertheless, some maintenance practitioners did exhibit the potential of ‘middle actors’ to ‘disable, rather than enable, carbon reduction targets in the built environment’ (Janda and Parag 2013: 43), given that they shared with residents a lack of engagement with carbon emission reduction as a ‘meaning’ and an underlying belief that windows are a more effective ‘thing’ than ventilation systems for providing fresh air.

7.3.4 Summary: the influence of ‘meanings’

The ‘meanings’ or beliefs of staff that underpin the bundle of practices shaping maintenance reveal the connections and disconnections between performers of these practices. Underlying these interrelationships appear to be conflicting perspectives on timescales, even though short-term and long-term factors influence the practice of both maintenance and development and practice throughout the dwelling’s life is critical for the effective ventilation of low-energy homes.

A shortage of the expertise required to design, install and maintain ventilation systems is evident in the case-study associations, compounded by an alarming lack of organisational learning. As a result, the integration of new ventilation technology into maintenance practice is hindered, with long-term effects on the effectiveness of ventilation in low-energy homes.

7.4 The influence of ‘rules’

7.4.1 Impact of service delivery rules

There is little evidence that the maintenance regimes specified by manufacturers of ventilation systems are followed, or even known about, in the case-study schemes, despite the risk of invalidating the warranty. One interviewee explained that mechanical ventilation systems are not included in routine service programmes as a ‘rule’:

> No-one’s ever costed them in. (Head of Electrical Compliance)

This maintenance manager added that planning for longer term maintenance of systems is, as a 'rule', driven by cost information in the Schedule of Rates (SoR) (see glossary) and hindered where this information is lacking:

> You've only got to look in the SoR books, there's very little codes for MVHR, because that shows you. So basically we're driven by this book, that's how we price everything. There's no replacing motors, there's no ducting, there's no nothing. (Head of Electrical Compliance)

Cost-effectiveness is a significant 'rule' of service delivery. One interviewee reported that this resulted in no planned preventative programme at his association as the risk of ventilation systems failing was deemed to be low:

> If overall the system is seen as a system that works, for a long time, with minimum maintenance, they will not spend money maintaining it, because it will not be cost effective. (Mechanical Engineer)

Cost-effectiveness rules for service delivery also exert pressure on timescales for investigating building problems, which can lead to failure to identify underlying ventilation issues. One focus group participant described the incompatibility of standardised survey times with typical ventilation-related problems. She contrasted the normal process of 'just sending an inspector to have a quick whizz round' with the need to spend time to understand the problem 'at a real dumbed down level' (Repairs & Maintenance Manager).

The impact on residents' health of ventilation systems failing or declining in performance due to lack of maintenance was not counted as a 'cost' and therefore did not drive maintenance practice. However, there was evidence that the regulatory and reputational risk of health-related complaints, and potential compensation costs, did exert an influence on maintenance rules, as one interviewee reflected:

> Some things are driven on cost aren't they, but then we had someone, there was a big claim and she suffered, it's only then you realise what the system can do. She was asthmatic and everything, then the expensive filters most probably would have helped and you just think, we've missed something there. (Head of Electrical Compliance)

It appears that any occurrence of mechanical ventilation failure that is perceived as a health and safety risk where legislation applies is given immediate priority. At one of the case-study schemes, faulty installation of an MVHR system led to water collecting in the ventilation ductwork. As one interviewee recounted:

> When that sub-contractor went out and said there was a potential Legionella risk, it was sort of like a bit of a knee-jerk reaction: 'We need to get these sorted straightaway'. (Senior Contracts Officer)

The financial, regulatory and reputational cost of failure to comply with health and safety legislation in respect of fire safety, gas, electrics, asbestos and Legionella, the 'Big Five' risk areas for landlords, is business-critical (Brierley 2018). Maintenance practice is influenced by these high-level risks to the business, making inspection, monitoring, servicing and record-keeping for these areas of risk a corporate priority.

Indeed, by comparison with other risk areas, which are tightly regulated, one maintenance practitioner considered whole-house ventilation systems to be a distraction:

> They're just like, a bit of a bugbear to be honest, for want of a better word. I mean there's a lot more riskier stuff we need to concentrate on, like gas servicing or fire risk assessments and stuff like that. It's taking our mind off that. (Senior Contracts Officer)

In one case described, the staff interviewee recognised that the objective of achieving tenant satisfaction, as a 'rule' of service delivery, depended on effective ventilation and justified investment:

> We put in an additional extractor in the bathroom, again to increase the extraction because it didn't seem to be adequate…But by putting that extra ventilation it cured the problem. We had a couple of very unhappy tenants and we turned that round into happy tenants. (Head of Asset Operations)

It appears, however, that typical service delivery rules in housing associations do not always take account of the impact of ineffective ventilation on residents. The short-term financial or time cost of ventilation maintenance appears, as a rule, to dominate practice, ignoring the cost to residents' health and comfort. The long-term costs to the business, in terms of regulatory and reputational risks, influences practice where legislation is in place, but not, it seems, in respect of ventilation maintenance practice as domestic air quality is not regulated by law.

7.4.2 Impact of changing external drivers

Ironically, it was not the experience of installing and maintaining mechanical ventilation systems, or internal drivers, that led some housing associations to reduce the standard of ventilation installations after 2015, but funding constraints and the abandonment of standards prescribed by funders as a change in 'rules'. The UK Government's Red Tape Challenge, launched in 2011, was intended to ease the burdens on business, including the house-building sector, by removing onerous regulation. Consequently, the Homes and Communities Agency (Homes England from 2018) Affordable Housing Programme 2015-18, announced in 2014, removed any requirement for new homes to exceed the Building Regulations standard. At that time, the Code for Sustainable Homes was being wound down, although it was still planned to mandate a zero-carbon housing standard by 2016. This plan was subsequently abandoned by the Government before being implemented.

As one interviewee explained:

> Because we've now put a moratorium on everything that we don't have to, so we're not putting any specialised kit in at the moment into our new properties, except in these situations where it's outside of our control. We decided all the constraints were removed from us in the bonfire of the red tape so, being R, what we decided was we would rather deliver more properties than higher quality properties.
> (Quality & Value Manager)

One interviewee was dismayed that the learning from a series of eco-homes, developed in-house, was being lost as the housing association's development strategy changed to acquiring properties through Section 106 (see glossary). Whereas in-house, grant-aided development enabled housing associations to specify higher environmental standards and build-in learning from previous schemes, reductions in grant funding, as a new ‘rule’, led to an increase in buying new homes, for letting at low rents, from private developers. This procurement route allowed little opportunity for the association to enhance the typical minimum environmental standard of market housing schemes.

One interviewee described his experience of this change in procurement in relation to mechanical ventilation:

> We’re just dipping our toe back in to s106. It’s a whole different world. It’s gobsmacking. Well yes because it’s really not improved a lot in the last decade, whereas actually in the high-performance sector people that are experts have developed a lot, the expertise has developed a lot, there’s a lot more robust solutions than there were…It hasn’t got through to the mainstream at all. (Development Director)

It appears that one consequence of the changing external rules for development in the last decade has been the reduction in environmental standards in housing association new-build schemes. Less airtight homes, without the need for whole-house ventilation, became acceptable, but the impact of this change was tempered where associations acted on the assumption that zero-carbon homes, requiring whole-house ventilation systems, would become mandatory in due course.

7.4.3 Design, specification and build

Regulatory or voluntary standards implemented as a ‘rule’ for low-energy homes can evidently influence ventilation provision in conflicting and unintended ways. The design of one scheme was reportedly driven by scoring points to achieve a certain level of the Code for Sustainable Homes (CfSH), not by an assessment of how to achieve optimum ventilation. As one interviewee explained:

> That might have been good enough to get the points we needed. They may have got more points elsewhere and therefore they didn’t need an MVHR unit. (Development Project Manager)

A similar concern was expressed by one interviewee regarding the impact of trying to achieve high SAP (Standard Assessment Procedure) ratings (see glossary) at the design stage through gaming the SAP system. Zoned heating in a small bungalow worked against the MVHR installed but was included in the design as:

> A quick way of getting 3% on your SAP calc. (Quality & Value Manager)

One of the case-study associations had taken the strategic decision to 'always go one level higher' than the minimum level of the CfSH required by the Homes and Communities Agency as a condition of grant funding:

> So that we were actually slightly better off as far as the performance and the build quality of the scheme. (Development Project Manager)

However, it appears that having set the standard required, the development team allows the designers to select products that will deliver that standard, without further input from the association. Input from maintenance personnel at the housing association, which could alert them to the maintenance implications of products used previously, appeared to be non-existent at the case-study associations. One interviewee confirmed that his maintenance team had no involvement at the development stage, adding:

> That's where it fell apart. (Head of Electrical Compliance)

Given that significant defects in whole-house ventilation systems were discovered post-handover at all four of the case-study schemes where these systems were installed, it appears that inadequate inspections on site and at handover are typical:

> Proper quality inspection and quality check on the client side, unusual, very unusual. (Development Manager)

More usual than engaging specialist M&E consultants to provide quality assurance, was reliance by the housing association on architect's certificates, oversight and sign-off by a Clerk of Works, commissioning certificates for mechanical ventilation installations provided by the installers, or compliance with specified standards, such as CfSH, assessed by registered Code Assessors. It is evident that, in the case-study schemes, none of these checks guaranteed fault-free installation of mechanical ventilation systems.

Time and cost constraints placed on sub-contractors as ‘rules’, as well as the management of building contracts, were identified as a hidden part of the bundled practices influencing ventilation, with one interviewee pointing to the correct sequencing of work on site as a key factor in avoiding ventilation installation faults:

> Something left-field, something no-one had thought of, was the installation sequence. (Quality & Value Manager)

7.4.4 Handover and communication

Communicating the ‘rules’, in other words ‘how this should be done’, regarding the maintenance of ventilation systems in low-energy homes, is evidently a common dilemma. One interviewee described maintenance errors resulting from lack of information:

> How do you let them (maintenance practitioners) know that this is not a standard property? And we haven’t cracked that nut. (Quality & Value Manager)

The importance of embedding changes in practice, and the consequences of failing to do this, were highlighted by one interviewee:

> The bit we’d forgotten, or overlooked, was the filter changing and getting it built into our systems so that we would automatically go out and change the filters. Unless you’ve got your IT system to help you with maintenance and servicing, and it was quite unusual to have that sort of feature built into your servicing schedules, but that’s what we did in the end, and it has worked. But we’d caused the problem before we realised what we needed to do. Damp and mould. (Head of Asset Operations)

It was not surprising that the maintenance team was unprepared to take responsibility for the ventilation systems at one association, given that they had not had any input during the development stage or at handover:

> Before Practical Completion demonstration sessions are always good practice and the maintenance hardly ever turned up, so in that effect there was actually no such handover. It became then the Health & Safety files, but it was a flawed process. (Development Manager)

As another interviewee explained:

> What you'd get in the Health & Safety file was literally just the manufacturer's leaflet, which actually doesn't tell you anything and it's only when you've got drips in the roofspace and mould coming and thinking what's happening here, that you actually go and dig out the ventilation guidance and realise that things do need changing, filters and stuff like that. (Head of Asset Operations)

Communicating the 'rules' of ventilation in a new home to residents appeared to be equally problematic. A Home User Guide (HUG) (see glossary) is usually provided by housing associations to new tenants, incorporating handover documentation and guidance on means of ventilation. However, the quality of the case-study scheme HUGs varied considerably and few provided the essential information in a user-friendly format (see section 6.5.2).

It was evident that not all new tenants in the case-study schemes had received a HUG, in particular those who moved in after re-lets or mutual exchanges. One staff interviewee, responsible for signing-up new tenants, could not locate a HUG for the scheme in the association's files, although a resident had shown this document to the researcher:

> Right ok, that's interesting. There is one then, floating about. The last three sign-ups won't have had that pack, unless it's been left at the property. That's a possibility, but I've not seen one. (Housing Officer)

It appeared that lines of communication had been broken by frequent internal reorganisations at this association, a common experience in the current housing association sector as associations seek to improve cost-effectiveness. One interviewee explained how restructuring, as a new 'rule', impacted on the induction process for new tenants, leading to vital information about ventilation being omitted from handover packs:

> We've changed, we've just had a big re-structure and there's that gets done in that office, and that gets done by that team, and that gets done by this team, so there's a lot, it's not one person now that deals with it all from start to finish, so there might be a little bit of breakdown of communication. (Compliance Coordinator)

This interviewee was frustrated that essential details about ventilation were often lost in a plethora of information handed to a new tenant:

> When I say they sign-up and they do get information overload, they get all the information that they can possibly need, that could ever happen while they're in the tenancy. (Compliance Coordinator)

In one case-study, the initial residents at a new scheme received one-to-one induction sessions on the day they signed the tenancy agreement, in order to 'get them right at the beginning, saying don't touch that, you don't need to touch that, this is all you're concerned about' (Area Housing Manager). However, it is arguable whether inductions about ventilation systems at that point are effective (Menon and Foster 2017), when 'they just want the keys and they want to go to the property and move their couch in and stuff' (Compliance Coordinator). However, later inductions may mean 'they've tried to work the system themselves, fiddled, pressed buttons, and that's when things start to go wrong' (Area Housing Manager). It is also evident that subsequent residents at the case-study schemes, after re-lets or mutual exchanges, received no such induction, irrespective of timing.

Even where associations carry out Starter Tenancy (see glossary) visits during the first year, before confirming an Assured Tenancy (see glossary), these are invariably conducted by housing management staff, with the emphasis on how the tenancy is being conducted, as a 'rule'. It appears that at the case-study schemes these visits do not include any technical information about the property or checks on ventilation performance.

The typical lack of involvement of maintenance or housing management staff at the handover of new homes, and failure to communicate to these staff the requirements of unfamiliar means of ventilation, evidently contributed both to inadequate maintenance of ventilation and to failure to communicate to residents how to operate the ventilation equipment in their new home. As interviews with residents illustrated, first encounters with ventilation equipment were critical in influencing subsequent ventilation practice, thus rules on information and guidance at the start of a tenancy have long-term consequences for air quality in the home.

7.4.5 Feedback rules

The accounts of staff at the case-study schemes indicate that feedback of maintenance experience regarding ventilation systems in low-energy new homes is, at best, ad hoc, and, at worst, resisted by development teams as a 'rule' driving practice. Indeed, the input of maintenance teams to the briefing or specification for new schemes, or during the on-site stage, appears to be rare.

The knowledge of housing management staff is similarly overlooked at the development stage, with little or no feedback, as a 'rule', on the ventilation experience of homes in use. As one interviewee reflected, understanding the habits of prospective occupants could have avoided damaging air quality for this resident by greater support at the start of the tenancy:

> She kept one room warm, not uncommon, and that's probably the naivety of us. We were focused on the technical, so she had a calor-gas heater in her living room. They produce a huge amount of moisture, in a highly airtight property the worst thing you can do. (Quality & Value Manager)

Although housing association low-energy schemes have been the subject of numerous research projects on performance in-use (Sharpe et al. 2016; Pretlove and Kade 2016; Macintosh and Steemers 2005; Innovate UK 2014), systematic post-occupancy evaluation of completed schemes is not a standard element in the development process for all associations.

One of the housing associations in the research had undertaken two ad hoc in-depth post-occupancy evaluations of the case-study schemes, at approximately two years and five years after handover. However, it appears that the learning from this exercise had not been embedded in the association's processes or corporate knowledge. As one interviewee, responsible for explaining the heating and ventilation system to new tenants at that scheme reported:

> No, I've had no training on that whatsoever, because (the scheme) was developed quite some time ago, and way before I was with (the housing association), so no information has been passed. (Senior Housing Officer)

Despite this lack of integrated learning, the case-study associations were aware of the direction of travel towards zero carbon emissions and the need for feedback from pilot schemes, as expressed by this interviewee:

> We've got to start giving it some thought, even if we don't do anything about it we've got to start giving it some thought. Be ready for it, it's coming, it's not going to go away. (Quality & Value Manager)

Learning from the experience of maintaining, managing and living in low-energy homes does not appear to be embedded in the practice of housing associations as a 'rule', increasing the risk that ineffective ventilation will be ignored and perpetuated in future schemes.

7.4.6 Summary: the influence of 'rules'

The impact on ventilation practice of 'rules' imposed on housing associations by external bodies, and the comparative impact of internally determined 'rules', is evident in the interview data. The availability of grant funding and the funder's 'rules' are principal determinants of build standards, reflecting the Government's variable priorities for the sector. It appears though that some of the learning about airtightness and ventilation from associations' experience of higher standard schemes may have been lost when the 'rules' were relaxed.

The absence of legislation in England mandating indoor air quality standards in homes, despite the evidence of potential consequences for health of polluted air, resulted in indoor air quality not being a major concern for most maintenance practitioners in the case-studies. It appears that concern about ventilation is typically triggered by complaints by residents about damp, condensation and mould, rather than by concerns about air quality.

It is evident in the case-studies that the association's own processes or internal rules exert a crucial influence on ventilation practice, potentially compromising the design intention and reducing the effectiveness of ventilation in new homes.

The stage of handing over new homes from the contractor to the housing association, when building is complete, should trigger the essential process of inducting the maintenance team in the ventilation strategy and equipment installed in the homes. However, it appears that the internal rules set for this critical process were inadequate in all the case-study schemes, and indeed non-existent in some cases. The failure of this internal process is evidently a key factor in the failure to establish maintenance habits that are consistent with the technology installed, which may be unfamiliar to the maintenance team.

The induction of prospective residents to the ventilation features of their new low-energy homes appears to be equally inadequate in some cases, missing the crucial 'time-window' of residents' first encounter with unfamiliar technology. Regardless of timing, guidance that may seem counter-intuitive, given residents' know-how of ventilating older, draughtier homes. The long-term influence on ventilation practice of inadequate handover 'rules' was apparent in the responses both of staff and residents interviewed.

Dissemination within the housing association of experiential knowledge of ventilation systems in use, from both maintenance practitioners and residents, was mostly absent in the case-study associations. Although individual instances of failure may prompt wider action across an association, there was no evidence of systematic feedback loops in any of the associations. Even where post-occupancy evaluations had been carried out, it was unclear how, or whether, the learning from these exercises had been embedded in development or maintenance practice.

Moreover, none of the associations studied had internal rules that captured the knowledge of in-house maintenance and management teams, and the experience of residents, at the briefing and specification stages of new housing schemes.

7.5 The influence of 'things'

7.5.1 Design and build quality

As the imperative of reducing carbon emissions leads to highly airtight homes, with continuous mechanical ventilation becoming the norm, the practice of maintenance will encounter new 'things'. It is evident that in some cases these will be 'things' that have been badly designed, specified and installed, with a consequential effect on ventilation maintenance.

The impact of physical faults at the design and build stages, or in the installation of ventilation equipment, may only become apparent after occupation. One interviewee described the experience at a case-study scheme with MVHR:

> It turned out they'd put it all in back to front. It was a fundamental kind of wiring problem. So yes, we ended up with tenants in the first house with, running in condensation in a scheme that should have been really perfectly ventilated, in the summer. It didn't become apparent that the problem was there until they were living in it. (Development Director)

An example of installation faults at another scheme, with potentially more serious consequences for the health of residents, was described by this interviewee:

> There was excess ducting, they were just pushing it together or expanding it up and down in the loft just to use it, but when they were doing that they were creating wells and the condensation, the water, was gathering in them as well. (Head of Electrical Compliance)

It appeared that badly designed or installed ventilation systems frequently influenced ventilation maintenance practice, as one maintenance practitioner expressed, resignedly:

> The thing that starts from the ground up really is the fact that you make sure that it's built properly, because they're quite often not. (Maintenance Surveyor)

7.5.2 Windows

Evidence from the case-study interviews, both with staff and residents, indicates that windows are widely regarded as the ‘normal’ or ‘natural’ ventilation ‘things’, even where mechanical ventilation is installed offering fresh indoor air with minimum heat loss. While the maintenance of windows is a routine activity, homes built to an airtight, low-energy design may incorporate non-standard windows.

It appears from the case-studies that the influence of non-standard ‘things’ on ventilation practice may be significant, relative to both use and maintenance. Although rated highly for environmental sustainability, new high-performance timber windows proved to be problematic in use, for both residents and maintenance, in one case-study scheme:

> If the openings are so big, and the doors and windows that tilt and turn, sometimes it becomes quite difficult to operate and they’re not very user-friendly. We risk damaged windows, because it’s just the size of the windows and the doors is enormous. (Development Manager)

While large windows provide welcome natural light and solar heat gain, the size and weight of double- or triple-glazed windows, with mechanisms that are not habitual to users and require know-how and dexterity to operate, affect usability and influence ventilation practice (see resident perspective on windows in 6.5.5).

7.5.3 Continuous mechanical ventilation

Maintenance practitioners are evidently aware that new mechanical ventilation systems are not maintenance-free:

> The DriAir system that this one’s got, the positive pressure ones. Providing the filter’s clean on it it’ll work. If the filter’s dirty, then it won’t. (Maintenance Surveyor)

> If initially, when it was installed (MVHR unit), it is designed to do, like, say 90% heat recovery, with the dust and everything on the heat exchanger, that might reduce to 80% over time, 70%, because the heat exchange surface needs cleaning or dusting. (Mechanical Engineer)

> When you switch it off (MVHR unit), you have to actually take out the heat exchanger, get it dried and so on, in order to stop the mildew growth within the units. (Development Manager)

However, there is little evidence from the interviews with staff that this knowledge about a product installed is consistently followed through into action by the association's maintenance team. The manufacturers' maintenance instructions for the MVHR systems installed in two of the case-study schemes, checked on the manufacturers' websites by the researcher, did not appear to be followed at all.

For example, at one scheme, where no regular servicing was carried out, the manufacturer recommended changing filters every 12-18 months and inspecting the heat exchanger at 5-year intervals. At another, the MVHR inspection and maintenance schedule was extremely detailed, including changing the 'construction dust filter' after 3 months in use, replacing filters every 12-18 months, an annual noise check, and intervals for cleaning the ducts and motor. None of this work was carried out or planned, until a problem was reported, bringing to the attention of the maintenance team, for the first time, that the properties had MVHR installed.

A particular source of frustration for maintenance practitioners is difficulty obtaining spare parts for mechanical ventilation products, particularly those sourced from outside the UK. One interviewee, aiming to repair rather than replace ventilation equipment, felt that this practice was thwarted by the manufacturer in one case study scheme:

> Maintainability was a key thing. We wanted, we didn't want to get something that was hardly used and exotic and we wouldn't be able to get parts for. What did we find? Actually, VentAxia import them from Germany and they don't know what they're doing with them…S ended up getting a whole new unit put in because we couldn't just replace a little motor. That's pretty bad. (Development Director)

The staff interviews suggest that changing filters in mechanical ventilation systems in rented homes is regarded as problematic and not all the case-study associations carried out this essential task. Interviewees reported problems sourcing contractors willing to carry out this task, particularly where there were only a small number of relevant homes in the stock. One maintenance manager had taken matters into her own hands, taking advice direct from the manufacturer and then doing the task herself, being surprised to find:

> And how easy was it to change, even I could change it! (Head of Asset Operations)

Frustrated by the lack of contractors with the knowledge to service mechanical ventilation systems, several associations have trained maintenance staff in-house to undertake the servicing and change filters (see skills for ventilation maintenance in 7.2.5).

It appears that in some schemes, it is not lack of understanding of what maintenance is required, but lack of access to the ventilation unit and ductwork, that hinders maintenance:

> Basically, maintaining it should be easy if installed right, and basically the installation has never been right from day one. So when you're getting asked to go back and maintain a system, a lot of it, when it's in apartments, you can't get to the ducting once it's encased, you're snookered aren't you basically. (Head of Electrical Compliance)

This interviewee found, in one case, that it was not just the ductwork that was inaccessible but the MVHR unit itself:

> If you're going to box something in it's got to be accessible, you'd use the pop-studs, like you can screw in and take it away. It's totally enclosed and been skimmed up where it's sat, the full unit. So where the pipes come out, where the ducting comes out, he's enclosed all that, and that's where you've got to get to, for your motor speeds and stuff like that, so we couldn't get to it. (Head of Electrical Compliance)

Opinions on the ability of residents to carry out filter cleaning were evidently mixed, with one interviewee concluding:

> You could introduce that as a tenant's responsibility. It's just a simple thing isn't it, pulling the filters out, hoover them and put them back in. As a tenant responsibility it most probably wouldn't work but some people would do it. It depends on the person doesn't it. (Quality & Value Manager)

The assumption that residents will 'mess' with the mechanical ventilation equipment, thus causing or exacerbating the problems they experience, is evident in the response of one association that deliberately locates ventilation units in locked, inaccessible spaces, such as lofts, ironically hindering access for maintenance practitioners as well as for residents.

Awareness by the maintenance team of the presence of whole-house ventilation systems is no guarantee that the required servicing and regular filter changing will be implemented. Lack of knowledge of the maintenance requirements, shortage of skills, availability of spare parts and inaccessibility of the ventilation unit are all cited in the case-studies as barriers, resulting in the risk of inadequate maintenance and poor performance of systems. Although some residents take responsibility for cleaning filters, this is not typical practice and indeed discouraged by the location of the units in some schemes.

7.5.4 Noise

The incidence of noisy ventilation systems, and the inadequate response of landlords, illustrates how 'things' influence the practice of maintenance in conflicting ways. It is evident that noise is a significant issue for this interviewee:

> The only problems we ever have with this (MVHR system) is if they make a noise and that's when people tend to ring us up. (Technical Services Manager)

Many studies have confirmed that the noise of mechanical ventilation systems in use is one reason why systems are not always used as intended (Baborska-Narozny and Stevenson 2016; Sharpe et al. 2016; McGill, Oyedele, and McAllister 2015). While sensitivity to noise is affected by its frequency and sound level, the level of background noise and the timing of the noise also affect its impact (Harvie-Clark et al. 2019).

The noise from domestic building services is not regulated in the UK (see glossary), although there is guidance in Approved Document F (Department for Communities and Local Government 2015). However, there is evidence of poor design, installation and commissioning of MVHR systems (NHBC 2017) which could lead to noise levels exceeding this guidance at handover.

A former maintenance manager at one association had, in the past, attempted to 'normalise' their MVHR noise issue, resisting any change in practice:

> D seemed to think it wasn't an issue if the unit became very loud, it was just all part of MVHR, the resident had to live with it. (Development Manager)

Another was inclined to hold residents responsible for causing the noise, as a result of:

> Not understanding the fact that when they were cleaning it (MVHR extract vent in wall/ceiling), that they have actually unintentionally closed the valve, which has increased the velocity but in a small space to come out and that has created the noise. (Mechanical Engineer)

An interviewee at another scheme concurred with this approach:

> We've balanced the system on that date and you go back and suddenly it's shut off and you know that then the customer is messing with the system. I think that's a design fault. I think it should be accessible with a lock-nut, where when you balance it you can lock-nut it off, and that's it. (Head of Electrical Compliance)

However, an experienced Development Manager explained that a higher specification for MVHR units to reduce noise will result in a better outcome for ventilation:

> It definitely pays back that residents would accept them better. You haven't got a noise issue. And you overall achieve a better ventilation strategy with this, that's the main thing. (Development Manager)

Ongoing performance depends, critically, on appropriate maintenance of the system and it is evident that maintenance practice is both affected by, and affects, noisy ventilation 'things'.

7.5.5 Novelty and complexity

Maintenance problems appeared to be compounded when the systems installed were novel and subject to 'teething troubles', such as innovative heating and ventilation systems:

> They were sold as the best thing, but they weren't. (Maintenance Surveyor)

Given the increasing complexity of 'things' related to ventilation systems, there is a reaction in some housing associations to seek simpler, non-mechanical solutions to effectively ventilate low-energy homes. One interviewee was pleased to describe the simplicity of her case-study scheme:

> They haven't got any fancy ventilation schemes in them. We did all the air-tests and everything, but there's no sort of filters and things like that to be looking at and monitoring and changing and stuff like that. (Head of Asset Operations)

By contrast, another maintenance interviewee referred to the 'nightmare' complexity of one scheme as:

> Too much, too complicated, nobody understands it and it's not a good thing that we've done. We've probably tried to over-complicate it. (Technical Services Manager)

Moreover, the level of complexity reached by mechanical ventilation in some schemes seemed to be beyond maintenance staff understanding, as one maintenance interviewee reflected:

> I think we got more complex as we went on…The last one is a nightmare…If you send a normal heating engineer they don't understand it, sent specialists but they didn't really understand it either. (Technical Services Manager)

Despite the challenge to maintenance practitioners, and residents, of over-complex, untested technology, one interviewee took the view that:

> You've got to have active ventilation in any approaching-airtight house or it's going to be a problem. (Development Manager)

Another maintenance practitioner, accepting that mechanical ventilation will become increasingly necessary, confirmed that his preference was for MVHR:

> I'd go with MVHR, properly installed. It's good. You've only got to go on YouTube. There's some cracking units out there. (Head of Electrical Compliance)

These interviewees were expressing the belief that passive means of ventilation would not provide adequate air flow in a highly airtight dwelling, thereby compromising air quality, although this view is contested (Sassi 2013; de Selincourt 2014). Given that healthy air quality is critical, as well as minimising heat loss, continuous mechanical ventilation was apparently accepted as an inevitable 'thing' that maintenance practice will need to accommodate, although the complexity of products was clearly a challenge to practitioners.

7.5.6 Summary: the influence of 'things'

The influence of ventilation 'things' on maintenance practice highlights the bundled nature of ventilation practices. The evidence shows that the maintenance, and indeed the operation, of means of ventilation is closely bound up with the design, specification, building and installation of services in new homes. In highly airtight, low-energy homes, dependent on whole-house ventilation systems, these practices are thus critical to the performance of homes, in energy use and related carbon emissions, as well as in the quality of indoor air.

Windows designed to be highly airtight, particularly those manufactured for the mainland European market, may be operated in ways that are unfamiliar to English householders. Experience of maintenance practitioners in the case-studies, reinforced by reported resident dislike of these 'continental' windows, has hindered the incorporation of high-performance windows of this type into ventilation practice, and indeed strengthened the habitual preference of maintenance practitioners for standard products.

The briefs for the case-study schemes, as described by interviewees and, where available, examined by the researcher, included 'ease of maintenance', 'low maintenance' or a similar objective. However, there is no evidence that the maintenance requirements, or costs, of the ventilation 'things' installed were identified at the development stage or discussed with maintenance teams. The location of MVHR units in two of the schemes had clearly not considered 'ease of maintenance', resulting in awkward and unsafe access to equipment for the necessary regular filter changes.

The regular cleaning or replacement of filters in mechanical ventilation systems, without which performance will decline and noise will increase, generated widely varying practice in the case-study housing associations. It appeared that some maintenance practitioners did not understand the implications of the filters becoming clogged, and the link between declining performance of the system, air quality and residents' health, until a particular incident or serious complaint raised the profile of ventilation within the association.

There was ambivalence too in relation to residents' responsibility for changing filters. In this respect, maintenance practice was influenced not only by the physical 'things' involved, but by attitudes towards the competence and reliability of residents in carrying out this task. This contrasts with the attitude of some residents that the housing association is, indeed, incompetent and unreliable in carrying out the task. This mutual lack of confidence was evidently not a sound basis for building good communication between residents and maintenance practitioners in the case-study schemes.

The long-term consequence of lack of engagement with ventilation 'things' by maintenance practitioners or residents may be that homes designed to be airtight, reliant on continuous mechanical ventilation, cease to perform as intended. This risk was expressed succinctly by one interviewee:

> It's a danger it just becomes a normal house, with a few bits of kit in it that no-one really knows what they do. (Technical Services Manager)

7.6 Sub-conclusion

The findings in this chapter indicate that maintenance practitioners at the case-study schemes typically feel frustration, and a sense of powerlessness, when faced with responsibility for maintaining the ventilation systems in low-energy rented homes. Habits, meanings, rules and things interweave to shape the performance of complex and bundled maintenance practices and, through repeated performances, to re-shape the practice itself.

Maintaining effective ventilation in their rented homes is vital to housing associations in three respects: it represents a principal service to residents under the ‘rules’ of the tenancy agreement, impacting on residents’ health, safety and comfort; it has an impact on the association’s maintenance budget; and it is a factor in homes continuing to meet the needs of occupants, thereby generating rental income. However, in the case-study associations, **the importance of effective ventilation for healthy indoor air, and the impact of maintenance practice on ventilation ‘things’ in low-energy homes, appeared to be undervalued or underestimated** by the associations, leading to frustration for maintenance practitioners.

As a consequence, **the involvement of maintenance practitioners in the briefing or specification for new schemes was not typically part of development practice**. Although the design and specification of new homes reflected a future target for zero carbon emissions, future maintenance implications were not considered, even though the *continuous* responsibility for maintenance is significantly impacted by decisions made at the *time-limited* development stage.

It appears that performance standards for the ventilation systems installed in the case-study schemes were not specified as a ‘rule’ and performance in use was not routinely monitored. **Although ‘ease of maintenance’ was generally specified in the brief for new schemes there was no evidence that this ‘rule’ meaningfully influenced design, build or installation practice**, exacerbated by the absence of maintenance input at the development stage.

The ‘rules’ of the handover process are material in establishing maintenance arrangements and habits consistent with the ventilation equipment in new homes. However**, the practice of handover to maintenance was wholly inadequate in most of the case-study schemes**, resulting in maintenance practitioners having inadequate understanding of the ventilation systems and the maintenance regime required. Weak connections between maintenance practices and development practices at this point increased the risk that new maintenance habits were not established, resulting in declining performance and loss of confidence in the systems by residents.

The variety of ventilation technologies that are specified in airtight new homes conflicted with **maintenance practitioners' habit of using standard tried-and-tested products, even if these did not optimise ventilation in low-energy homes**. It appears that maintenance practitioners were supported in resisting new ventilation 'things' by the knowledge that residents similarly preferred familiar means of ventilation, consistent with their own established habits. It is arguable that this alignment of habits can obstruct the incorporation of whole-house ventilation into practices, despite its benefits in low-energy homes, but is not recognised and thus not addressed.

It appears that **maintenance practitioners relied on their habits of ventilating their own homes to advise residents**, even though that know-how might not be appropriate for the airtight, low-energy housing association homes they maintained. By contrast, it appears that maintenance practitioners did not always reflect their everyday know-how in other 'rules' that they issued to residents, for example continuing to instruct residents to dry laundry outdoors, advice which was roundly rejected by some residents as lacking in common sense.

However, encountering new ventilation 'things' in airtight homes that required continuous mechanical ventilation, the habits of both maintenance practitioners and residents are challenged, as the effective performance of these systems requires different habits and imposes new rules. It appears that **maintenance practitioners' habits in the case-study schemes were resistant to change, underpinned by the belief that residents' habits were responsible for negative consequences of ineffective ventilation.** It is suggested that this reveals underlying conflict between technical expertise and experiential know-how. Maintenance practitioners' belief that their *technical knowledge* of ventilation (whether or not that knowledge is accurate) is more relevant to the practice of ventilation than residents' *experiential knowledge*, is a 'meaning' strongly contested by some residents (see section 6.6).

It is clear from the case-studies that ventilation maintenance practices, rooted in deeply-held meanings and long-established habits, do not readily evolve to accommodate new ventilation 'things' and 'rules', exacerbated by the sense of frustration among maintenance practitioners that maintenance is an afterthought rather than a key practice. In chapters 8 and 9, themes identified in the analysis in chapters 6 and 7 are discussed and developed, offering conceptual and real-world insights on ventilation practice.

Chapter 8. Discussion – A concept of Time Horizons

8.1 Introduction

In this chapter, the concept of Time Horizons is introduced, defined and discussed. This is a practice-related notion, identified in the data, that appears to be sufficiently distinct and significant to warrant exploration. It is suggested that this concept of time has the potential to contribute theoretically and practically to the current understanding of ventilation maintenance practice in the UK social housing sector.

State-of-the-art literature exploring concepts of time, and the relationship between time and Practice Theory, is first reviewed. A new concept - Time Horizons - is then drawn out from the data, with reference to the literature on time and practice. The influence of three conceptual Time Horizons on ventilation practice, in the experience of residents and maintenance practitioners, is discussed, supported by the previous analysis in chapters 6 and 7. The influence of diverse Time Horizons on practice is considered and the interaction between bundled practices is then explored with reference to Time Horizons.

This study uses the particular approach to Practice Theory described by Gram-Hanssen (2009) as the framework for analysis (see chapter 2). First-order coding is applied inductively for initial analysis in chapters 6 and 7 (see analysis methods in 4.5). This is followed by second-order analysis in this chapter, iterating back and forth abductively between the data and literature to reveal emergent themes. A further dimension to practices and Practice Theory is suggested in this chapter, applied in chapter 9 to an understanding of ventilation maintenance as performed in housing association dwellings.

8.2 Time and Practice Theory

Philosophers have continuously grappled with understanding the nature of time. Considering the current era, the late 19th century philosopher Henri Bergson theorised that there were two kinds of time that he called 'spatialised' time, meaning clock or calendar time, and 'duration', the flow of lived time (Blue, Greene, and Morosanu 2014: 25). Others have referred to these categories as A-series and B-series time (McTaggart 1908), event time and abstract time (Adam 1994), fungible time and epochal time (Bluedorn 2002), and more recently Snyder has distinguished between timescapes and time maps:

> Timescapes structure the rhythm and flow of organizational events, while time maps structure the ordering of those events 'in' time (Snyder 2019: 650).

In relation to Practice Theory, Shove (2009) suggests that 'practices *make* time' (Shove, Trentmann, and Wilk 2009: 17), meaning that while practices happen in 'objective' time, they simultaneously create a 'subjective' experience of time. Shove even fantasizes about complex tools to represent 'practice-timescapes', such as an imaginary 'Societal Synchronization Index' and 'Chart-Atlas of Contemporary Practice', indices that she herself describes as 'the stuff of future fiction' (Shove, Trentmann, and Wilk 2009: 30).

Shove (2012) expands the concept of time in relation to practice, describing four timeframes: clock time and time duration, temporal rhythms and scheduling, the durability or life of a practice, and the 'temporal sequence…born of the practice itself' (Shove 2012: 129). Nevertheless, it appears that the underlying duality of time in Shove's theory essentially mirrors the work of Bergson. Schatzki too has built on Bergson's definition, linking practices as entities to spatialised time and equating the performance of practices with the duration of time (Schatzki 2013).

Many social practice-based researchers engage with the influence of time on practices (Gram-Hanssen et al. 2019; Spurling 2018; Walker 2014; Blue, Greene, and Morosanu 2014). The work of Spurling (2018), in the field of energy consumption and practice, is of particular relevance to this research, given that Gram-Hanssen's definition of a practice, used as the analytic framework in the current study, includes material things as a component of practices (see influence of material things in resident practice in 6.5 and in maintenance practitioner practice in 7.5). Spurling draws 'temporality and materiality of practice into the same frame' (Spurling 2018: 13), challenging the static concept of time in the seminal sociological work of Zerubavel (1985). She concludes that:

> Materiality has a distinctive role in the temporal stitching of social practices, and that social practices influence the timing of material consumption and usage. (Spurling 2018: 15)

However, Spurling's concept of time and timing does not challenge the assumption in practice-based studies that:

> We organize time, it does not organize us. (Holt and Johnsen 2019: 1)

Holt and Johnsen, by contrast, writing in the field of time and organization studies, suggest the concept of 'time-beyond-us' (Holt and Johnsen 2019: 2), challenging 'the ascendancy of organized time' (ibid.: 13). They assert that clock-time is the most dominant version of time but imply that there are other versions 'woven into and embodied in human practice' (ibid.: 5). In section 8.3 another version of time 'embodied in human practice' is proposed.

8.3 Time Horizons

8.3.1 Defining the concept

Time Horizons, as theorised here from the researcher's interpretation of the data, are neither clock time nor time duration, but an individual and collective awareness of future, past or present experiences or expectations that plays a part in the life of practices. Holt and Johnsen's concept of 'time-beyond-us' (Holt and Johnsen 2019: 2) appears to be closer to the notion of Time Horizons introduced in this chapter in relation to ventilation practice; not the binary division of time theorised by Bergson, Schatzki and Shove, described in 8.2, but instead defined as a continuous, shifting awareness of knowledge, understanding and desires, extending backwards and forwards through time, that influences the performance of practices. It is suggested that the influence on practices named here as Time Horizons is a cognitive process, at a level 'beyond' the awareness of events through the physical senses.

The term 'Time Horizon' is given to this concept to indicate influences on practice that are within the limits of our cognitive knowledge but beyond the timeframe of definable habits, meanings, rules and things that shape practices. It is suggested that these influences include ‘group knowledge’ or ‘common knowledge’ but that these are not simply a constraining influence, as implied in the social science literature on social norms (Bicchieri, Muldoon, and Sontuoso 2018: 1).

Time Horizons are thus distinct from clock time, defined as ‘a point of time as measured in hours or minutes past midnight or noon’, or time duration, defined as ‘a moment or definite portion of time allotted, used, or suitable for a purpose’ (Lexico 2020: 1), although these are of course relevant to how practices are performed and evolve. Instead, Time Horizons are encapsulated in the dictionary definition of time as ‘the indefinite continued progress of existence and events in the past, present, and future regarded as a whole’ (ibid.: 1).

In discussing time in relation to practices, Shove asserts that:

> Space and time are not elements equivalent to those of materiality, meaning and competence. (Shove 2012: 134)

‘Materiality, meaning and competence’ are defined by Shove as the key components of a practice. However, she contends that time and space:

> Act like elements in that they constitute media of aggregation and storage, holding the traces of past practice in ways that are relevant for the future. (ibid.: 134)

It is proposed here that Time Horizons, as defined above, are more than ‘traces of past practice’ and exert a more significant role on the performance of practices than Shove suggests, as discussed in the following sections.

8.3.2 Three conceptual Time Horizons

While it is not suggested that Time Horizons are equivalent in theoretical status to the four components described by Gram-Hanssen (2009), Time Horizons influence each of these components in multiple and diverse ways. Although time, in this context, is regarded as continuous, in order to discuss the concept three Time Horizons influencing performance of a practice are described, relating to the past, present or future, as indicated in figure 29.

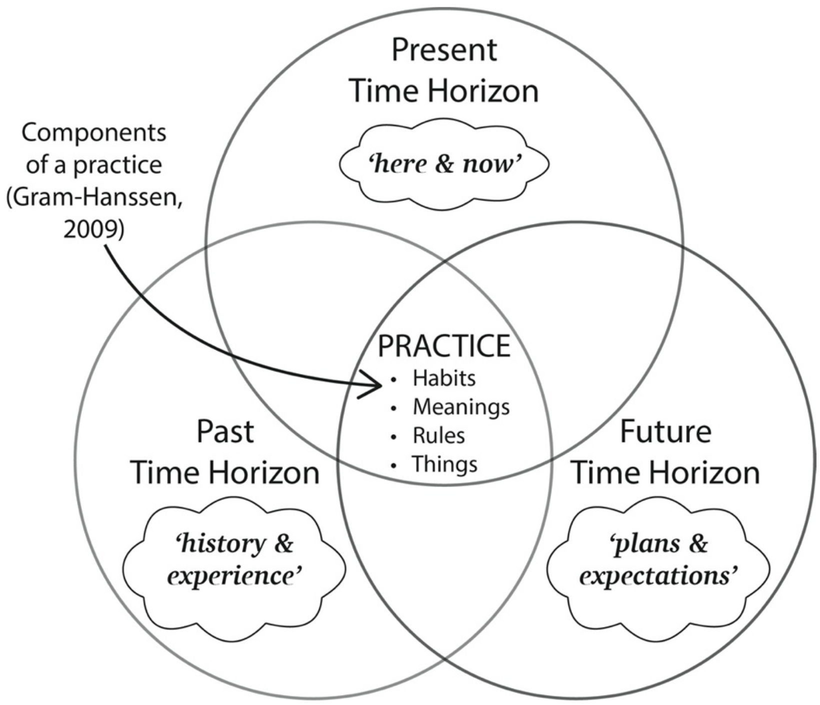


Figure 29. Time Horizons and Practice Theory components

Findings in this research suggest, for example, that the influence of childhood experiences of home ventilation (see 8.4.1) persist in habits over an individual's lifetime, reflecting research findings of 'sticky' practices in energy consumption (Hansen 2018) and the influence of 'practice memories' on sustainable practice (Royston, Daly, and Foulds 2014). It is suggested, from the evidence, that a past Time Horizon, reflecting understanding about fresh air from collective history and experience, beyond individual lived experience, can also influence ventilation practice.

The influence of a Time Horizon on performance of a practice will differ according to the 'meaning' of the practice for an individual. For example, in relation to ventilation practice, a future Time Horizon, such as common knowledge of the damaging effect of carbon emissions on the climate, could interact with a 'meaning' that adapting to change is positive, prompting a change to more environment-friendly practice for that individual. But if the dominant 'meaning' for an individual is that the climate is out of control whatever they do then a future Time Horizon may lead their practice to become more reckless - why bother, turn up the heat if you are cold, even if the windows are open! Alternatively, a practice may be reinforced where Time Horizons influence the practice in a similar way for different performers, such as the adoption or rejection of innovative ventilation technology both by residents and maintenance practitioners (see 8.7.2). It is suggested that Time Horizons offer an extra layer of analysis of practices, explored in this chapter in relation to ventilation practice.

In sections 8.4 to 8.6, the influences of past, present and future Time Horizons on ventilation maintenance practice are firstly explored separately, in order to understand how different Time Horizons may influence practice.

Although staff interviewed in the case-studies occupied a variety of roles (see table 24), references to staff in sections 8.4 to 8.6 are to maintenance practitioners, being the staff most directly involved in the maintenance of ventilation and interacting with residents in this practice.

8.4 A past Time Horizon

It is evident in the interview data that historic experience of home ventilation, both for residents and maintenance practitioners, exerts an influence on how practices related to ventilation are performed in the present. While individual past experiences clearly contribute to habits and meanings that shape practices, it is suggested that a shared historic Time Horizon also shapes the collective practice.

8.4.1 Childhood homes, older homes and fresh air

Although interviewees' current low-energy new homes differ significantly from the draughty, poorly heated, childhood homes often described, their feelings about fresh air, and, in particular, a belief in the health benefits of a flow of air through the home from open windows, as illustrated in 6.3.1, appear to be rooted in early life experience:

> At Dad's we've got no heating anyway, we've got the old-fashioned Rayburn, so we never really suffered from damp or anything then and it was always well ventilated because there wasn't the heat there. I'm quite one for opening the windows and

> letting the breeze brush through, kind of, brush out the cobwebs. Because if you live in a house and it's so hot, all the germs and everything never gets aired out does it. HR2

The influence of a past Time Horizon, grounded in life experience of different homes and climates, giving rise to varied approaches to ventilation, comfort and health and differing cultural understandings of fresh air, contributes to the ambivalence shown by some residents towards the ventilation systems in their new homes:

> This is the first new-build I've had, with that sort of system (MVHR). I would prefer an old house, by miles, there's no two ways about it. They're built better. That system is the most stupid thing I think that's ever been invented. LR1

However, the belief that opening windows gets rid of 'all the germs', or that older houses are 'built better', does not always appear to be based on direct personal knowledge or experience but rooted in awareness emanating from a past Time Horizon.

Maintenance practitioners, similarly, have personal experience of living in different types of home to the ones they are maintaining, as highlighted in 7.2.2. Although the practice of maintaining ventilation in low-energy homes requires practitioners to understand and maintain the mechanical systems installed, there is evidence that their personal beliefs about fresh air and ventilation influence their performance of the practice.

In one case-study scheme, where residents were formally advised to leave their MVHR system switched on to run continuously, mixed messages were being given informally:

> In my visits and then the discussions with residents I often said 'Well there's natural ventilation, there's nothing wrong to naturally ventilate the units'. (Development Manager)

Although the influence of a past Time Horizon may be masked by the current requirements or 'rules' of a maintenance practitioner's role, it may emerge when engaging with residents who share their doubts about the systems installed and are similarly influenced by a historic Time Horizon (see 7.2.2). This shared *historic scepticism*, especially if unacknowledged, may indeed hinder the effectiveness of ventilation maintenance.

8.4.2 Laundry and cooking

A bundle of domestic practices influence, and are influenced by, ventilation in the home, as shown in chapter 6. Design rules applied to ventilation for highly airtight new homes, regarding practices such as laundry and cooking for example, may reflect a past Time Horizon, based on 'common knowledge' rather than personal experience, although there are inconsistencies in this respect, as the following two examples illustrate.

The practice of drying laundry has a substantial impact on ventilation requirements (Menon and Porteous 2011). However, the things typically provided for drying laundry in social housing do not reflect present-day household arrangements. A designer's assumption or 'rule' that laundry can be dried outdoors not only overlooks the reality of English weather but relates to an era when fewer women were employed outside the home and were expected to juggle hanging out the washing with rainy spells through the day, as highlighted in 6.2.2. One interviewee explained logically why she normally dried laundry around the house rather than outside:

> We do use it (outside washing line) on a Saturday when we're here, but I work and I don't get in until gone 7 normally of a night, and by then it's dark out there and you start getting the bugs out there, and it might have rained. LR4

The notion that present-day UK residents in flats are willing to use communal drying areas may also reflect a past Time Horizon influencing designers, resulting in unplanned indoor drying compromising ventilation. While shared drying facilities may be considered acceptable as a 'rule' in European countries with a longer tradition of flat dwelling, this practice has become less acceptable over time in the UK. As one resident in an upper flat elaborated:

> It is an issue for drying, because obviously we've got the shared garden. It's very rare that I'll actually dry anything outside. Like, I have to go down and use the (security) gates which is fine but I suppose if you're downstairs it's more convenient for you to go out the back door. I don't know, it just doesn't feel like my garden. RR4

On the other hand, current ventilation ‘things’ do not always meet the needs of traditional cooking practices, as indicated in 6.2.1. This suggests that a historic Time Horizon exerts less influence on designers in respect of cooking practice than in respect of laundry practice. One interviewee, whose wife cooked for their large household in the traditional style of their East African community, found that the typical kitchen extract fan installed was not powerful enough:

> It’s not very strong, so there’s a lot of yellow (on the kitchen ceiling), even though painted four times. Always painting it, because of oil cooking. Sometimes, when she’s cooking vegetables or making bread, sometimes the whole house is full of humidity. The whole accommodation gets all the smells. AR1

This problem is exacerbated by open-plan layouts and small kitchens without cooker hoods, typical of new housing association properties.

Maintaining effective ventilation in low-energy homes is evidently aggravated where the practices of designers, residents and maintenance practitioners are influenced not only by different personal experience but by past Time Horizons rooted in differing ‘common knowledge’, thus contradicting each other.

8.4.3 Knowledge, memory and forgetting

It was evident in some case-study schemes that there was neither individual nor organisational awareness of past events relevant to the ventilation of the homes, such as details of the ventilation ‘things’ installed and their maintenance history, as highlighted in 7.2.3.

While the tacit knowledge and experience of maintenance practitioners may be considered a valuable asset (Pathirage, Amaratunga, and Haigh 2008), habits may relate to ventilation things and rules pre-dating current highly airtight new homes with whole-house ventilation systems. It is apparent from the staff interviews (see 7.2.3) that reliance on ‘shared understandings, know-how and standards’ (Warde 2004: 5) to induct new performers of maintenance practice is not a dependable strategy for incorporating unfamiliar ventilation technology into the practice, where habits have been built up through repeated performance of the practice in older properties and the practice is influenced by a past Time Horizon that compounds this understanding.

Building an organisational record system or 'corporate memory' can mitigate the influence of a past Time Horizon that is not rooted in individual or collective awareness relevant to current ventilation systems. As one maintenance practitioner in the focus group commented:

> Responsive surveyors do tend to move around quite a lot, probably because it's not an easy job to do. So if you've got someone at least capturing data and putting it into one place you can then look at it…gives you a little bit more to work with, just flags something up you may otherwise ignore. (Stock Data Manager)

By contrast, the scenario described by de Holan et al. (2004) where 'information might be stored in the minds of employees as well as in disconnected, idiosyncratic "databases", such as bits of paper pinned on corkboards' (de Holan, Phillips, and Lawrence 2004: 5), is indeed typical of some housing association information management systems, in the experience of the researcher and as observed in interviews with staff in their offices. The influence of a past Time Horizon on ventilation practice in this scenario is unlikely to be offset by a 'corporate memory'.

Corporate forgetting of rules and know-how in the lettings process is evidently equally damaging to ventilation maintenance. In the absence of effective property data systems, accessible to and routinely used by lettings staff, awareness of ventilation systems in low-energy homes will not be established for either new residents or lettings staff. Ventilation practice from the outset of future new tenancies may then be overly influenced by a past Time Horizon and shaped by experience of practice in different types of home.

8.4.4 Landlords and tenants

The landlord-tenant relationship will be influenced by direct previous experiences of these roles, as well as shaped by underlying expectations of the relationship that may emanate from a past Time Horizon. A resident, for example, will be influenced by previous experience of the landlord's repairs service (see 6.4.4), and a maintenance practitioner will have observed residents' ventilation practices (see 7.2.1). In the case-studies these experiences appear to reinforce a resident's meaningful assessment of the usefulness of reporting a repair issue, or prejudgement by a maintenance practitioner of the cause of a problem:

> To be honest, there's thousands of things you could report to (housing association) but they, it's like praying for rain in the desert. There's no point. GR3

> When a surveyor is asked to go out and inspect a property because a tenant is complaining about condensation, damp, mould, there's an immediate assumption before they even leave the office that it's lifestyle…because a lot of the time it IS lifestyle. (Tenant Services Manager)

It is suggested that ventilation practice is also influenced by deep-rooted perceptions of the status of a tenant, as indicated by one tenant who reflected that she would take a different view of understanding the ventilation systems in the house if she was an owner (see 6.3.1). The influence of Time Horizons on the interaction between the bundled practices of landlords and tenants, and the impact on ventilation practice, is discussed further in section 8.7.2.

8.5 A present Time Horizon

It is clear from the data that the immediate demands and priorities of everyday reality influence the performance of ventilation practice, for both residents and maintenance practitioners. The evidence also suggests that an awareness of issues that are significant 'here and now', but beyond the experience of the individual, may influence practice, a notion described in this chapter as a 'present Time Horizon'. It is suggested that this awareness influences the practice of maintaining ventilation in significant, though sometimes unacknowledged, ways.

8.5.1 Start of a tenancy

The influence of immediate priorities related to the practice of letting homes may result in a focus on the speed of lettings in order to minimise void periods, which incur rent loss for the housing association (see 6.4.1). The lettings process typically specifies, as a ‘rule’, an induction for the incoming resident, explaining features of the property and their correct use, in order to minimise future calls for advice or repairs. However, lettings rules in some of the case-studies appear to prioritise speed of letting over averting future problems in occupation, resulting in only a cursory viewing of the property prior to signing the tenancy agreement, with little or no explanation of the ventilation things installed:

> I viewed the property on the Tuesday, so I came here, very briefly, five minutes, looked around, and he said do you want it and I said yes definitely, and he said right, come to my office tomorrow to get all the paperwork. So I went to (office), obviously done the sign-up and everything, got the keys, and that was it, done. I didn’t even know it (MVHR) was there until someone told me it was in the cupboard, so that’s why I didn’t really know what it was. LR2

However, the incoming resident may be equally influenced by immediate priorities, being anxious to sign the tenancy agreement and meet their pressing housing need, and, as a result, remains unaware that their new home has an unfamiliar ventilation system until they move into the property:

> Because we were fed up of the building where we were living, because it was a temporary house, so we were rushing just to change, regardless of the advantage or disadvantage that we would face. AR1

Developing an effective and appropriate ventilation practice is clearly not a priority for either party at that point, hindering early engagement with the ventilation system installed, leaving residents to continue with, and normalise, habitual practices that may be sub-optimal in an airtight, low-energy home. Although neither the lettings officer nor the incoming tenant may know that ventilation of the house requires the use of unfamiliar technology, the data suggests awareness that speed at the point of letting is unsatisfactory, that issues beyond individuals’ direct experience may be relevant to the practice of occupying the home. It is suggested that this can be interpreted as the influence of a present Time Horizon.

8.5.2 Residents' everyday priorities

A present Time Horizon influencing ventilation practice, beyond the influence of immediate experience, impacts on a bundle of domestic practices that interact with ventilation (see 6.2). Given the intangible nature of air quality, and general absence of domestic air quality monitoring, it is unsurprising that current thermal conditions in the home are typically expressed by residents as the primary measure of comfort (Nicol, Humphreys, and Roaf 2012) rather than air quality, albeit a critical outcome of ventilation. The exception, when air quality exerts an immediate influence on practice, rather than reflecting a present Time Horizon, is where a household member has a health condition affected by poor air quality.

However, it is evident that some practices reflecting concern about noise (see 6.3.4) or about energy bills (see 6.3.3) may unwittingly compromise effective ventilation, potentially leading to health risks linked to indoor air pollution. For example, a mechanical ventilation system with noisy fans, located close to bedrooms, is highly likely to be switched off to avoid disturbing sleep:

> I just thought it's a bit too noisy (MVHR) so that's why I haven't really carried on with it. It's in the cupboard upstairs, directly opposite his (the baby's) room, and he's a very light sleeper as it is. I was worried it was keeping him awake and disturbing him. LR2

Households in a precarious financial situation are evidently inclined to switch off all appliances considered non-essential, including ventilation systems:

> People can't afford to run things 24/7. GR4

The realities of family life evidently lead to ventilation practice for some residents that prioritises freedom of movement for children and pets over air quality and heat loss considerations:

> I've got the dogs, so I'm not being funny, the doors are always open and shut, and I have children, so they're always open and shut. Really it's just everyday life, it's doors and windows open in here, willy-nilly, all day long. HR2

It is suggested that ventilation practice is influenced not only by these everyday experiences but by an undefined awareness of air quality, an influence on the practice that is present but not directly acknowledged.

8.5.3 Maintenance practitioners' everyday priorities

Similarly, immediate priorities for maintenance practitioners, such as a housing association's target response times for repairs, appear to undermine the effective maintenance of ventilation systems. Regardless of the manufacturer's 'rules' for maintaining ventilation equipment, repairs practice may place the priority on quick solutions. It appears that this can mitigate against taking time to investigate and fix a reported problem related to ventilation equipment (see 7.4.1).

Indeed, maintenance practitioners appear particularly frustrated that lack of standardisation of systems, as a 'rule', and the complication of acquiring skills and holding spare parts for multiple systems, impedes their ability to meet service delivery targets (see 7.2.4).

However, one maintenance practitioner in the focus group acknowledged that standardising equipment to facilitate service delivery takes priority over selecting equipment that is optimal for each property and designing services to maintain a wider range of equipment (see 7.2.4). This argument suggests that prioritising immediate service delivery efficiency as a 'rule', is exerting a greater influence on ventilation maintenance practice than knowledge that the maintenance of effective ventilation in all the landlord's properties is required, awareness emanating from a present Time Horizon.

A housing association 'rule', made intentionally or by default, that the maintenance of ventilation systems is a responsive, rather than planned, practice, in effect determines that service delivery rules will be prioritised in the practice (see 7.4.1). It is suggested that this rule made by the housing association is therefore fundamental to the outcome and ignores the deeper awareness of a present Time Horizon. Indeed, this was questioned by one focus group participant:

> What triggers a response maintenance request? What causes this? How reliable is this as a predictor of unacceptable air quality or inadequate ventilation? (Maintenance Advisor)

8.6 A future Time Horizon

The influence on ventilation practice of assumptions about the future is evident in the data, reflecting the plans and expectations of residents and maintenance practitioners in the context of their knowledge and experience. It can be inferred from the data that awareness of underlying broader future projections also plays a part in shaping practice, beyond individuals' specific experience, described here as the influence of a future Time Horizon.

8.6.1 Long-term asset plans

Given that housing associations intend, generally, to be the long-term owners and managers of their rented housing stock, and therefore have an interest in maintaining the properties to ensure ongoing lettability and protect the asset value, adopting a whole-life view of costs and benefits as a 'rule' of maintenance practice might be expected. It is suggested that this 'rule' is only likely, however, when practice is influenced by a future Time Horizon, as demonstrated by the maintenance manager at one case-study housing association:

> There wasn't one here when I came (a long-term maintenance plan). I'm now working towards a 30-year proper, costed, but I'm not there yet. I'm used to working with everything, anything that needs doing to that building, in my view, should be in that budget and it always shocks me when I go places and they're not. (Technical Services Manager)

Although future climate projections are instrumental in the design of new low-energy homes, it appears that the future costs of ventilation maintenance are not always considered as a 'rule' at the development stage (see 7.3.1). Failure to include ventilation servicing costs in revenue forecasts for new schemes embeds an assumption that mechanical ventilation systems are ‘fit and forget’ technology. After handover, the servicing of the systems fitted may indeed then be ‘forgotten’, ignoring awareness of a future Time Horizon.

8.6.2 A cost-effective approach?

A future Time Horizon influencing the maintenance of ventilation systems is no guarantee, however, that the recommended regular maintenance regime will be adopted as a ‘rule’ and become habitual. An alternative ‘rule’, adopted by one case-study housing association, is that action will only be taken when the system fails, ignoring the manufacturer’s servicing guidance, regardless that this invalidates the warranty (see 7.4.1).

This ‘rule’, based on projections of equipment failure, is deemed to be cost-effective by the association, given that ventilation systems typically decline in performance gradually over time, with few failures. Moreover, this slow decline in performance may be imperceptible to the resident, thus not triggering repair requests. A future Time Horizon in this case is interacting with the characteristics of the systems (things) and with cost issues (rules) to influence the present practice of ventilation maintenance.

8.6.3 Health risks

However, the declining performance of mechanical ventilation systems in airtight homes is not without costs to residents. The long-term risks to health of poor air quality in homes is increasingly evidenced (RCP & RCPCH 2020), as examined in 3.5.1, leading to calls for greater regulation and public awareness raising. Rising expectations of residents regarding air quality in their homes, particularly as home air monitors become more affordable and available, suggest that the influence of a future Time Horizon on the ‘rules’ shaping ventilation maintenance practice may become more critical for housing associations, ahead of any regulatory changes. Travel in this direction has accelerated significantly since the advent of Covid-19 (see 10.4.1.2), which has arguably re-positioned domestic air quality from the influence of a future Time Horizon to a present Time Horizon.

Typical housing association practice, influenced by a present Time Horizon, of defending claims under housing fitness legislation of dampness and mould, evident in new highly airtight homes where ventilation is ineffective, is rooted in assumptions about residents' lifestyles (see 7.2.1). It is suggested that this defence will in future be unsuccessful where a housing association cannot evidence regular servicing and filter changes for mechanical ventilation systems, driving associations to reflect a future Time Horizon in their maintenance practice.

Indeed, one focus group participant was daunted by increasing claims relating to damp and condensation, potentially due to inadequate or badly maintained ventilation, especially following the introduction of the Homes (Fitness for Human Habitation) Act 2018 (Ministry of Housing Communities & Local Government 2019c):

> What we're facing in a lot of the big cities where we work is that the first notification that we have of damp or alleged damp or condensation is accompanied by a solicitor's letter. If you haven't got experience of the door-knockers brace yourself because it will be coming. Quite how we get ahead of the curve on that is a massive challenge. (Projects Manager)

It is suggested that taking a long-term planned approach to ventilation maintenance, influenced by a future Time Horizon, may not only be relevant to property condition, but may indeed become critical to mitigate the financial and reputational risk of claims for damage to health caused by poor indoor air quality (see 7.4.1). Heightened awareness of the need for ventilation in the light of the Covid-19 pandemic may significantly increase the pressure for change (see 10.4.1.2).

8.6.4 Household changes

Over the lifetime of a rented property, typically there will be numerous changes of occupant, with diverse demographic characteristics, patterns of use of the property, and expectations. Moreover, social, economic, and technical change over this time will inevitably affect the use of the property, spacially and temporally. In some cases, the changing needs of residents will be the impetus for physical alterations to the home (see

6.4.3). There is further evidence in the case-studies that changing household needs, interacting with residents' future plans and capacity to stay or move home, may impact on ventilation effectiveness in unintended ways. Adaptability of the property to meet future needs may be a feature of the design, but physical alterations may in practice compromise the performance of ventilation 'things'.

An interviewee at one case-study scheme occupied a one-bedroom home designed to be adapted by dividing the bedroom. The door and window positions facilitated this division but the ventilation system layout did not. After adding a room-divider the resident found that the ventilation was inadequate but this was not remedied:

> They were supposed to have come and put another one in for me (an additional vent). I asked at the beginning if they could come and put another one in so I had one both sides to take the air out. They said 'Oh yes, we can do that' but I never heard from them since. GR2

Physical adaptability in spatial design to accommodate unknown future patterns of use, a practice influenced by a future Time Horizon, may therefore be undermined by lack of attention to the ventilation system, both at the design stage and in the association's practice regarding alterations.

8.7 Crossing Time Horizons

Although conceptually this notion of time is continuous, three discrete Time Horizons are discussed in sections 8.4 to 8.6 in order to show more clearly how this concept influences ventilation practice. In this section, the influence of diverse Time Horizons on specific factors in ventilation practice for residents and maintenance practitioners is considered in 8.7.1. Observations are then made in 8.7.2 on the relevance of Time Horizons to the interaction between the bundled practices performed by these groups.

8.7.1 How diverse Time Horizons influence ventilation practice

The key influences on ventilation practice in low-energy rented homes have been distilled from the case-study, survey and focus group data, by an iterative process of reading and re-reading transcripts, checking back to the original recordings and fieldnotes where necessary to clarify emphasis and context. These key influences have been listed in tables 27 and 28, relating to residents and maintenance practitioners respectively. In both tables the key influences have been categorised with reference to three conceptual Time Horizons.

A single factor shaping ventilation practice has been selected for each group, as examples to illustrate the concept. Table 27 has been annotated to highlight health issues that shape ventilation practice for residents. In table 28, skills issues shaping practice for maintenance practitioners are highlighted.

8.7.1.1 Health and ventilation: an example from resident practice

Table 27 below takes health issues as an example to illustrate the influence of Time Horizons. The issue of health has been selected due to its significance for residents, recurring frequently in the data, from a range of participants across all the case-studies. However, alternative factors equally illustrate the concept. Diverse Time Horizons influence how ventilation technology, financial circumstances, or the landlord-tenant relationship, for example, shape ventilation practice for residents.

Table 27. Health and resident ventilation practice, illustrating the influence of Time Horizons

Ventilation practice in low-energy homes: Key influences of Time Horizons on resident practice		
Time Horizons		
Past horizon: History and experience	Present horizon: Here and now	Future horizon: Plans and expectations
Historic experience of home ventilation: childhood memories, previous homes of different types, cultural background, different climates	Comfort, draughts from vents/tricklevents	Protecting family health
Household practices and ventilation in previous homes: laundry, cooking, welfare of children, pet care, bathing, cleaning	Sleep, noise from fans at night, babies' daytime sleeping	IAQ awareness, home monitoring
Experience of living with innovative home technology	Steam and smells from cooking	Household budgeting, cutting energy use to reduce bills
Experience as tenant of this or other housing associations	Bathroom steam and smells	Climate change concern, cutting energy use to reduce carbon emissions
First encounter with new home and ventilation system	Drying laundry, weather, seasons, times of day	Adapting to low-energy home design and systems
	Children's health, window safety	Upskilling to control ventilation system, change filters
	Pet access, smells	Changing household size and needs, adapting house or moving
	Cleaning, dust	Adapting to, or resisting, socio/economic/technical/environmental change
	Flies, bugs, rodents, disease	Feeding back experience to future residents
	Security, fear of intruders, window locks	
	External noise, road, rail, people, music	
	External pollution, traffic fumes, cannabis smoke	
	Financial worries, running cost of fans	
	Signs of damp, condensation, mould	
	'Door knockers' pushing compensation claims	
	Time, trust, confidence to report problems	
	Housing need, speedy access to new home	
	Ventilation system user info/controls, accessibility, availability	

References to cleanliness, fresh air in the home, and keeping germs at bay, relating to previous homes or countries of residence, at different life stages, were frequently made by interviewees, particularly in the context of children's welfare (see 6.2.3). Household practices, including the specific activity of airing the home, are clearly rooted, for many of the case-study residents, in ***past*** experience (see 6.3.1). It appears in the data, however, that resident practice is influenced not only by personal past experience but by a wider, less specific, past Time Horizon linking health and ventilation.

One interviewee, for example, expressed the view that 'when they talk about "sick house syndrome", I think this is mildly ill' (GR3). He considered the house to be causing unexplained nasal infections and rashes in his children, that they had not experienced in previous homes, and consequently preferred to utilise the 'old-fashioned windows open' method of ventilation, rather than the 'cold air return thing' (MVHR system) installed.

Residents' immediate health concerns, such as experience of noisy fans interrupting sleep (see 6.3.4), or fear of ventilation ducts harbouring disease-carrying rats present in the house (see 6.2.3), resulted in some residents failing to use the ventilation systems installed. The alternative of opening windows, considered by many interviewees as 'the answer to everything' (GR3) regarding ventilation, reflecting a wider ***present*** Time Horizon, was however frequently thwarted by upstairs windows that could be easily opened by young children, ground floor windows that had no secure ventilation position (see 6.3.4), or bin areas or water butts located close to windows leading to insect infestations in the home. Thus, resident practice reflecting a present Time Horizon regarding health may, ironically, lead to homes failing to deliver healthy indoor air quality, despite ventilation systems being provided for that specific purpose, because no viable alternative method is available.

Nevertheless, the data indicates that, influenced by plans for the ***future*** residents place a high priority on health. Expectations that the home will provide a healthy environment, and meet the household's changing needs, are reflected in interviewees' comments (see 6.4.3). However, the expectation of one resident that her house could be adapted as her family grew, to provide separate well-ventilated bedrooms, was thwarted by the housing association refusing consent, despite the house being designed to allow this adaptation. She did not understand why this rule had changed and inferred that a future Time Horizon was not influencing the association's practice in meeting its long-term obligations regarding the health of residents.

As an example of how ***diverse*** Time Horizons interact, resident ventilation practice may be influenced by the notion that a breeze through the home is healthy (the influence of a past Time Horizon), but also a deep-rooted concern for children's safety (a present Time Horizon), while reflecting whether the means of ventilation in a new low-energy home will be healthy for the family long-term (a future Time Horizon). The case-study resident interviews suggest that these conflicting influences undermine the consistent practice needed to optimise the benefits of a whole-house ventilation system. The influences of a past or present Time Horizon, in particular, hinder the practice, whereas the influence of a future Time Horizon appears to be more ambivalent and open to change.

This sub-section suggests that residents' ventilation practice, in relation to health, is influenced by diverse, shifting Time Horizons that ebb and flow in everyday life. The data suggests that the identifiable habits, meanings, rules and things that constitute the practice are influenced by underlying awareness, described as Time Horizons, and that exploring this dimension of ventilation practice offers a deeper understanding of the practice than analysis by the four constituents alone.

8.7.1.2 Skills and ventilation: an example from maintenance practitioner practice

Table 28 below identifies a range of influences on the practice of ventilation maintenance, as performed by maintenance practitioners, attributed to three conceptual Time Horizons. This data has been extracted from interviews with staff at the case-study housing associations, as well as responses to the scoping survey and participants' comments at the focus group.

Themes running through the data, influenced by diverse Time Horizons, include the influence of organisational rules, experience of different ventilation technologies, and the quality and availability of data on the housing association's properties, as discussed in chapter 7. The theme of skills appears prominently in the data and has therefore been selected as the example for discussion. The annotation in table 28 illustrates the impact of skills on ventilation maintenance related to different Time Horizons and suggests that these are connected.

Table 28. Skills and maintenance practitioner ventilation practice, illustrating the influence of Time Horizons

Ventilation practice in low-energy homes: Key influences of Time Horizons on maintenance practitioner practice

Time Horizons		
Past horizon: History and experience	Present horizon: Here and now	Future horizon: Plans and expectations
Personal experience of home ventilation: current home, previous homes, cultural background, different climates	Access to current/historic data on properties/systems installed	Performance-based planned maintenance, following manufacturer's service schedule, meeting warranty conditions...or risk-based approach
Work experience of home ventilation technology: different systems, maintenance approaches of different organisations, experience of innovative schemes in use	Maintenance instructions for systems installed, availability	Cost-effective maintenance service
Trade background, skills in ventilation system maintenance	Faults in equipment/installation	Long-term budget, cash flow, priorities
Handover of new homes and maintenance induction	Target response time for ventilation repairs	Whole-life cost appraisal of ventilation systems
	'First Time Fix' target	Skills for ventilation maintenance, specialist contractors, in-house training
	Spare parts availability	Resident skills/responsibility for filter changing
	Maintenance skills availability	Induction, hands-on training, information for successive residents/staff
	Access to occupied homes	Feedback of experience to future schemes
	Void turnaround target	Data collection/management to build 'organisational memory'
	Annual maintenance budget	Investigating root causes of problems
	Defending complaints, compensation claims	Keeping homes lettable/in demand
		Adapting properties as household needs change
		Keeping homes healthy, awareness of IAQ, home monitoring, changes in H&S legislation on air quality
		Minimising energy costs, reducing fuel poverty
		Reducing carbon emissions to slow climate change, adopting net-zero emissions target, taking mitigation action
		Technological change, new ventilation options
		Rising resident expectations, rising standards, added landlord responsibilities, tighter regulation

The trade specialism of maintenance practitioners and typical training habits in the building sector appear to influence practice related to ventilation systems in the case-study homes, reflecting not only individual experience but the influence of a deeper ***past*** Time Horizon. The literature suggests that training and experience in technologies and building techniques that pre-date energy-efficient construction, particularly training in narrowly defined trades, may 'lock practitioners into ways of working that may no longer be appropriate' (Gleeson 2016: 2). A past Time Horizon may thus give rise to scepticism about current low-energy construction, for example, one maintenance practitioner talking about Passivhaus homes expressed the view that 'I can't say that's not the way forward. I'm only going by my experience of the problems it's caused' (Area Housing Manager).

However, a past Time Horizon may promote, rather than hinder, the evolution of a practice. Another participant influenced by a past Time Horizon regretted that a broad-based understanding of building fabric has been lost in the changing role of the Building Surveyor (see 7.2.5), but as a result she actively promoted the new skills required to effectively maintain ventilation technologies now being installed in new homes. This view reflects the findings of Clarke et al. (2017) that a low-carbon future requires 'energy literacy' in all construction trades, to 'break down occupational divisions' (Clarke, Gleeson, and Winch 2017: 78).

All the case-study housing associations reported an actual or perceived lack of availability of maintenance practitioners with the skills and knowledge required to service whole house ventilation systems, with one interviewee stating that 'there's not lots of people with knowledge about these systems out there' (Head of Asset Operations). An assumption, influenced by a ***present*** Time Horizon, of a shortage of experienced contractors appeared to be one factor, among others, leading to failure to replace filters regularly or carry out servicing at the recommended intervals.

By contrast, one maintenance manager, realising the importance of replacing filters, took matters into her own hands after being unable to find a contractor to take on this work and carried out the task herself. Being influenced by actual experience to act pragmatically, she discovered that replacing filters is in fact a simple task, requiring minimal training and well within the skill-set of the association's in-house maintenance operatives (see 7.5.3). Indeed, three of the five case-study associations reported that concerns about lack of competent contractors to carry out servicing had led to maintenance teams undertaking training to acquire this skill in-house.

The need for enhanced skills to maintain ventilation systems in the future was a recurrent issue reported by interviewees, particularly as the range and complexity of technologies in new developments continues to expand. Influenced by a ***future*** Time Horizon, maintenance practitioners acknowledged, albeit reluctantly in some cases, that the imperative of reducing carbon emissions will eventually necessitate whole house ventilation systems in all new homes (see 7.5.5) and that such technologies will not be maintenance-free. However, a future Time Horizon evidently interacts with past and present Time Horizons, which can hinder or promote the skills training required for this future practice.

As well as considering the skills required to service and maintain ventilation systems, all the case-study associations made reference to the lower-level skills needed to clean or replace filters. Several interviewees reflected that this task could be carried out by residents (see 7.5.3), although none of the case-study associations had implemented this at the time of the research. Whereas shared ownership leaseholders are responsible for filter replacement (and indeed for all maintenance of their homes), residents in rented homes continue to rely on the landlord for this service. A future Time Horizon in respect of training and skills acquisition may influence practice to move towards greater resident responsibility for filter changing, although other factors, such as accessibility of the ventilation unit and the likelihood of the task being carried out, not only the skill required, will be relevant.

This example illustrates how ***diverse*** Time Horizons interact to influence practice. In relation to skills and ventilation, maintenance practice is evidently hindered by awareness that pre-dates homes with current levels of airtightness (the influence of a past Time Horizon) while confronting here-and-now unfamiliar systems requiring different skills and a perception that these require specialist skills that are unavailable (the influence of a present Time Horizon). Although these influences impact negatively on the evolution of maintenance ventilation practice, the findings also indicate that the influence of both past and present

Time Horizons can positively promote the acquisition of the new skills required. The influence of a future Time Horizon opens the prospect of change, particularly where this interacts with positive influences that arise from past and present Time Horizons.

As illustrated in this sub-section, ventilation maintenance practice in relation to skills is influenced by the complex interaction of all three Time Horizons with the habits, meanings, rules and things that constitute the practice. It is argued that understanding these elements shaping the practice is enhanced by considering the influence of Time Horizons.

8.7.1.3 Diverse Time Horizons summary

In sub-section 8.7.1 the complex influence of different Time Horizons on ventilation practice has been explored and explained, using the examples of health and skills to illustrate the concept for residents and maintenance practitioners separately. In both examples, it appears that different Time Horizons exert conflicting influences on the practice, beyond the influence of direct knowledge and experience.

There are anecdotal indications in interviewees' responses of the importance of the timing and depth of the influence of different Time Horizons. Whereas one Time Horizon may exert a predominant and entrenched influence on ventilation practice for one performer of the practice, others may be influenced simultaneously or iteratively by more than one Time Horizon. The data in this study suggests that the influence of a past Time Horizon in ventilation practice is particularly dominant, although complex, both for residents and maintenance practitioners, as revealed in the next section.

8.7.2 How Time Horizons relate to interactions between bundled practices

8.7.2.1 Alignment, mismatch and conflict

In the preceding section, the influence of differing Time Horizons on ventilation practice has been explored by considering examples of significant themes, separately for residents and maintenance practitioners. In this section, interactions between bundled practices that shape ventilation are considered with reference to Time Horizons in order to further test the relevance of the concept.

Table 29 summarises the bundled practices that are key to ventilation in low-energy homes, related to three Time Horizons, extracted inductively from the data for residents and maintenance practitioners shown in tables 27 and 28 (see sections 8.7.1.1 and 8.7.1.2). Arrows indicate examples where the bundled practices appear from the data to be aligned (green arrows), mismatched (yellow arrows) or conflicting (red arrows). Abductive reasoning applied in observation of this high-level summary suggests that there is a pattern in the interactions that can be interpreted with reference to Time Horizons.

Table 29. Bundled ventilation practices: the relationship between interactions and Time Horizons

Time Horizons: Influences on practices	**Residents and ventilation: bundled practices**	**Maintenance practitioners and ventilation: bundled practices**
Future horizon: Plans and expectations	Healthy lives Financial security Space for family to grow and ability to meet changing household needs Living with changes in technology, economy, society, environment	Cost-effective maintenance, within budget Rising resident expectations, changing needs Advances in building services technologies Tougher regulation, higher building and service standards Enhanced data management systems
Present horizon: Here-and-now	A clean, sweet-smelling, pest-free home A comfortable, warm, dry home A healthy and safe home for children and pets Protection from intruders, freedom from external noise and pollution Affordable bills	Service delivery targets Complaints and claims Inbuilt defects Data and spare parts Skills
Past horizon: History and experience	Childhood memories of household practices Living in different homes, cultures, climates Owning or renting from different landlords Technology appetite and experience	Working with different ventilation technologies Trade and skills New homes induction Living in different homes, cultures, climates
Examples of interactions between practices: Alignment ⟷ Mismatch ⟷ Conflict ⟷		

8.7.2.2 A present Time Horizon and interactions

In table 29, as an illustrative example, ventilating the home to ensure a clean, dry, fresh-smelling home at all times is a practice influenced for residents by a present Time Horizon, as well as by here-and-now experience. Stuffiness and damp may be experienced where ventilation is ineffective, even in homes designed with whole-house ventilation systems, meaning that this practice for housing association residents interacts with the association's practice of maintaining ventilation.

The data suggests that the practice of ventilation maintenance, shaped by factors such as skills, may not be aligned with residents' present expectations. Whereas residents expect action to remedy damp (see 6.4.2) in relation to the meaning that this has for them, maintenance practice rules (see 7.4.1) may determine that this is resisted, indicating a ***mismatch*** in practice (see yellow arrows in table 29). The mismatch between bundled practices may mean that the interaction is characterised by ***conflict*** (see red arrows), as evidenced in the data, expressed in complaints and counter-accusations, which can escalate into legal disputes.

Although legal confrontation may be exceptional, the case-study data suggests a degree of friction is typical between residents and maintenance practitioners when everyday priorities influence practice. For example, a resident switching off a ventilation system in order to save energy, or drying laundry indoors without a tumble dryer, may be criticised for their supposed 'lifestyle choices'. On the other hand, when inbuilt defects in the ventilation system or unavailability of spare parts delays repairs, residents may question maintenance practitioners' competence.

8.7.2.3 A past Time Horizon and interactions

Analysis of the data indicates that where a past Time Horizon, as well as historic experience, influences ventilation practice for both residents and maintenance practitioners, the interaction between bundled practices may reflect ***alignment*** of history and experience (see green arrows). This shared historic practice is typically expressed in a shared dislike or distrust of whole-house ventilation systems, creating a positive interrelationship between residents and maintenance practitioners but compromising effective practice by both groups.

8.7.2.4 A future Time Horizon and interactions

In contrast to the evidence of friction, or even conflict, in the interrelationship when ventilation practice is influenced by a present Time Horizon, analysis of the data suggests that the influence of a future Time Horizon may lead to greater ***alignment*** in the interaction between bundled practices (see green arrows). Whereas the influence of a past Time Horizon may lead to *negative* alignment in the interaction based on shared rejection of ventilation technology in low-energy homes, the influence of a future Time Horizon may lead to *positive* alignment based on shared plans and expectations. However, the apparent openness to changes in ventilation practice, reflecting a shared desire for healthy homes and recognition of the need to adapt to changing home technologies, is not supported by underlying meanings related to low-energy homes. There is no evidence in the data, for example, that the need to reduce carbon emissions, which is driving the requirement for airtight homes with whole-house ventilation systems, is a significant influence on the ventilation practice of either residents or maintenance practitioners.

8.7.2.5 Interactions summary

The interactions between bundled practices illustrated in table 29 suggest that influences on ventilation practice of either a past or future Time Horizon lead to alignment. However, while the interaction influenced by a future Time Horizon for both parties could have potential to *support* effective ventilation in airtight homes, the evidence suggests that where the parties are both influenced by a past Time Horizon there is a compounding effect that *hinders* rather than supports effective practice. By contrast, the influences of a present Time Horizon are evidently not aligned between the two groups and can lead to friction, undermining effective practice.

8.8 Sub-conclusion

I propose in this chapter that practices are shaped not only by identifiable 'habits, meanings, rules and things', as described by Gram-Hanssen (2009), but by an awareness beyond direct experience and knowledge. These underlying diverse influences I have described as Time

Horizons. This new concept is proposed from an abductive reading of the data, building on the extensive literature on theories of time. I define Time Horizons as neither clock time nor time duration, but *an individual and collective awareness of future, past or present experiences or expectations that play a part in the life of practices*. This concept adds to existing theory on the influence of time on practice, much of which focuses on the organisation of time and practice, rooted in a binary understanding of time.

I suggest that **the concept of Time Horizons offers an additional dimension to the analysis of practices** and I have illustrated this approach in the context of understanding ventilation practice in low-energy homes. Building on current literature on practices, I suggest that the influences of Time Horizons, whether rooted in history and experience, related to here-and-now social life or reflecting assumptions about the future, shape ventilation practice in multiple ways, but that the data indicates a discernable pattern in their effect.

As well as the influence of diverse Time Horizons on practices for the two groups *separately*, the relevance of Time Horizons in the *interaction* between the bundled practices of residents and maintenance practitioners is explored. It is suggested that **the influence of Time Horizons is a factor in the alignment or mismatch between bundled practices, with an impact on ventilation maintenance***,* as discussed in chapter 9.

Although the data suggests that the influence of a future Time Horizon could support effective ventilation practice for *residents*, it appears that the influence of history and experience (a past Time Horizon) and the here-and-now (a present Time Horizon) typically overshadow the influence of a future Time Horizon. The data suggests that for *maintenance practitioners*, the influence of a past or a present Time Horizon may similarly compromise effective maintenance of ventilation in low-energy homes, but also suggests that these influences can instead lead to positive change in maintenance practice. The potentially positive influence of a future Time Horizon on maintenance practitioner practice is apparent in the data but may be compromised if the influences of a past or present Time Horizon are not recognised and acknowledged.

In the next chapter, ventilation maintenance is discussed in the context of the phases and transition points in the lifecycle of a typical low-energy rented home, demonstrating how understanding the influence of Time Horizons on practices strengthens understanding of how effective ventilation can be maintained in such homes.

Chapter 9. Discussion – Bundled practices, interactions and ventilation

9.1 Introduction

Analysis of the experience of maintaining ventilation in low-energy rented homes, for maintenance practitioners (see chapter 7) and residents (see chapter 6), through the lens of Practice Theory, revealed first-order themes (see 6.6 and 7.6) related to the four components of practices (Gram-Hanssen 2009). Chapter 8 introduced a further new dimension relevant to practices, and to the interaction between practices, revealed through abductive insight and described as Time Horizons (see 8.8).

The empirical data collected in the case-studies reveals a wide range of practices which promote or impede effective ventilation maintenance in low-energy homes. Four practices that are prominent in all the case-studies are discussed in section 9.2. These have been identified as having a significant impact on ventilation maintenance by re-examination of the data in chapters 6 and 7 and the discussion in chapter 8. Each of these practices is, in effect, a bundle of practices (see 2.6), performed not only by residents and maintenance practitioners, but by a wider group of performers. The part played by Time Horizons in how these bundled practices are performed is considered.

In order to understand the impact of bundled practices on ventilation maintenance in a real-life scenario, practices throughout the lifespan of a typical housing association dwelling are discussed in section 9.3, focusing on the interaction between practices and reflecting on the influence of Time Horizons. Typical and alternative interactions between practices are compared.

9.2 Four bundled practices

9.2.1 Beliefs about fresh air and windows

Residents interviewed typically equated ‘fresh air’ with ‘external air’. The quality of external air was questioned only when a specific, unwanted smell was detected, such as a neighbour’s barbeque or cannabis smoke. Although traffic fumes and agricultural smells were evident to the researcher at the case-study schemes, these were commonplace to residents and did not appear to detract from their belief that external air is ‘fresh’. Interviewees repeatedly described opening windows or doors as the ‘normal’ or ‘natural’ way to allow fresh air to displace cooking smells, germs and stuffiness in the house (see 6.2.3).

Residents referred positively to the physical feeling of a breeze through the house, the fresh smell that this creates, and the visual cue of open windows, and reflected that opening and closing windows gives freedom to control the flow of air, as well as control the two-way transmission of noise. The practice of opening windows for ventilation can be interpreted as deeply rooted in personal know-how, meanings and things, further influenced by a past Time Horizon (see 8.4), while reinforced by the incidents of everyday life and the influence of a present Time Horizon (see 8.5).

By comparison, ventilation systems installed in the case-study homes, designed to allow adequate air exchange in these highly airtight buildings, were not generally perceived by residents as providing fresh air (see 6.2.3). Whereas the purpose of whole-house ventilation systems is to provide filtered external air – assuming that filters are regularly cleaned or replaced – some residents believed that they spread disease around the house and preferred to open windows to get rid of germs.

In contrast to the beliefs about fresh air expressed by residents, the design of the case-study low-energy homes had been driven principally by the housing associations' objectives of achieving a recognised standard exceeding the Building Regulations, underpinned by quite different beliefs. In four of the five case-studies this resulted in high levels of airtightness and whole-house ventilation systems. In the fifth scheme, ventilation in a highly airtight building was achieved by extract fans and tricklevents. It was evident in interviews with staff, analysed in chapter 7, that ventilation practice for the designers and development team was shaped by know-how and meaning attached to reducing carbon emissions, influenced by a future Time Horizon.

When discussing the material objects or 'things' relevant to ventilation, development staff focused on technologies, air change rates and types of filter. Windows were rarely mentioned, and then mainly with respect to the choice between materials in terms of environmental impact. It was evident, however, in interviews with maintenance practitioners that many shared residents' beliefs about 'fresh air' and considered the practice of ventilation by opening windows as normal, even in low-energy homes with whole-house ventilation. This shared perception reflects the influence of a past Time Horizon for both groups. However, while a present Time Horizon reinforces residents' ventilation practice based on window opening, for maintenance practitioners their role requires them to engage with the ventilation equipment installed. Indeed, the maintenance of windows was rarely mentioned by maintenance practitioners when talking about ventilation.

9.2.2 Association rules v. household rules

The categorisation of ventilation equipment either as a building component requiring planned maintenance, such as filter changes and periodic servicing, or as an item requiring only responsive repairs when a problem arises, is a 'rule-based' decision by the housing association, intentional or by default, that has a significant impact on the effectiveness of ventilation and on the interaction between maintenance practitioners and residents. Associations that adopt a responsive approach, 'if it breaks we fix it', depend on residents reporting problems with ventilation systems, even though declining air quality may be difficult to detect and residents may not know the signs of equipment failure.

Even where the need for maintenance action is identified, following a report of damp or mould for instance, the repair may be categorised as non-urgent and, indeed, not linked to inadequate ventilation. Only one of the five case-study housing associations classified repairs to ventilation fans as urgent, belying the importance of indoor air quality to residents' health. Monitoring indoor air quality was not standard practice, or a 'rule', in any of the schemes, with one maintenance practitioner stating that monitoring is only carried out in order to defend the association in disputes regarding responsibility for mould, not in order to ensure the health of residents. In such cases, interaction between maintenance practitioners and residents may become confrontational, testing the maintenance 'rules' of the association against legislation.

Where regular filter replacement is carried out by the housing association, there may still be a conflict between the rules (maintenance budget) of the association and the rules (household budget) of the resident. In one instance, the association met the cost of standard grade filters only, expecting the resident to pay if higher grade filters were required, an expense that low-income households could not afford, thus underexploiting the potential health benefit of a whole-house ventilation system.

Conflicting rules had a more fundamental effect on ventilation effectiveness for some case-study residents. Ventilation systems installed with the intention of ensuring healthy indoor air while minimising energy use for heating were switched off by a significant number of residents, in order to save the energy required to operate the system. The association's instructions to keep the system running continuously, and heat the home adequately, were ignored where the household's budgeting rule was to cut all energy use regarded as non-essential.

The stage of letting a rented home, whether to the first occupant of a newly built home or a future resident, is a key point in the bundled practices of the housing association and residents. Where the association's priority is to minimise the time that a property is vacant, this 'rule' does not allow time for an effective induction for new residents. Residents' priorities at the point of letting appeared to compound the emphasis on speed, with interviewees describing the urgent housing need they faced, eager to sign the tenancy agreement and move in, after only a cursory viewing. The rules of the lettings team and prospective resident can thus coincide, with speed of the process compromising understanding of ventilation in the home.

The rules applicable to mutual exchanges appeared, at the case-study schemes, to further exacerbate the effective operation and maintenance of ventilation. The 'handover' from outgoing to incoming resident in the exchange was almost entirely the responsibility of the exchange partners, with minimal involvement of the housing management team and no involvement of the maintenance team. Typically, the information about ventilation of the property was incomplete or incorrect, with outgoing residents advising incoming residents not to use the system. Mutual exchange rules thus represent another example of bundled practices compromising effective ventilation maintenance practice.

9.2.3 Silo working and internal communication

An underlying factor impeding interaction between teams and with residents in the case-study schemes, and compromising effective ventilation in the low-energy homes studied, appears to be the practice within the housing associations of ‘silo working’, i.e. a high degree of separation between disciplines and teams in the organisational structure. Although good communications and integrated working may mitigate the effects of this practice, its impact on ventilation maintenance can be clearly identified in the case-study schemes.

Maintenance practitioners typically regard development staff as ‘a little bit out on their own’ (Stock Data Manager) and ‘not very technical’ (Technical Services Manager), criticising their ‘early adopter’ mindset and lack of thought for the implications of innovative ventilation technologies for maintenance and for residents. On the other hand, development staff recounted maintenance colleagues’ resistance to change, for example, ‘a maintenance objection to putting in cooker hoods, because they’re a fire hazard, they’re a maintenance problem, nobody changes the filters, and so on’ (Development Director). One manager who initiated a pilot zero-carbon scheme was exasperated that maintenance colleagues persisted that ‘none of these systems are working’ and held ‘a perception that this is too big a risk’. From his development experience, with no exposure to feedback from residents or maintenance practitioners, the data on MVHR performance did not reveal problems in use, ‘so why perceive them from that negative perspective?’ (Quality and Value Manager).

As a result of this narrow development understanding, the maintenance manager found that ‘development won’t speak to us about anything that’s going into there’. He considered that this was the 'missing link' in ensuring effective ventilation in new homes and asserted that 'they should use us for our knowledge sometimes' (Head of Electrical Compliance).

The silo mentality of both parties appeared to be deeply rooted, feeding, and fed by, habits and meanings about the relative importance of development and maintenance to the business of the housing association. The evidence suggests that the barriers to early engagement by maintenance practitioners in the development process are not primarily about time pressures, which was the reason stated by some interviewees (both maintenance and development staff), but rooted in a belief or 'meaning', implied by both maintenance and development practitioners, that maintenance is secondary in importance to the business of procuring new homes. If development staff perceive maintenance as a necessary, but essentially unexciting, 'housekeeping' practice, a secondary follow-up to the primary creative and innovative practice of development, then the habit of ignoring maintenance issues will persist, rooted in that meaning. By contrast, it can be argued that for housing associations, maintenance is the primary service to residents, constitutes a major portion of the revenue budget, and is fundamental to maintaining the lettability and value of the association's property assets. Exploring the roots of the silo attitudes evident in development and maintenance practice, and the link with the training and status of both professions, is beyond the scope of this thesis. Nevertheless, the attitudes revealed in the case-study interviews indicate that silo working is a relevant factor in the bundled practices related to ventilation maintenance.

The evidence suggests that staff typically perceive colleagues in a different role to themselves as having a limited vision of the whole activity of the housing association. For example, development staff may be perceived as concerned only with chasing 'points' (to achieve a higher level of the CfSH) or chasing funding, with no concern for the needs of future residents (see 7.3.1). On the other hand, maintenance staff may be regarded as unwilling to look beyond the immediate problem reported to uncover the cause and long-term solution (see 7.2.1).

Although there is evidence that some staff may have such limited visions of their own role, this is by no means universal. Staff responses indicate that the meanings staff attach to the provision of homes may extend well beyond the stage of their individual active involvement in the overall process. Indeed, there are examples of staff in each of the siloed functions who perceive connections between the limited timescale of their involvement and the entire timescale of the dwelling's life.

For example, some development staff seriously consider the long-term implications for homes of a changing climate, influenced by a future Time Horizon, while the objectives for their role in the organisation may be to meet current standards, keep within the cost limits, and deliver homes on time with minimal build defects, influenced by a present Time Horizon. One development interviewee, for example, frustrated by the focus of his organisation on short-term capital cost, reflected that:

> Trying to get the right ventilation is going to be a huge problem in 10, 15 years' time. (Development Manager)

Similarly, some maintenance staff, while focused on the current upkeep of the building fabric, looked beyond the present task at issues that will be increasingly significant for maintenance, as indicated by this comment:

> I was listening and thinking, this (author: indoor air quality) is coming, it's got to be the next thing. (Technical Services Manager)

A focus group participant who had experience across both activities, believed that effective ventilation maintenance required 'joining the dots up to have a proper strategy and a solution' (Projects Manager).

However, it is suggested that when staff, in any of the disconnected functions that appear typical of the housing associations studied, do take a holistic view of the business of providing housing, this may be obscured by the boundaries placed around their role and the lack of organisational connectedness (see 9.4).

9.2.4 Communication with residents

The detrimental impact of silo working on interaction between teams was characterised by one focus group participant, with regard to ventilation maintenance, as:

> Our own misfortune we don't tend to communicate well, one side of the business and another. (Stock Data Manager)

The evidence from the case-studies indicates that ventilation maintenance in low-energy homes is significantly impacted not only by internal communication, but also by the quality and timing of communication between the housing association and residents. Communication with prospective residents may pre-date their move into a new home by months, or even years, and will continue throughout the tenancy, but communication about ventilation at the start of a tenancy appears to impact significantly on whether and how residents engage with ventilation equipment in a low-energy home (see 7.4.4).

The quality and quantity of documentation for residents was widely variable in the case-study schemes, with only one example being concise, in non-technical language, and designed for the specific scheme (see 6.5.2). Whether information was provided in verbal or written form, the language evidently failed to communicate the purpose and operation of ventilation equipment in the case-study schemes, with residents variously describing the systems as the 'weird thing at the top of the stairs', 'cold air exchanger', 'recovery system', 'air con', and 'thing that blows out cold air'. The term 'heat recovery' caused particular confusion for residents, implying that ventilation and heating systems were linked.

The equipment and controls themselves also conveyed unhelpful messages. Ventilation units located in inaccessible spaces did not indicate any need for regular attention to filters. Non-intuitive controls did not communicate how to achieve optimal performance from the system. One maintenance interviewee was aware of residents' scepticism about using a system when they could not see or hear whether it was operating and recognised the need for controls to provide feedback (Bordass, Leaman, and Bunn 2007). Even though the ventilation system at that scheme was designed to be fully automatic, controlled by humidity sensors, manual boost switches had been retro-fitted to communicate on/off operation, in the light of experience in use.

Two of the case-study schemes took a different approach to controls, locating these purposefully so that there was no resident access, although this was only partially successful as some residents found ways to circumvent the restrictions. It is arguable that the messages that housing associations and residents were communicating to each other in this situation, for example, the association lacking trust in the resident to control the ventilation system, and the resident asserting a right to control their living environment, indicate contradictory ‘meanings’ that can be detected more generally in communication, with an impact on ventilation maintenance.

A mutual disregard between residents and housing associations is evident in some interviewee comments, such as one resident talking about a member of staff ‘poking his nose into everybody and, you know, you can’t do this, you can’t do that’ (GR1) (see 6.4.3) or a maintenance officer asserting that ‘some residents just don’t want to listen’ (Repairs & Maintenance Manager) (see 7.2.1). Communication is thereby obstructed, impeding the identification of problems with ventilation systems. Indeed, one interviewee confirmed that ventilation problems are normally only uncovered ‘when we’re having conversations with (tenants) about something they’re not doing i.e. not paying the rent or causing nuisance’ (Head of Housing Operations).

Mixed messages from housing association staff about ventilation was evident in the case-study schemes, reducing some residents’ confidence in the systems installed. Frequent staff changes and lack of information systems in associations typically led to loss of knowledge of the ventilation strategy for the homes, both for residents and maintenance practitioners. In the absence of consistent and accurate communication it appears that residents' reversion to habitual practice for airing the home, or associations' generic responses to reported maintenance issues, may then ensue, undermining ventilation maintenance in low-energy homes.

The disconnections between bundled practices relating to ventilation may be further undermined when disputes arise over the cause of damp and mould, leading to complaints, involvement of the Ombudsman or recourse to legislation. Communication then becomes formal and defensive, typically prolonging the impact of ineffective ventilation and poor indoor air quality, which, as one maintenance manager reflected, 'we could have dealt with earlier, could have prevented or treated earlier' (Tenant Services Manager).

9.3 Practice interactions in a real-life scenario

9.3.1 Typical interactions

The timeline of an archetypal housing association rented home, from inception to end of life, provides a framework for considering the impact on ventilation maintenance of bundled practices between key players at different stages of the timeline. The simplified diagrammatic timeline shown in figure 30 shows the phases and transition points in the life of a dwelling, identified in the researcher's experience as typical of housing association practice. The RIBA work stages, in relation to the development process, are shown for information (RIBA 2020).

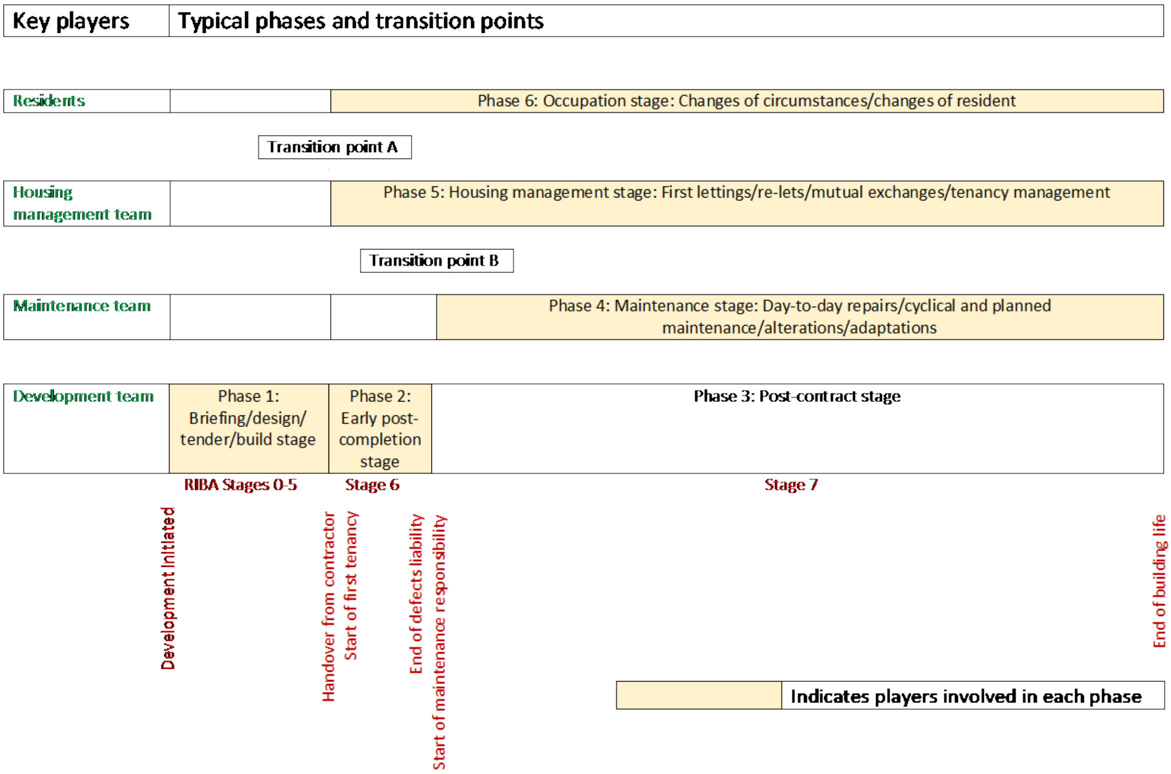


Figure 30. Typical interactions during the life of a housing association rented dwelling

The four groups of key players shown in figure 30 are those identified in the data as having a significant impact on ventilation maintenance, not only through their separate performance of practices, but through the bundled practices holding them together. The impact of interaction between these key players at each phase and transition point, as shown in figure 30, is now discussed and a practice-based interpretation is offered, taking account of Time Horizons as discussed in chapter 8.

Phase 1 Building/design/tender/build stage

Although the design and specification of new homes may reflect a long Time Horizon, for example by anticipating future 'rules' as the climate crisis triggers mandatory reductions in carbon emissions, it appears that the implications of airtight dwellings with whole-house ventilation for occupation and maintenance over the long lifespan of the dwellings receive little consideration at the development stage. The long-term responsibility of maintenance teams, with highly significant implications for the association's business performance, is impacted by decisions made at the time-limited development stage.

However, the case-studies indicated that little or no interaction had occurred between the development team and other key players at this stage. Ventilation strategy and systems in these new low-energy homes therefore reflected the habits, meanings, rules and things shaping the practice of designers, development staff and contractors; the elements of ventilation practice influencing other key players were not considered part of design practice.

None of the associations studied had internal 'rules' that captured the knowledge of in-house maintenance and management teams at the briefing and specification stages of new housing schemes, at least not in meaningful detail. Indeed, there is anecdotal evidence that maintenance staff may be omitted from the development process as they are perceived as not sharing the 'early adopter' mindset that is valued by the development team.

The inclusion of residents in the development process appears to be unusual (Foulds 2013) and did not occur in any of the case-study schemes.

Although ease of maintenance and the usability of ventilation 'things' for occupants may be included in scheme briefs, as a 'rule' in development practice, it is not evident that these intentions are carried through and influence design, construction and installation. As a result, the essential maintenance of ventilation things is obstructed from the outset.

Transition point A *Handover from contractor*
Start of first tenancy

An effective induction for initial residents, housing management staff and maintenance practitioners was not typical. Lack of interaction between key players at this stage meant that some residents had no hands-on induction, user-friendly operation guidance or follow-up advice, resulting in ventilation practice reflecting a past Time Horizon, ineffective in a new airtight home, being established from the outset by default. It appears that new residents who received a thorough induction in the ventilation system, during the critical time-window at the start of their tenancy, were more likely to establish new ventilation habits and less likely to abandon use of the system.

It appeared that housing management and lettings staff in some associations had no briefing whatever. This gap in knowledge at the point of handover thus had an impact not only for initial residents but for subsequent lettings, perpetuating the influence of a past Time Horizon on ventilation practice. The long-term consequences of ineffective ventilation practice have no 'meaning' in lettings practice, even where it is known that homes have unfamiliar ventilation systems installed.

Crucially, it appeared that maintenance practitioners typically were not involved as a 'rule' at the handover of new schemes, did not receive an induction at that stage, and in some cases had no knowledge of the ventilation systems installed until the defects liability period ended.

Phase 2 Early post-completion stage

Maintenance teams in the case-study associations did not take responsibility for new homes until the end of the defects liability period, typically 12 months after handover, other than carrying out non-defect repairs. However, maintenance practitioners reported taking responsibility at the end of phase 2 for schemes with unresolved construction, installation and commissioning faults, in some cases where residents had experienced noisy, leaking or inoperable systems for months.

Although maintenance involvement at an earlier stage would not overcome failures in quality control on site, it is arguable that interaction between maintenance and development teams during the early post-completion stage would lead to earlier understanding of the system and its maintenance requirements, less likelihood that the manufacturer's 'rules' for maintenance, including attention during the first year, would be ignored, and more effective ongoing maintenance of ventilation.

A light-touch Post-Occupancy Evaluation (Stevenson 2019) is specified as a 'core task' at stage 6 in the RIBA Plan of Work (phase 2 in figure 30), however development practice at the case-study associations did not include post-occupancy evaluation at any stage as a 'rule' for new developments. Stevenson (2019) recommends that such surveys are directed at the client, design team and residents, thus failing to capture the experience of the maintenance team, which is not habitually perceived as a 'client' or internal 'customer'. This omission is further evidence that the importance of maintenance is not recognised and the input of maintenance practitioners is undervalued.

As figure 30 indicates, post-occupancy evaluation at this phase is unlikely to give early warning of ventilation maintenance problems as maintenance practitioners typically have little involvement with new schemes until the end of the defects liability period. Early concerns about ventilation raised by residents are referred to the contractor, but the evidence shows that these may be passed on to the maintenance team unresolved. The value of post-occupancy evaluation is thus undermined if the scope and timing does not allow for maintenance practitioner input. As a result, ventilation problems inherent at phase 1 escape detection at phase 2, risking ineffective ventilation long-term, illustrating the importance of interaction between bundled practices.

Transition point B *End of defects liability*
Start of maintenance responsibility

Ventilation maintenance practice at the case-study schemes appears to reflect the lack of specific interaction between key players at phase 1, the lack of effective handover from the contractor at transition point A, and the failure to rectify defects at phase 2. This is compounded by the evident lack of induction for maintenance practitioners at transition point B. Moreover, system documentation and manufacturer's maintenance requirements are not always passed on to the maintenance team at this point.

The 'meanings' of ventilation for the development team, influenced by a future Time Horizon, do not appear to be shared by maintenance practitioners in the case-study schemes. As a result, ventilation maintenance may be classified by default as a responsive task, influenced by the here-and-now priorities of a present Time Horizon, ignoring the need for regular servicing with negative consequences for its effectiveness.

The absence of effective handover practice for either residents or maintenance practitioners, and persistent defects in ventilation 'things', appeared to entrench the influence of a present Time Horizon in the bundled practices between residents and maintenance practitioners. However, analysis of the data suggests that here-and-now priorities of these groups are mismatched and potentially conflicting (see 8.7.2.2).

Phase 3 Post-contract stage

Whereas the RIBA framework envisages a construction project as extending for the life of the building, it is evident that the end of the defects liability period signalled the end of development practice in the case-studies. Interaction between the development team and other key players from that point was minimal, contributing to the lack of any effective feedback loops.

Ad-hoc feedback to the development team on the performance of innovative ventilation technologies was observed in some schemes, however feedback did not appear to exert any influence on development practice. Indeed, one development manager implied that changes in 'rules' regarding building standards, and a shift to procurement from private developers, negated the value of post-occupancy evaluation as the findings would not be relevant to future schemes.

It is suggested that the evolution of practice regarding ventilation in new low-energy homes is more closely related to changes in associations' priorities triggered by external requirements than by internal feedback on effectiveness. Despite the continued influence of a future Time Horizon, and the meaning of carbon emission reduction in ventilation practice for development teams, the reduction of standards required by funders led associations to abandon plans for further cutting-edge schemes. In other words, a change in the 'rules' was the driver.

Phase 4 Maintenance stage

Ventilation maintenance practice at the case-study schemes appeared to be shaped, for both residents and maintenance practitioners, by lack of know-how on the systems installed, meanings of ventilation influenced by a past Time Horizon, rules influenced by here-and-now priorities, and flawed ventilation things. It is suggested that these elements of practice can be traced back to handover practice and lettings practice, and, further, to the lack of interaction between key players at phase 1.

The data suggests that interaction habits established early in occupation persist, whether hindering or promoting the effective operation and maintenance of ventilation. Interaction between some residents and maintenance practitioners appeared to be shaped from the outset by the influence of a present Time Horizon for both parties, resulting in friction which hindered effective ventilation practice. Although the influence of a future Time Horizon in the ventilation practice of both residents and maintenance practitioners can be observed in the data, this influence appears to be obscured where interaction is characterised by confrontation (8.7.2.2).

Phase 5 Housing management stage

The lack of induction or information on ventilation systems at handover stage, coupled with the influence of a present Time Horizon on lettings practice, compromised ventilation practice in low-energy homes, both for the first and, significantly, for subsequent residents in the case-study schemes. Ventilation practice did not appear to be an issue of concern in the interaction between housing management staff and residents. In the case of a mutual exchange, it was entirely the responsibility of the outgoing resident to pass on correct information about systems in the property, which evidently did not always happen.

'Organisational forgetting', as ventilation system data was not recorded or not accessed by housing management staff, exacerbated by staff changes over time, further undermined ventilation know-how among staff, precluding this being passed to residents in the course of interaction with staff during the tenancy.

Phase 6 Occupation stage

The practice of letting homes, and particularly the practice of mutual exchange, appeared to compromise the effectiveness of ventilation in use, as any know-how about ventilation 'things' in the home was lost through changes of occupant over time.

As residents' circumstances changed, alterations to properties without regard to the impact on ventilation further affected ventilation operation and maintenance practice. While the influence of a future Time Horizon may have led to adaptable house design, able to accommodate changes necessitated by household circumstances or social, economic or technological change, it appears that the impact of alterations on ventilation is not always taken into account in the design or in later changes to the property.

9.3.2 Alternative interactions

The timeline of a typical housing association rented home, from inception to end of life, reveals characteristics of bundled practices within the association and with residents which, it is argued, fundamentally impede effective ventilation maintenance. The simplified timeline, shown in figure 30 indicates a separation of phases in the timeline, contrary to the concept of a building being a continuous work-in-progress throughout its life (Brand 1997).

Figure 30, as described in section 9.3.1, illustrates diagrammatically the disconnection of the short-term design and construction phase from the long-term occupation, management and maintenance phase. This discontinuity, with little or no overlap at key phases and transition points in the dwelling's life, appeared to have long-term consequences for ventilation practice in the case-study schemes.

An amended timeline, shown in figure 31 and outlined briefly below, suggests alternative interactions which may overcome some of the issues discussed in this section and contribute to more effective ventilation maintenance.

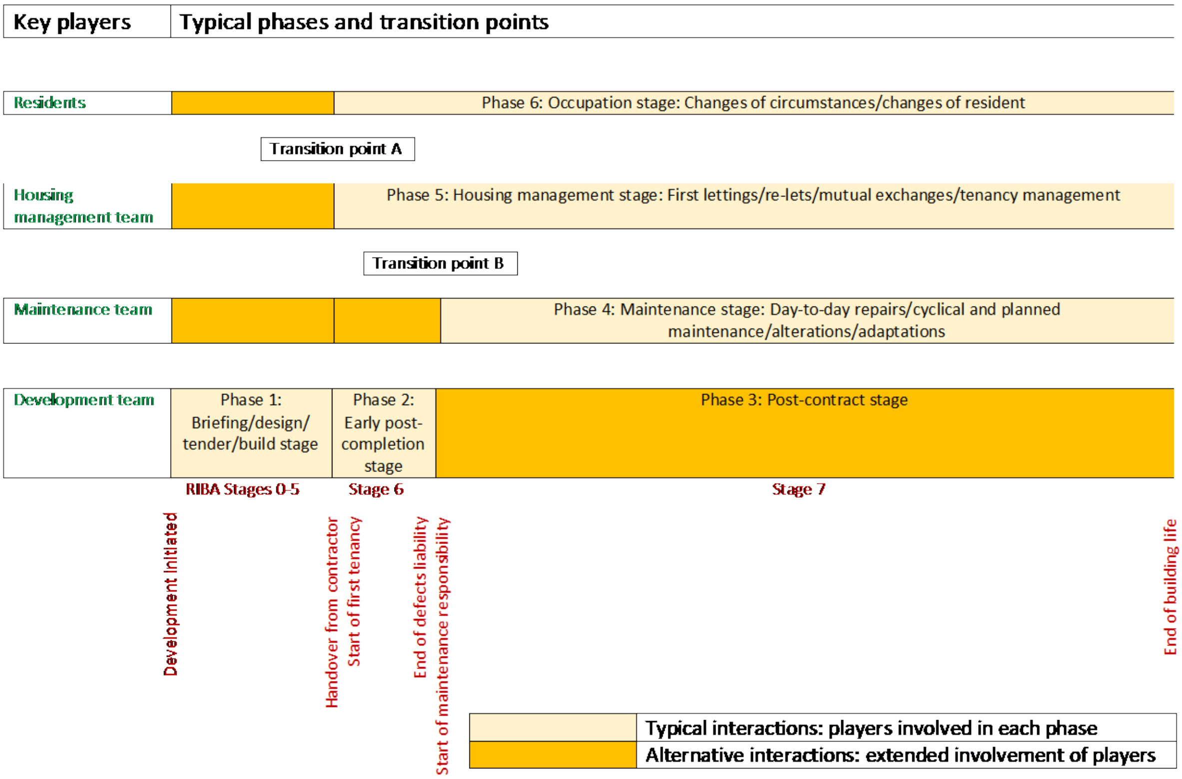


Figure 31. Alternative interactions during the life of a housing association rented dwelling

Phase 1 Building/design/tender/build stage

An intervention to promote dialogue between key players at the earliest stage would enable the practice of design and specification of new homes to reflect a wider understanding of a future Time Horizon in ventilation, i.e. not only the meaning of reducing carbon emissions, but also the meanings of those who will occupy, manage and maintain homes over the long term. Although interaction with future residents of a specific scheme in development may not be feasible until phase 2, due to typical lettings practice of housing associations, this does not preclude the experience of residents in similar homes shaping practice at this stage.

Transition point A *Handover from contractor*
Start of first tenancy

The inclusion of key players (maintenance, housing management and residents) at the handover stage, as a rule of practice, has the potential to transform ventilation effectiveness. Establishing ventilation habits appropriate to low-energy homes from the start of occupation, enabling the inclusion of ventilation induction in future lettings practice, and influencing the practice of maintenance practitioners in preparation for the start of maintenance responsibility, could all contribute to the evolution of more effective ventilation practice.

Phase 2 *Early post-completion stage*

An intervention to establish dialogue between development and maintenance teams at this stage offers the opportunity to establish a planned maintenance regime for ventilation systems, rather than the ineffective reactive practice observed in the case-studies. Although post-occupancy evaluation at this stage continues to be hindered by the short time in-use, there would be greater potential to capture feedback on ventilation from maintenance practitioners if they are already engaged with the practice.

Transition point B *End of defects liability*
Start of maintenance responsibility

Given the proposed interventions at phases 1 and 2 and transition point A, an effective handover of responsibility for maintenance of ventilation systems at transition point B, with defects remedied, is more probable. No other intervention is proposed at this point.

Phase 3 *Post-contract stage*

The value of feedback of the longer-term ventilation experience of residents and maintenance practitioners to phase 1 suggests that interaction of the development team with other key players post-contract is desirable and should be promoted as an intervention. The practice of feedback might include periodic evaluations and formal feedback loops, as a rule of development practice.

Phase 4 Maintenance stage

Establishing ventilation maintenance practice consistent with the ventilation 'things' and 'meanings' of low-energy airtight dwellings as an intervention at an early stage lays the foundation for continuing practice influenced by a future Time Horizon, rather than shaped primarily by the here-and-now priorities of maintenance practitioners.

Phase 5 Housing management stage

Introducing a dialogue at handover between housing management staff and development and maintenance colleagues, combined with more effective systems for retaining, accessing and disseminating know-how on ventilation systems for future lettings, including mutual exchanges, could contribute to effective ventilation maintenance long-term in low-energy homes. The dialogue of housing management with other key players at phase 1 offers two-way benefits in ventilation practice, i.e. feedback of experience of homes in management to the design stage and feed forward of ventilation 'meanings' and 'things' to those with long-term responsibility for homes.

Phase 6 Occupation stage

Ventilation practice for residents in low-energy homes, based on introducing an effective induction at transition point A, offers the benefits of both energy efficiency and good indoor air quality, consistent with the influence of a future Time Horizon indicated by residents in the case-studies. Taking account of ventilation in lettings practice and in adapting homes could transform the experience of residents over the lifetime of the dwellings.

9.4 Sub-conclusion

The significance of the diverse practices of maintenance practitioners and residents for the effectiveness of ventilation in low-energy rented homes has been analysed in chapters 6 and 7. In this chapter, the impact of bundled practices between key players on the practice of maintaining ventilation is discussed, with reference to Practice Theory and to the influence of Time Horizons, a concept introduced in chapter 8, to synthesise further the evidence from chapters 6 and 7.

Four significant bundled practices have been identified in the data, practices that materially impede or support interaction between key players and thereby impact on effective ventilation. The data reveals that a **difference in beliefs about fresh air and windows**, and **conflict between the ‘rules’ shaping ventilation practice** for each group, underlie the bundled practices between residents and maintenance practitioners. These obstacles to meaningful and effective interaction between players appear to be compounded by the **typical silo working arrangements and limited internal communications** in the case-study housing associations and **poor communication between the associations and residents**, regarding unfamiliar ventilation equipment installed in new low-energy homes.

It is suggested that these bundled practices operate at two levels, the individual and the structural. At an *individual* level, it appears that these practices are rooted in real-life experience of residents and maintenance practitioners, further influenced by diverse Time Horizons, and reflected in repeated performance of ventilation actions.

The life-cycle of a typical low-energy rented dwelling is used as a framework in section 9.3 to illustrate the impact of the bundled practices identified in section 9.2 at a *structural* level. It is argued that lack of interaction between key players at each phase and transition point, illustrated in figure 30, creates fundamental obstacles to effective bundled ventilation practices, as performed by residents and maintenance practitioners. **These obstacles in effect constitute a barrier between the short-term design and construction phase and the long-term occupation, management and maintenance phase of a dwelling’s life.**

However, **Time Horizons influencing practice for residents and maintenance practitioners suggest there is common ground across this conceptual barrier.** For example, although a future Time Horizon may influence practice at the development stage, leading to near-zero-carbon design and innovative ventilation systems, this phase is also characterised by the immediate ‘buzz’ of being at the cutting-edge of building technology and engaged in competition for sites, funding and recognition. There is evidence from the case-studies that development teams are perceived by their maintenance colleagues and by residents as risk-taking ‘early adopters’ of experimental ideas and technologies, while they regard themselves as dealing with the, often problematic, consequences. On the other hand, while ventilation practice for maintenance practitioners and for residents may be regarded typically as shaped by a past or a present Time Horizon, a future Time Horizon is also influencing these players, reflecting the importance of effective ventilation through the life of the dwelling.

Development, housing management and maintenance teams are all, in reality, influenced by Time Horizons spanning past, present and future, but exist in separate silos, with apparently little connection between these teams. However, this habitual disconnection may become critical when the ‘rules’ lead to homes with ventilation ‘things’ that are novel or unfamiliar. The specification and installation of whole-house ventilation systems without regard to maintenance needs, and the maintenance of these systems without understanding of their operation, is a precarious scenario in respect of healthy air quality.

Recognising the mutual dependence of teams in procuring, managing and maintaining homes that are healthy and energy-efficient over the dwelling’s lifespan challenges the lack of interaction in their bundled practices. An alternative view of the life stages of a dwelling, illustrated in figure 31, suggests the impact that changes in interaction could have on ventilation practice and, ultimately, on the effectiveness of ventilation systems in delivering both low carbon emissions and healthy indoor air.

Chapter 10. Conclusion

10.1 Thesis summary

The *Introduction* sets out the context of this research, locating domestic ventilation within the broader concerns of climate change, energy use, indoor air quality and health. The implications of increased airtightness of homes, and evidence of unintended consequences, suggest that the maintenance of effective ventilation in low-energy homes is being overlooked. Consequently, the aim of the research is to understand how maintenance practitioner and resident practices influence the maintenance of effective ventilation and healthy indoor air in low-energy homes. The research questions (see 1.4) focus the study on maintenance practitioners and residents and the interaction between practices. The scope is defined as housing association low-energy homes in England and the reasons for the limitations are explained. The interpretive approach of the research and the practice-based theoretical framework are introduced and the thesis structure is set out.

Chapter 2 explains why Gram-Hanssen's definition of Practice Theory, focusing on how people act in the real world, is adopted as a fitting framework for the research, being consistent with the interpretivist stance of the researcher. It appears that unintended consequences arising in low-energy homes in use are commonly attributed to the behaviour of residents (Innovate UK 2016b; Kempton 2014), an individualistic paradigm that discounts the role of collective experience in everyday life. By contrast, this study focuses on practices, rather than individual actions, to understand how the complexities of social life relate to operating and maintaining ventilation.

Chapter 3 explores state-of-the-art knowledge on the subject. The need for a radical reduction in carbon emissions from homes, in order to mitigate climate change, is well evidenced. The UK target of zero emissions by 2050 is leading to increasingly airtight dwellings that cut heat loss and thus energy use for heating. Given the acceleration in policy and practice towards greater airtightness in homes, this research focuses on homes defined as low-energy in relation to their designed air exchange rate or airtightness (see definition at 3.3.1) and, specifically, on the effectiveness of ventilation in these homes. As evidenced in the literature (RCP & RCPCH 2016; Howieson 2014; McGill et al. 2017), ineffective ventilation not only affects the energy use and carbon emissions of the home but has long-term consequences for the health of residents.

Although the design and construction of airtight homes and associated ventilation technologies have received increasing attention, the literature reveals that design and technology alone do not guarantee effective ventilation. Previous research refers to the importance of maintenance and operation of the means of ventilation in low-energy homes, but there is a gap in knowledge of the ventilation practices of residents and maintenance practitioners, the latter being a group largely missing in the literature. This research seeks to address this gap.

Chapter 4 develops a qualitative, multi-method, case-study design as an appropriate strategy for collecting rich experiential data from a range of participants, in order to fulfil the objectives set out in chapter 1.

The results of the fieldwork are set out in *chapter 5*. Following a scoping survey (34 respondents) and focus group (17 participants), data collection focuses on five case-studies of low rent, low-energy housing schemes in England, meeting the airtightness definition set out and having a range of ventilation systems. Interviews took place with 18 residents and 16 housing association staff in a range of roles, including maintenance practitioners in each case.

In *chapter 6,* data from residents is analysed, using the practices framework adopted. This reveals the range of influences on ventilation practice and the scale of ventilation demand created by normal household activities, dimensions of ventilation not reflected in low-energy home design. Findings indicate that the experiential knowledge of residents is typically undervalued by comparison with technical expertise, compounding the lack of systematic post-occupancy evaluation. Adopting new ventilation practices in homes with continuous mechanical ventilation is evidently further hindered by inadequate communication and mixed messages.

In *chapter 7,* data from maintenance practitioners is analysed, using the same practices framework. The analysis reveals that the importance of effective ventilation and the impact of maintenance practice are undervalued by housing associations. Maintenance practitioners express frustration that maintenance is rarely considered in the design and specification of new homes and an underlying belief that residents' habits are responsible for ineffective ventilation.

The discussion in *chapter 8* introduces and defines the concept of Time Horizons and discusses this in relation to the literature on time and practices. It is contended that Time Horizons represent an additional dimension to practices and deepen understanding of the research topic. Analysis of the influence of Time Horizons on significant issues in ventilation practice for residents and maintenance practitioners illustrates the concept. The relationship between Time Horizons and their relevance to the interactions between bundled practices is then discussed.

The theoretical insights in chapter 8 are followed by a discussion in *chapter 9* of ventilation maintenance in the context of bundled practices through the lifecycle of a typical low-energy housing association dwelling. Four significant bundled practices are identified in the data. The findings indicate that ventilation effectiveness is significantly hindered by obstacles to interaction between practices, which can be partly explained as the influence of conflicting Time Horizons. An alternative pattern of interactions is proposed, that would support effective ventilation practice.

This *Conclusion* draws on the analysis and discussion to answer the research questions. Three key themes, that link ventilation effectiveness to health, carbon emission reduction, and housing practice, are drawn out in the response to research question 3. The contribution to theory of the concept of Time Horizons is offered. New knowledge on the research topic is set out and the contribution to practice and policy is proposed.

Reflections are made on the wider context of this research: the ongoing climate emergency that drives the need for airtight homes and the Covid-19 pandemic that has dramatically raised the importance of domestic ventilation and the significance of this research. Finally, recommendations are offered for policy and practice and for further research.

10.2 Key findings in relation to the research questions

10.2.1 Research question 1

> What are the key practices of maintenance practitioners and residents that shape the maintenance and operation of ventilation in low-energy housing association homes?

Gathering data to answer this question was initiated by an exploration of the state-of-the-art relating to the topic, through a systematic literature review and discussions with relevant experts in the field (Objective 1). Typical ventilation maintenance practices in UK social housing organisations were scoped in an online survey and follow-up focus group (Objective 2). Ventilation practices in low-energy housing association homes were then investigated in depth in five case-studies, using qualitative methods, focusing on the experience of maintenance practitioners and residents (Objective 3). The rich data gathered at these stages of the research revealed the key practices of ventilation maintenance and operation in low-energy homes, as follows in answer to question1.

1. **Maintenance practitioners typically take responsibility for maintaining new low-energy homes only at the end of the defects liability period, with little or no involvement in the design and specification of schemes or in handover from the contractors.** As a result, ease of maintenance is overlooked as a factor in the specification, physical accessibility for maintaining equipment is not considered, and advance planning by maintenance practitioners for the skills or contracts required for servicing is hindered. Recommended maintenance practice is not established at the outset and essential servicing may not be carried out. Maintenance of ventilation equipment is typically categorised as a routine and non-urgent practice, and thus dependent on residents' variable ability and willingness to identify and report problems with ventilation or air quality. Reports that could indicate ineffective ventilation may be ignored as a result of lack of knowledge or understanding of the systems installed, due to maintenance practitioners having no involvement in development practices.

2 **A key hidden aspect of maintenance practice is that the impact of indoor air quality on the health of residents does not appear to be considered** as this lacks meaning for maintenance practitioners in relation to ventilation. Health-unaware maintenance practice therefore does not evolve to incorporate the new tasks of replacing filters and planned servicing that whole-house ventilation systems in low-energy homes require to ensure healthy indoor air.

3 **The findings indicate that maintenance practitioners habitually attribute any negative consequences of ineffective ventilation, such a condensation, damp or mould, to residents' habits or 'lifestyles'**. This practice appears to be underpinned by a strong hidden driver in the practice, a belief by maintenance practitioners in technical know-how, in opposition to the experiential knowledge of residents. As a result, potential problems with ventilation equipment are not investigated as a routine practice. Maintenance service delivery rules appear to compound the reluctance to investigate the causes of reported problems believed to be the 'fault' of residents.

4 **Short-term priorities in delivery of the maintenance service can also overshadow long-term planning to upskill operatives** to maintain the new ventilation technologies in low-energy homes in the development pipeline. This is exacerbated by a wider shortage of the skills required to maintain whole-house ventilation technologies, which are underdeveloped and fragmented between traditionally separate building trades.

5 **The design and specification of means of ventilation in low-energy homes appears to ignore the diversity of practices that can influence ventilation and underestimate the scale of demand generated by normal household practices,** particularly in small, fully occupied, low rent homes. For example, family-sized laundry loads will be dried indoors if there is no practical and affordable alternative, creating a need for extra ventilation that the system design cannot cope with. The first-hand experience of residents is not routinely captured and fed back to designers as a part of development practice, leading to such shortcomings in ventilation provision in low-energy homes being perpetuated.

6 **Ventilation by opening windows and doors is typical 'natural openings' operational practice, used by residents to supplement, or in some instances replace, use of a whole-house ventilation system.** This practice reflects beliefs

that fresh air is external air and therefore airflow from open windows is necessary to clear germs and unwanted human and pet odours from the home. The practice of window use is, however, commonly hindered by concerns about safety and security and physical difficulties with access and operation and, in this practice, tricklevents are frequently ignored or obstructed.

7 **Lettings practice does not always, as routine practice, include a home induction when residents move into a low-energy home with unfamiliar ventilation 'things'.** User-friendly instructions and one-to-one guidance appear to be the exception rather than the rule. Induction is often cursory and at the point of moving in, when residents have other priorities. Induction is frequently missing altogether, particularly when a mutual exchange has taken place, so that residents move in unaware that their new home has a whole-house ventilation system. As a result of ineffective induction new residents may continue ventilation habits from a previous home that compromise effective ventilation in a low-energy dwelling.

8 **The findings also indicate that residents' practice in seeking advice on unfamiliar home technology frequently leads to ineffective ventilation practice.** Confusing early encounters with ventilation systems are compounded when residents receive inaccurate or mixed messages about ventilation from neighbours, family or, indeed, from different housing association staff. It appears that uncertainty can lead residents to abandon use of ventilation systems, believing them to be a risk to health by spreading disease, for example from rodents in the property, or by circulating dusty air. Mixed messages about the costs and benefits of systems can similarly deter residents on low incomes from using systems consistently or at all.

10.2.2 Research question 2

> What shapes the interaction between bundled practices related to ventilation and how does this impact on ventilation effectiveness?

The foundation for answering this question was the data collected during the scoping and case-study stages of the research (Objectives 2 and 3). Applying a practice-based framework for the analysis, inductive coding techniques identified patterns, themes and linkages in the data. This revealed how bundled practices and interactions between them impacted on ventilation effectiveness (Objective 4). Understanding practices in this depth enabled the key bundled practices and their impact to be identified, as outlined below in answer to question 2.

1 The findings indicate that **beliefs about fresh air and ventilation** play a prominent part in the ventilation practice of residents and maintenance practitioners, strongly influenced by a past Time Horizon for both groups (see 9.2.1). These beliefs led residents in the case-study schemes to regard window opening as their primary means of bringing healthy fresh air into the home, a 'meaning' that they did not associate with whole-house ventilation systems. Although maintenance practitioners shared these beliefs to some extent, their practice of maintaining the systems as installed created friction with residents' ventilation practice, both practices being influenced by a present Time Horizon. The findings suggest that this friction between bundled practices can lead to a degree of mutual disregard between these parties, rather than any change in practices to optimise operation and maintenance of the installed ventilation 'things'.

2 The **'rules' shaping practices** of residents and maintenance practitioners evidently interact in ways that can undermine the effectiveness of ventilation. Maintenance practice 'rules' assume the 'correct' ventilation of homes by residents, leading to reluctance to investigate ventilation problems that they attribute to residents' 'lifestyles'. However, this can be in conflict with, for example, the budget 'rules' of residents that lead to switching off ventilation systems to save money. The findings indicate that a conflict between rules can hinder interaction between bundled practices, seriously compromising effective ventilation (see 9.2.2).

3 The research reveals that lack of interaction between the wider bundled practices of housing associations has a significant, but sometimes hidden, impact on ventilation effectiveness. The underlying factor impeding interaction between diverse practices is identified (see 9.2.3) as **the practice of 'silo working'** evident in the case-study associations, accompanied by inadequate and random internal communications. The impact of these practices is demonstrated in section 9.3 by considering bundled practices impacting on ventilation at each phase and

transition point in the lifecycle of a typical low-energy rented home. Silo working hinders interaction between practices by creating a disconnection between the short-term design and construction phase, and the long-term occupation, management and maintenance phase of a dwelling's life. However, analysis in chapter 8 of Time Horizons influencing practices suggests that this conceptual barrier can be overcome by an alternative ordering of housing association practices, that will promote interaction and support effective ventilation of low-energy homes for the long-term.

4 A further factor identified as relevant to the interaction between ventilation practices is the **quality of communication** between housing associations and residents in low-energy homes. The impact of lack of effective induction practice and mixed messages, especially at the first or early encounters with unfamiliar ventilation systems, evidently has a material and enduring impact on residents' ventilation practice, entrenching practice influenced by a past Time Horizon that can be inappropriate in a low-energy home (see 9.2.4).

10.2.3 Research question 3

What are the underlying themes that inform the effectiveness of ventilation in low-energy housing association homes?

Building on the understanding of bundled practices and interactions (Objective 4), thematic analysis led to the identification of underlying issues relevant to the research topic (Objective 5). This analysis revealed three significant themes influencing ventilation effectiveness in low-energy housing association homes. These are detailed below in answer to question 3.

Theme 1 The impact of ventilation on health is not reflected in housing association ventilation maintenance practice

The link between indoor air quality and occupants' health has been extensively researched and documented by others. However, the findings of this research indicate that the impact of home ventilation on indoor air quality, and therefore on health, is not reflected in ventilation maintenance practice related to low-energy housing association homes.

Building regulatory practice applying to the design and specification of new homes is driven by the imperative to mitigate climate change by reducing carbon emissions, a goal that underlies the progressive airtightness of homes. Means of ventilation consistent with airtightness levels are prescribed by the regulations, but although the airtightness of new homes is tested at build completion, there is no requirement to test means of ventilation and resulting air quality. This means that passing the airtightness test at the point of completion of new homes is a priority for building contractors but ongoing ventilation and air quality are not considered important. The findings indicate that development practice is focused on complying with building regulation but not with how ventilation will be operated and maintained to ensure healthy homes in use.

Moreover, there is no legislation prescribing air quality standards in occupied dwellings or a requirement to monitor air quality, as required in some types of non-domestic buildings. In the absence of any legal requirements, and in the light of low awareness of the health impact of inadequate ventilation, housing association practices do not attribute the same priority to ventilation maintenance as to practices related to, for example, the maintenance of gas, electricity and water facilities, where legislation is in place to protect health. Although voluntary codes and standards, and indeed the business objectives of many housing associations, promote a wider meaning of a 'healthy home', funding pressures and competing priorities were found to override a desire to exceed minimum standards.

By contrast, residents' concerns about health typically underpin ventilation practice within the home. Opening windows is commonly described by residents as the 'healthy' way to ventilate the home. Nevertheless, window-opening is not universal practice, its effectiveness in meeting the ventilation need of the home is variable, and its impact on air quality is uncertain, particularly where external air is polluted. Ironically, a ventilation system intended to ensure healthy indoor air may be ignored in favour of random ventilation believed by residents to be a healthier option.

However, awareness of the health implications of indoor air quality, and the importance of effective ventilation in dwellings, abruptly and significantly increased in the light of the Covid-19 pandemic, which gained momentum in the UK from March 2020. As the Deputy

Chief Medical Officer for England, Professor Jonathan Van-Tam, asserted, ‘there is a definite truism across all of the science literature that ventilation is a most critical part of reducing transmission from respiratory viruses’ (Government 2020). Discussion on the impact of the pandemic on the practices of home design and regulation related to ventilation quickly emerged in the architectural community (Gbolade 2020; Hipwood 2020). A reassessment of the priority accorded by housing associations to the maintenance and operation of ventilation, to ensure healthy air quality in airtight low-energy homes, is similarly required.

Theme 2 Ventilation design is driven by carbon emission reduction, but maintenance and operation practices are not

Increasing the airtightness of homes, to reduce heat loss and thus minimise energy use and carbon emissions, is regarded as a key strategy in meeting the UK target of zero-carbon emissions by 2050. Designing and building airtight dwellings, with appropriate ventilation strategies and systems is therefore becoming the norm.

Cutting carbon emissions was a key motivation for the low-energy design of the housing schemes selected as case-studies, in anticipation of expected legislation. A related driver was reducing fuel bills for residents, given the low incomes of typical housing association tenants. Both these objectives require practices in use that optimise ventilation performance, whatever means are installed, to reduce heat loss.

However, the findings indicate that ventilation operation and maintenance practices are influenced by a bundle of practices (see chapters 6 and 7 and 10.2.1). Cutting carbon emissions does not appear to be a ‘meaning’ in ventilation practices for either maintenance practitioners or residents, even if it underlies the design of the homes that they occupy or maintain and is an explicit objective of the housing association. As a result, the means of ventilation are not, as practices, maintained or operated as intended by the designer, compromising performance.

However, abandoning the use of whole-house ventilation systems in favour of window-opening as the primary means of ventilation, in response to the dissatisfaction with whole-house systems expressed by maintenance practitioners and residents, is inconsistent with optimising the reduction of carbon emissions (London Energy Transformation Initiative 2020). This contradiction between design practices driven by carbon emission reduction, and maintenance and operational practices motivated by quite different factors, presents a critical challenge for the industry to address.

Theme 3 Disconnections between housing practices inhibit effective ventilation practices

Practices associated with rented housing association dwellings are characterised by the disconnection of the short-term design and construction phase from the long-term occupation, management and maintenance phase, with implications for ventilation operation and maintenance practices throughout the life of the dwelling (see chapter 9).

Structural factors, observed in the typical practice of 'silo' working in the case-study housing associations and poor communication practice within and between teams, entrench this disconnection, which is perpetuated by conflicting meanings and rules in interrelated practices. The wider bundle of practices that shape ventilation practice operate within different timeframes (see 9.3.1), although all impact on ventilation effectiveness throughout the lifespan of a dwelling.

Disconnections between this bundle of wider housing practices obstruct both the 'feedforward' of technical knowledge from the design and build stage to the occupation, management and maintenance stage, and 'feedback' of experiential knowledge vice versa. It appears untypical for maintenance and housing management expertise to be engaged in the development process, and rare that residents make any input at that stage. Similarly, it is unusual for designers and development practitioners to be involved after the end of the defects liability period and untypical for meaningful post-occupancy evaluation to be a part of development practice. Furthermore, the practice of 'silo working' evidently hampers the development and use of corporate data systems and, as a result, 'organisational forgetting' perpetuates ineffective ventilation practice.

Breaking down this conceptual 'silo' barrier (see 9.3.2) has the potential to reinforce interaction between bundled practices and communication between performers and ensure effective ventilation in the long-term. However, the alternative pattern of connected housing practices proposed will only achieve this goal if experiential, as well as technical, knowledge is respected.

10.3 Contribution

10.3.1 Contribution to theory

This research adopts Practice Theory as the framework for investigating the topic, analysing the data against four components of practices described by Gram-Hanssen (see chapter 2). The analysis in chapters 6 and 7 identified an additional new dimension of practices, interacting with the four components, described in chapter 8 as Time Horizons and defined as *the individual and collective awareness of future, past or present experiences or expectations that plays a part in the life of practices.* This concept challenges the binary understanding of time – clock-time and time-duration – that predominates in the literature on theories of time.

The influence on ventilation practice of cognitive knowledge beyond definable habits, meanings, rules and things, described as a continuous and shifting Time Horizon, is applied as a new concept in the practice-based analysis in this study. The analysis indicates that Time Horizons interact with habits, meanings, rules and things to shape practices, offering a deeper understanding of why ventilation practices may conflict with each other and fail to ensure effective ventilation in low-energy homes. It is argued that awareness of these underlying influences on practices offers greater potential for success in changing practices and may indeed suggest new opportunities for change (see chapter 8).

10.3.2 Contribution to knowledge

This study reveals new knowledge about how bundled practices impact on the effectiveness of ventilation in providing healthy air in low-energy housing association homes. This knowledge is significant and timely in the light of the increasing levels of airtightness required in new homes to reduce carbon emissions and growing awareness of the importance of effective domestic ventilation for indoor air quality and residents' health. The insights detailed below therefore represent a meaningful contribution to knowledge on the research topic.

1 The ventilation practices of maintenance practitioners and residents are shaped by a diverse bundle of practices. Ventilation effectiveness in low-energy homes is impacted by numerous practices throughout the lifecycle of the dwelling, some of which are hidden, such as practice on repair categorisation, mutual exchanges, household budgeting and pet care (see findings in relation to RQ1, RQ2, RQ3).

2 Disconnections within housing associations between practices, characterised as 'silo working', contribute to ineffective ventilation in airtight homes. The lack of integration between practices at multiple phases and transition points in the lifecycle of a low-energy dwelling obstructs the evolution of ventilation practice, resulting in inappropriate maintenance and operation of the ventilation systems required in such homes (RQ2, RQ3).

3 The design and specification of low-energy homes ignores the diversity of practices that impact on ventilation practice and the scale of demand for ventilation created by normal household activities (RQ1).

4 The impact of indoor air quality on health is not considered a factor in maintenance practice. By contrast, 'fresh air' is a high priority for residents, who typically regard opening windows as the healthy option for ventilation, even where whole-house ventilation is in place (RQ1, RQ2, RQ3).

5 The design of low-energy homes is driven by the need to reduce heat loss and carbon emissions, objectives that underpin building regulatory practice, placing the emphasis on airtightness. The absence of mandatory testing of means of ventilation and the lack of legislation in England regarding domestic air quality contribute to housing associations placing a low priority on ventilation effectiveness. Specifically, the findings indicate that the ventilation practices of maintenance practitioners and residents are not driven by carbon reduction but by a variety of other factors, leading to maintenance and operation of ventilation

systems that is inconsistent with the designer's intentions, risking ineffective ventilation and, indeed, higher than projected heat loss (RQ3).

6 The objective of maintenance-free ventilation systems, using standard equipment and existing skills, informs ventilation maintenance practice. However, this conflicts with the maintenance required for effective ventilation of airtight homes with whole-house ventilation systems that need regular servicing and new skills (RQ1).

7 The findings indicate that effective ventilation maintenance practice is hindered not only by disconnections between housing association practices, but specifically by friction between the practices of maintenance practitioners and residents. Underlying this friction appears to be a mutual discounting of know-how and expertise. The habit of maintenance practitioners valuing technical expertise above experiential know-how appears to be hindering ventilation practices in low-energy homes, with consequences for indoor air quality (RQ1, RQ2).

The use of a case-study design frame (see 4.3) to explore in depth a small number of cases, selected to encompass a range of defined characteristics, has uncovered rich data on the research topic. Although the findings cannot be generalised to *all* cases, they are nevertheless indicative and reveal knowledge that has wider significance across the field of the research (see scope at 1.4) (Flyvbjerg 2006). This suggests that further studies to build on these findings would be of value.

10.3.3 Contribution to practice and policy

Findings from the research confirm the critical importance of effective ventilation maintenance practices for ensuring that homes achieve two key criteria: healthy indoor air and low energy use to cut carbon emissions. These findings are relevant to the policy, legislative and regulatory frameworks in relation to carbon emissions and healthy homes, as well as being pertinent to the practices of housing associations developing, managing and maintaining low-energy homes.

1 Although the policy imperative of cutting carbon emissions, reflected in building regulatory practice, is the driver for low-energy home design practice, the findings indicate that *carbon emission reduction does not drive effective ventilation maintenance practices.* As a result, the policy objective of reducing energy use and carbon emissions is compromised. This finding is relevant to the current review of Building Regulations and the proposed Future Homes Standard.

2 The findings show that a second imperative, healthy air quality in homes, does not drive either home design practice or ventilation maintenance practice. Recognising that *ventilation is a critical health responsibility*, notwithstanding the lack of legislation on domestic air quality, calls for a review of policies and practices that contribute to, or obstruct, effective ventilation. The significance of this issue for policy and practice, in the light of Covid-19, cannot be overestimated.

3 Recognising that *practices relevant to maintaining healthy indoor air span the full breadth of a housing association's activities and the whole length of a dwelling's lifecycle* is a prerequisite for effective ventilation in the long term. Healthy air quality in highly airtight homes is rooted not only in the practice of residents and maintenance practitioners, but in the practice of designers, contractors, and housing management practitioners, among others. Enhanced integration of the bundled practices of housing associations will impact significantly on ventilation effectiveness in properties throughout their lifespan. Disconnections obstruct the sharing of crucial data from the development phase of new properties to the occupation, management and maintenance phase, and the feedback of experience of homes in use to designers and developers. Countering the 'siloed' nature of association structures and practices is essential to a strategic approach to ventilation.

These strategic contributions to practice and policy inform the detailed recommendations in 10.6.1.

10.4 Reflections and limitations

10.4.1 Reflections

10.4.1.1 Climate emergency and ventilation

Arguably, the most significant issue influencing both present and future Time Horizons for society as a whole is global climate change and its potentially catastrophic impact on the natural world. Scientific evidence that anthropogenic greenhouse gas emissions are creating global warming is the impetus for reducing carbon emissions, with the UK target now set at net-zero emissions by 2050 (Department for Business Energy & Industrial Strategy 2019b). Indeed, environmentally conscious designers, and some housing association strategic plans, may result in net-zero carbon targets ahead of the Government target (RIBA 2019). However, although the shift from a relative target, i.e. a percentage reduction in carbon emissions over time, to an absolute target, i.e. net-zero emissions, reflects the critical nature of the issue at a strategic level, it appears that, crucially, carbon emission reduction is not yet influencing housing association maintenance practice. Given the impact of maintenance practices on the performance of ventilation systems, as identified in this study, this suggests that housing association low-energy homes may not reduce carbon emissions to the extent projected.

The role that correctly maintained and operated mechanical ventilation systems play in reducing heat loss, and thereby carbon emissions, in airtight new homes does not drive ventilation practice for maintenance practitioners or residents. Indeed, there appears to be some annoyance among residents at ‘this eco stuff’ and a level of frustration among maintenance practitioners at the requirement to service ventilation systems. Although housing associations may be committed to mitigating climate change as a strategic priority, embedding this objective in the bundle of practices that shape ventilation maintenance and operation is necessary to cut carbon emissions from homes in use.

While rules to reduce carbon emissions from domestic buildings prioritise the construction stage and operational energy in use, it is now recognised that embodied carbon is critically important in the whole life carbon performance of a building (UK Green Building Council 2019; London Energy Transformation Initiative 2020). Maintenance activities contribute to embodied carbon and it is argued that servicing and maintaining ventilation systems as recommended by the manufacturer extends the life of the system, reducing the carbon emissions generated by replacement.

Thus, effective ventilation maintenance has a dual benefit in mitigating climate change: optimising energy performance of homes in use and minimising carbon emissions from maintenance over the dwelling's lifetime.

At the level of Government policy, the disconnect between policies specifically directed at carbon emission reduction and policies that impact on that objective but are not recognised as such, mirrors the analysis of energy policy by Royston and Selby:

> The assumption that energy policy is the only kind of policy that matters for energy demand is deeply embedded in the practice of many different organisations and institutions (whether it is made explicit or not). (Royston and Selby 2019: 113)

They argue that 'the effects of non-energy policies are rarely recognised in research and government' and that recognising the impact of policies apparently unrelated to energy 'opens up a new agenda for research and policy, and new opportunities for intervention and change' (ibid.: 117). It is suggested that recognising the impact of ventilation maintenance on the energy performance, and carbon emissions, of low-energy homes similarly offers additional scope for housing associations and policymakers seeking to mitigate climate change, while acknowledging that the climate emergency requires radical attention to the bigger picture in energy research (Galvin 2020).

10.4.1.2 Covid-19 pandemic and ventilation

The present emergency engulfing the world may not be an existential threat to the planet but nonetheless is threatening lives, economies and social structures in every continent. Given the increasing scientific evidence that airborne transmission is a major factor in the spread of the Covid-19 virus (Scientific Advisory Group for Emergencies 2020b), indoor air quality and ventilation in buildings have rapidly become high priority issues for prevention and mitigation of the disease. Advice to increase the air exchange rate raises questions about the flexibility and effectiveness of means of ventilation in the building (Scientific Advisory Group for Emergencies 2020a; CIBSE 2020; Miller 2020).

Concerns about air quality are particularly significant in relation to the focus of this study. As the research has revealed, low-energy airtight homes with whole-house ventilation systems may not be effectively ventilated if maintenance practice is inadequate. Residents may supplement or replace whole-house ventilation by opening windows and doors, but the resulting level of ventilation will be variable and not necessarily provide the air exchange rate required to reduce exposure to the virus. Although drawing in external air will dilute the concentration of the virus indoors, the external air may be polluted, a particular risk for low rent housing which is often located in inner city areas where external air pollution is high.

Poorly ventilated homes, fully occupied or overcrowded, where households are least able to heat the home adequately in winter, present the greatest risk to occupants of airborne transmission of viruses (Academy of Medical Sciences 2020). In the social housing sector, where a high proportion of residents are elderly, with long-term health problems or disabilities, the risk is compounded.

In the longer term, the current emergency may increase the pressure for legislation on domestic air quality and regulatory checks on ventilation systems. Calls are growing for the monitoring of CO_2 levels in indoor spaces as a proxy for sufficient air exchange (Miller 2020), as is already required in the principal bedroom in new airtight homes in Scotland to raise occupant awareness of the dangers of inadequate ventilation (The Scottish Government 2019). In the short term, the rationale for housing associations to treat air quality and ventilation effectiveness in their rented homes as a strategic responsibility is overwhelming.

10.4.2 Limitations

Restricting the fieldwork to England was a practical decision early in the research planning and eliminates the factor of variable policy and regulation in different countries, including variations between the UK nations. However, this precludes comparison of the effect that different national priorities may have on practices. For example, the significantly higher priority placed on the health impact of damp and mould in Danish homes would be interesting to compare with policy in England, to explore the impact of national policy on ventilation practice (Bonderup and Gunnarsen 2017). As such, the practice findings are only indicative for England, although the theoretical contribution has wider implications.

The limitation of the study to residents in low rent housing association dwellings and maintenance practitioners in the social housing sector relates to the knowledge gap identified and the aim of the research. However, the factors relevant to other tenures, including housing association tenants who have exercised the Right to Acquire, may be different. As all the residents in the case-study schemes held non-time-limited Assured Tenancies, it is not possible to assess how insecurity of tenure might change the influence of a future Time Horizon on ventilation practice. However, it is evident that engagement varies significantly, even between residents with the same tenure and equal level of security. While practice in the private rented sector has a similar split of responsibility for effective ventilation between landlord and tenant, practice in the owner-occupied sector has no such division. Ventilation effectiveness in low-energy homes in other tenures was outside the scope of this research.

While the focus of this research is the practices related to ventilation maintenance, not the individual performers of the practices, it is suggested that the factors shaping practices, including the influence of Time Horizons, are bound up with gender, class and culture and the intersections between these. Although a detailed analysis of these issues in relation to ventilation practice is outside the scope and resources of this study, this is acknowledged as a significant limitation of the research. Gender issues were evident from the outset of the fieldwork, with the pilot interviewee explaining that she did not understand how the ventilation system in her home worked as ‘it’s a boy thing’, supporting the assertion that ‘everyday practices in the home and ideas on home and housing are highly gendered’ (Mechlenborg and Gram-Hanssen 2020: 1). Practices within the building sector are no less shaped by gender and class, making these factors particularly significant in relation to ventilation in low-energy homes, where ‘the introduction of new technologies and new links in producer-consumer relations may also have unforeseen consequences for power relations and gender equality’ (ibid.: 1).

10.5 Conclusion

This research is rooted in the intersection of two critical issues related to housing at the current time. Firstly, mitigating climate change makes deep cuts in carbon emissions imperative. Secondly, the quality of indoor air in homes is a vital concern for the health of residents, a concern magnified by the emergence of Covid-19.

Making homes airtight to reduce heat loss is leading to whole-house ventilation systems becoming the norm, creating a risk to air quality if these systems are not maintained and operated effectively. A gap in knowledge regarding ventilation practices in low-energy homes in use has been uncovered, in particular the practices of maintenance practitioners, key players in ensuring effective ventilation but virtually missing from consideration of this issue to date.

Investigating how fresh air is maintained in homes, taking an interpretive case-study approach, has revealed the breadth and complexity of practices, including previously hidden practices, influencing ventilation demand and performance (see chapters 6 and 7). Analysis of these practices in low-energy housing association homes has deepened understanding of how they evolve and interact, leading to the proposal that a new theoretical dimension, Time Horizons (see chapter 8), can get closer to the root of practices and indicate the potential for change. Illustrating how bundled practices obstruct ventilation maintenance in a typical low-energy rented dwelling is the basis for an alternative view, exploiting the potential for change that different Time Horizons offer (see chapter 9).

The entrenched disregard for the importance of ventilation maintenance revealed in the study should be an issue of serious concern in the housing sector. The climate emergency will surely accelerate the shift to airtightness in home design, but without effective ventilation, maintained throughout the life of the dwelling, the health of residents will be at risk. The advent of Covid-19 has exposed, tragically and suddenly, the danger in the finding that indoor air quality has a low priority in housing association practices.

Revealing through this research a deeper understanding of how fresh air is maintained in low-energy homes, cutting carbon emissions *and* providing healthy indoor air, is therefore both significant and timely.

10.6 Recommendations

10.6.1 Recommendations for policy and practice

Specific recommendations for policy and for housing association practice, reflecting the strategic findings detailed in 10.3.3, the practices detailed in chapters 6 and 7 and discussion in chapters 8 and 9, are as follows.

1. The current review of Building Regulations for England and the proposed Future Homes Standard should consider how the effective maintenance of means of ventilation in homes in use can be incorporated in regulation. This is essential to ensure that the regulatory objective of reducing energy use and carbon emissions is not compromised, while ensuring healthy indoor air.

2. The need for policy and legislation on domestic air quality should be reviewed. This review should consider how effective ventilation maintenance over the lifetime of a dwelling can be ensured.

3. Good practice guidance for housing associations should highlight the importance of indoor air quality for residents' health and the responsibility of associations to effectively maintain adequate means of ventilation. Specific recommendations could include:

- Anticipate the wide range and scale of typical household practices, such as laundry, cooking and pet care, that create a need for ventilation. Assess the impact of these in fully occupied, low rent, highly airtight homes. Reflect these needs in design and in the ventilation strategy and specification.
- Incorporate input in the briefing and design of schemes from those with experience of living in, managing and maintaining homes, to avoid the repetition of ineffective ventilation in new homes in use.
- Build in feedback loops, as an integral part of practice for new homes and through the life of the dwellings, to capture and use experiential as well as technical data.
- Specify window design that avoids barriers to use, including security, safety of children, accessibility, location, usability, maintainability, enabling window-opening to supplement whole-house ventilation.
- Ensure an effective induction for all new residents in low-energy homes, as first encounters with unfamiliar ventilation systems significantly influence ongoing practice.
- Incorporate ventilation briefing in lettings practice for all new lettings, including mutual exchanges.
- Ensure maintenance practitioners receive full induction in the ventilation systems installed and the maintenance regime required.
- Establish appropriate maintenance systems at the outset, including planned servicing at recommended intervals and categorising repairs related to ventilation as urgent.

10.6.2 Recommendations for further research

1 This research has focused on new-build low-energy homes in the housing association rented sector. High levels of airtightness and associated whole-house ventilation systems will become the norm in all housing sectors and, as the pressure grows to reduce carbon emissions, a similar approach will extend to existing as well as new homes. The importance of effective ventilation in all homes, heightened by the presence of Covid-19, suggests that extending the research to other housing types and tenures would be of value. For example,

owner-occupiers are responsible for the maintenance *and* the operation of means of ventilation, so different practices could be relevant.

2 The research was limited to homes in England. Exploring ventilation maintenance practices in the other UK nations and outside the UK would allow comparison and learning from practices where different housing characteristics, policies and regulations apply in respect of ventilation.

3 The research indicated underlying perceptions of the nature of 'development' and 'maintenance' as practices, that played a part in the disconnection between them but could not be fully explored in this project. Further research exploring the contrasting characterisation of creative/innovative development practice and repetitive/housekeeping maintenance practice, would deepen understanding of these perceptions.

4 Exploring the impact of gender on the practices relevant to effective ventilation was beyond the capacity of this study. Given the relevance of gender, and its intersection with race and class, to everyday domestic practices, exploring these factors in the context of home ventilation would be a valuable direction for further research.

5 The concept of Time Horizons has been introduced in this research and illustrated in the analysis of ventilation maintenance practice. Further research is needed to explore whether the concept adds a useful dimension to the analysis of practices in other contexts and to gain a deeper understanding of how Time Horizons influence practices.

Appendix 1. Case-study planning meeting

Case Study Planning Meeting	
Housing association	
Location	
Date/time	
Present at meeting	
Case study scheme	

Phase 1 – online survey (Nov 17) and focus group (Jan 18) with maintenance practitioners, supported by NHMF
Phase 2 – five case studies, housing association schemes, low energy, low rent homes, across England

At each scheme
- Documents review
- Site observation
- Interviews, up to 8 in total — 4-5 with residents + walkthrough; 3-4 with HA staff
- Wrap-up meeting with HA lead contact

1 Timetable

Documents in advance – see 5

All interviews in one week - provisional date
Any problems foreseeable for that week?

2 Resident interviews

Aim is to select 4-5 residents per case study to give a mix, within the scheme if feasible, and across the five schemes, of

Dwelling types	size by number of bedrooms
	flat/house/etc
	ventilation strategy – MVHR/MEV/etc
Household types	single/multi-person
	with/no children

age range

Residents not chosen to be *representative* of these groups, but to cover the widest *range* of characteristics that are relevant to the study

Is the HA able to use data on dwellings and households to help with selection?

Invitation letter to be sent by HA to all residents (rented homes only) on the scheme see draft letter

- Participating in an interview is entirely voluntary
- All participants, their contributions and the HA will be anonymous
- Researcher is independent of the HA
- All responses will be acknowledged
- 4-5 residents of the scheme will be chosen to take part to give a range of dwellings and households
- Anyone in the household can take part in the interview
- Enclose information sheet copy
- Enclose consent form (to be signed at start of interview) copy

Ask those who are interested in taking part to contact the researcher by email or phone or post

- Confirm willing to be interviewed
- Give days/times in the interview week when available (daytime or early evening)
- Give preferred contact details

Discuss selection of 4-5 residents with HA to give a range of dwellings and households

Who will do this?

Exclude any residents who are known to be particularly vulnerable or on the HA risk register

I will contact all who have responded

- Thank for their interest
- Confirm whether selected
- Arrange interviews with those selected
- Keep others in reserve

If less than 3 offer to take part

- Follow up email
- Consider reserve scheme

Interviews will take 45-60 mins including walkthrough of home, if resident agrees to this

Interview and walkthrough will be voice recorded, with photos and short video clips taken during walkthrough

Will show photo ID card on arrival
Any other steps required for resident safety?

Will phone in/out to third party for my safety

Who should I report any safeguarding issues to? (e.g. child alone)

Data protection/anonymity
- All digital data will use codes only, no personal identifiers
- All hard copy data, including personal data, will be held securely
- Analysis and any reports etc will use codes only

No incentives offered, small thank you gift afterwards

3 Staff interviews

Aim is to select 3-4 staff per case study who are familiar with the scheme and/or with maintenance practices at the HA and/or with specifying new developments

Three key people will be

1 Devt Manager/Senior Devt Off/equiv post
Ideally person involved at devt and/or handover of the scheme
Person with knowledge of spec for new schemes, vent systems, devt procedures

2 Maint Man/Senior Maint Off/equiv post
Ideally person familiar with maint history of the scheme
Person with knowledge of maint policy and procedure, vent systems

3 N'hood or Hsg Manager/Senior Hsg Officer/equiv post
Ideally person familiar with management history of the scheme, involved at handover stage
Person with responsibility for scheme management, who carries out new/re-let inductions, knows the residents

Other to be considered – anyone else with significant influence on HA policy and practice re ventilation and/or significant interaction with residents re ventilation and/or significant knowledge of the scheme
e.g. Sustainability Manager, M&E Services Manager, Quality Manager, Energy Efficiency Officer, Customer Services Officer, Performance Officer, equivalent posts

Who are the relevant contacts at the HA?
Development
Maintenance

N'hood/Housing Management
Others

Email from lead contact to prospective staff interviewees
Adapt resident letter

- Participating in an interview is entirely voluntary
- All participants, their contributions and the HA will be anonymous
- Researcher is independent of the HA
- Enclose information sheet copy
- Enclose consent form (to be signed at start of interview) copy

Ask staff to respond to researcher by email

- Confirm willing to be interviewed
- Give days/times in the interview week when available (daytime or early evening)

I will contact all who have responded to thank for taking part and to arrange interviews

Interviews will take about 30 mins and will be voice recorded

If some staff decline - discuss and agree alternative staff to approach with lead contact

4 Documents

Documents still to obtain see document checklist

5 Site observation

Make notes on the site during the interview week
Take photos externally

Is it possible to look round a void property if there is one available during the interview week?

6 Wrap-up meeting

At end of interview week, one hour meeting, arranged in advance
Lead contact + others as HA wishes
All interviews are anonymous so individual comments, staff or residents, will not be shared
Discuss overall findings and add any further comments
Review the process and next steps
Association will be anonymous in research findings
Thank you to the association

Appendix 2. Ethics consents

Phase 1: Survey and Focus Group

Downloaded: 23/10/2017 Approved: 23/10/2017

Jennifer Brierley
Registration number: 160129542 School of Architecture Programme: Research PhD

Dear Jennifer

PROJECT TITLE: Ventilation in low energy rented homes: maintaining effectiveness and the impact of practices
APPLICATION: Reference Number 015570

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 23/10/2017 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

University research ethics application form 015570 (dated 07/10/2017). Participant information sheet 1035085 version 3 (07/10/2017). Participant consent form 1035086 version 3 (07/10/2017).

The following optional amendments were suggested:

(1) Including the identification number on the consent form will mean that it could be used to de-anonymise the data. Is this necessary? (2) TUoS approves two methods of saving your work as detailed here: https://www.sheffield.ac.uk/cics/saving-your-work Please be clear about which method you will use for data back up. A password protected laptop is insufficient as it could be stolen.

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Yours sincerely

Chengzhi Peng
Ethics Administrator School of Architecture

Phase 2: Case Studies

The University Of Sheffield.

Downloaded: 30/03/2018 Approved: 27/03/2018

Jennifer Brierley
Registration number: 160129542 School of Architecture Programme: Research PhD

Dear Jennifer
PROJECT TITLE: Ventilation in low energy rented homes: maintaining effectiveness and the impact of practices: Phase 2

APPLICATION: Reference Number 018317
On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 27/03/2018 the above-named

project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

University research ethics application form 018317 (dated 05/03/2018). Participant information sheet 1041244 version 1 (05/03/2018). Participant information sheet 1041245 version 1 (05/03/2018). Participant consent form 1041246 version 1 (05/03/2018).

Participant consent form 1041247 version 1 (05/03/2018).

The following optional amendments were suggested:

(1) Approval is granted on the basis that the housing association managers are knowledgeable about their tenants and will duly advise households of high risks not to be invited for interviewing alone in residents' homes. The level of such knowledge should be assessed by the researcher first if a housing association and manager is new to the researcher. (2) Video recording can potentially compromise participating households' anonymity - this needs to be carefully considered before any filming starts. Participants' previewing the clips will help to detect any obvious or potential points of breaking anonymity.

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Yours sincerely

Chengzhi Peng

Ethics Administrator School of Architecture

Appendix 3. Survey questionnaire

Five Quick Questions on Ventilation

1. How do you keep ventilation working well in your rented homes?
(please tick all that apply)

- ☐ Responsive maintenance as and when problems reported
- ☐ No regular maintenance required for means of ventilation used
- ☐ Regular servicing to replace filters, balance system, check controls, etc
- ☐ Regular replacement of filters by the landlord
- ☐ Filters supplied by the landlord and fitted by the resident
- ☐ Filters supplied and fitted by the resident
- ☐ Other (please describe)

2. Who carries out maintenance of any ventilation technology in your homes?
(please tick all that apply)

- ☐ In-house works team
- ☐ External maintenance contractor
- ☐ Gas servicing contractor
- ☐ Specialist heating/ventilation contractor
- ☐ No maintenance required
- ☐ Other (please describe)

3. From your experience of these means of ventilation, given the choice, which would you specify - or not specify - in future new homes?
(please tick one response for each option)

	No problem with specifying this	Some reservations but willing to specify this	Would not specify this	No experience of this
Openable windows	◯	◯	◯	◯
Trickle vents in window frames	◯	◯	◯	◯
Intermittent extract fans in kit/bath - manual/light switch operated	◯	◯	◯	◯
Intermittent extract fans in kit/bath - sensor activated	◯	◯	◯	◯
Passive Stack Ventilation	◯	◯	◯	◯
Continuous MEV - Mechanical Extract Ventilation	◯	◯	◯	◯
Demand controlled MEV - sensor activated	◯	◯	◯	◯
MVHR - Mechanical Ventilation with Heat Recovery	◯	◯	◯	◯
Extractor cooker hoods	◯	◯	◯	◯

Other (please describe)

4. What obstacles have you experienced to maintaining effective ventilation in your rented homes? (please tick one response for each issue)

	Not experienced this	Sometimes experienced this	Frequently experienced this
Maintenance requirement unclear	◯	◯	◯
Difficulty gaining access to homes	◯	◯	◯
Residents do not understand the need for ventilation	◯	◯	◯
Ventilation performance given low priority	◯	◯	◯
Cost of maintenance contract	◯	◯	◯
Equipment switched off by resident due to noisy system	◯	◯	◯
Equipment switched off by resident to save running costs	◯	◯	◯
Trickle vents/system vents blocked to prevent draughts	◯	◯	◯
Maintenance staff not familiar with technology installed	◯	◯	◯
Breakdown/unreliability of equipment/controls	◯	◯	◯
Filters difficult to replace/inaccessible	◯	◯	◯
Cost of replacement filters	◯	◯	◯

Other (please describe)

5. In your view, what are the three biggest problems, and the solutions, for social landlords in maintaining effective ventilation in rented homes?
(please describe briefly)

Problem no.1	
What would solve this?	
Problem no.2	
What would solve this?	
Problem no.3	
What would solve this?	

Appendix 4. Interview guide for residents

Interview Guide for residents

Date and time for interview in resident's home pre-arranged and confirmed by letter
Photo ID shown to resident on arrival

Voice recorder with mic worn by interviewer
Back-up freestanding voice recorder suitably positioned

Thank you very much for giving up your time to talk to me today.

My name is Jenny Brierley and I would like to begin by describing how the interview will work.

I'd like to learn from you how you keep your home well ventilated, or aired, and whether you experience any difficulties doing that. I'm interested too in any contact you have had with your housing association about ventilation in your home. Just to confirm, I'm a researcher at Sheffield University and completely independent of your housing association.

I hope that this research will help to ensure good ventilation in future new homes, especially housing association rented homes.

My questions should take around 30 mins. Please talk as freely as you wish on any issues you feel are relevant. There are no right or wrong answers. I'm here to listen, as you know best how your home works.

After the questions, if you are agreeable, I would like you to show me how the ventilation actually works in practice, by quickly showing me round your home. That should take about 15-30 mins.

I would like to record the interview, using a voice recorder, so that I catch all your comments. I will use the recording simply to make a written record of the interview. I would also like to make short video clips of any features around your home that are relevant to its ventilation, using an iPad. *Show recording equipment*

Everything you say, and anything that I video, will remain entirely anonymous. You will be able to check the notes and the video clips before I use them in the research.

The recording, the video clips and the written record will all be destroyed when the research is completed. If instead you are happy for these to be kept for future researchers to use, then you can agree to this on the consent form.

Check that the resident has received the information sheet and consent form to keep
Ask resident to complete and sign a consent form if happy with answers to any queries

Check that consent form has been fully completed and signed and retain this

Before we move on, is there anything you would like to ask? Are you happy to go ahead? Thank you. Let's start with some simple information.

Day/date of interview	
Start/end time/duration	
Weather	
Interviewer	Jenny Brierley
Interviewee	
Home address/postcode	
Phone/email/preferred contact	
Housing association	
Scheme name	
Anyone else present at interview	
Consent form signed	

How many people live in your home?			
	Female	Male	Unspec
Under 18			
18-34			
35-59			
60-79			
80 and over			

How many years have you lived here?	
If less than 3 years What was your previous home like? *Prompt: house/flat, old/new, low energy, type of heating/cooling*	
Does anyone in your home have long term health problems or a disability?	
Do you have any pets? What sort of pets? How many?	
Does anyone regularly smoke in your home?	
What is the usual pattern of occupation in your home?	

Always/usually someone at home Usually empty part of the day Usually empty all day Another pattern	

1 Airing or ventilating your home, and keeping it at a comfortable temperature, are closely linked, so first it will be helpful to know about how your home is heated and cooled.

Can you tell me about how you heat and cool your home and why you do it this way?
Prompt: main systems, additional appliances for heating/cooling, use in particular rooms, times, seasons

Do the facilities for heating and cooling your home meet your needs?
Prompt: comfort, cost, control

2 How do you ventilate or air your home and why do you do it this way?

What features or equipment is there in your home to keep it well ventilated and why?
Prompt: openable windows, trickle vents, fans, MVHR, cooker hood, vents

How easy is it to understand and operate this equipment and why?
Prompt: please show me when we walk round

3 How does the air inside your home generally feel? Why do you think this is?
Prompt: fresh, comfortable, stuffy, damp, stale, cooking smells lingering, unpleasant smells from outside or inside

If there are times when your home doesn't feel well aired, when does this happen and why?
Prompt: times of day, season, weather, after cooking, drying clothes, house full, after bathing, after being out, coming home from being away

4 What do you do to deal with these situations and why?
Prompt: open windows, close windows, use boost switch, turn on fan, use cooker hood, turn heating on

Do these ways of airing your home work well?

If not, why not?

5 Does your home have any signs of damp or condensation?
Prompt: which rooms, where exactly, please show me when we walk round

How long have you had these signs and what do you think might be causing this?

What steps have you taken to try to get rid of the damp or condensation and why did you do this?
Prompt: contacted housing association, changed clothes drying, altered ventilation

Have you altered the way you ventilate your home for any other reasons? If so, could you tell me why?

6 Can you remember receiving any advice or instructions about ventilation, or about maintaining the equipment in your home, from your housing association?

When did you get this and what form did it take?
Prompt: when you moved in or recently, verbal or written, instructions specific to your home or general advice to all

What advice or instructions were you given?
Prompt: how to operate the equipment, how to maintain the equipment, where to dry washing, when to open windows, how to deal with condensation

Have you been able to follow these instructions or advice?

If not, are there any particular reasons why you've not been able to do that?
Prompt: need to do other things, didn't understand it, unreasonable advice, physical difficulty, equipment doesn't work, lost the instructions, forgotten the advice

Just a couple more questions…

7 Have you ever reported a problem to your housing association that prevents you keeping your home aired as you would like?
Prompt: draughts, damp, noise, stuffiness, unable to operate controls

What action did the association take?

How did you cope with the problem in the meantime?

Prompt: blocked draughts, stopped using rooms, switched equipment off, put up with it

What advice did the association give you? Were you able to follow this? If not, why was that?

Was the problem solved?

Finally…

8 Thinking about ventilation in your home, how does this home compare with other places where you have lived?

Do you do anything differently in this home compared to previous homes and could you tell me why?

Before we finish this part of the interview, is there anything further you would like to add about keeping your home well ventilated and comfortable?

Please can we now take a tour of your home so that you can show me how the ventilation works in practice?

Follow the Walkthrough, Observation and Video Guide

After completing the walkthrough

Thank you very much for your time today and your willingness to answer my questions and show me round your home.

I will send you a copy of notes from the interview so that you can confirm that you are happy with these. I will aim to send these to you within two weeks. Please can you let me know within a week if there is anything that is inaccurate or that you would like me to remove.

Can I send these to you by email? If not, I'm happy to send the notes by post.

I would like to replay the video clips to you now before I leave so that you can tell me straightaway if you wish me to delete any of these. *Replay video clips to resident and delete any as requested*

Thank you again for your time and for sharing your experience with me.
By taking part, you've helped to make this research more complete and therefore more useful.

If you need to contact me for any reason about the interview here are my details. *Give resident a business card*

Appendix 5. Interview guide for maintenance practitioners

Interview Guide for maintenance contact

Date and time for interview at contact's office pre-arranged and confirmed by email

Voice recorder with mic worn by interviewer
Back-up freestanding voice recorder suitably positioned

Thank you very much for giving up your time to talk to me today.

My name is Jenny Brierley and I would like to begin by describing how the interview will work.

I'd like to learn from you how you keep the ventilation systems in your homes performing effectively and whether you experience any difficulties doing that. I'm interested too in contact you have had with residents, and with other people, association colleagues or external contacts, about ventilation in residents' homes. Just to confirm, I'm a researcher at Sheffield University and completely independent of your housing association.

I hope that this research will help to ensure good ventilation in future new homes, especially housing association rented homes.

My questions should take around 30 mins. Please talk as freely as you wish on any issues you feel are relevant. There are no right or wrong answers. I'm here to listen, as you know your homes and how maintenance in your association works.

I would like to record the interview, using a voice recorder, so that I catch all your comments. I will use the voice recording simply to make a written record of the interview.
Show recording equipment

Everything you say will remain entirely anonymous. You will be able to check the notes before I use them in the research.

The recording and written record will be destroyed when the research is completed. If instead you are happy for these to be kept for future researchers to use, then you can agree to this on the consent form.

Check that the interviewee has received the information sheet and consent form to keep
Ask interviewee to complete and sign a consent form if happy with answers to any queries
Check that consent form has been fully completed and signed and retain this

Before we move on, is there anything you would like to ask? Are you happy to go ahead?
Thank you. Let's start with some simple information.

Day/date of interview	
Start/end time/duration	
Interviewer	Jenny Brierley
Interviewee	
Job title	
Email	
Housing association	
Office address/postcode	
Scheme name	
Anyone else present at interview	
Consent form signed	

How long have you worked for this association?	
How long have you been in this role?	
Briefly, what does your current role include?	
Who do you report to in the association?	
What is your responsibility in relation to the case study scheme?	
Were you involved with this scheme during the development stage?	

1 I am interested in how well residents at this scheme are able to keep their homes ventilated or aired as they wish, and your experience of maintaining the ventilation systems in these homes.

Are you aware of any problems in maintaining effective ventilation in any homes at this scheme, or any problems that residents have keeping their homes aired and comfortable?

What are the problems that you are aware of?

Who has reported these problems?
Prompt: resident, internal, external

What do you think is the cause of these problems?

What action has been taken?

Have the problems been resolved?

2 What routine maintenance do you carry out on the ventilation systems at this scheme?
Prompt: filter changes, re-balancing fans, duct cleaning

How often is routine maintenance carried out?

Who carries out routine maintenance and why these particular operatives?

Do you train the routine maintenance team in the ventilation systems installed in these homes? If so, how and when?

3 How often do you carry out reactive repairs related to ventilation at this scheme?
Prompt: never, rarely, occasionally, frequently

What kind of reactive repairs are needed and why?

Who carries out reactive repairs and why these particular operatives?

Do you train the reactive repairs team in the ventilation systems installed in these homes? If so, how and when?

4 Was a briefing or training given to the maintenance team in relation to ventilation and heating systems at this scheme? If so, what was it?

Who carried out the briefing or training and why was it this particular person?
Prompt: development, contractor, installer, architect, product manufacturer

When was this given?
Prompt: before completion, at handover, after handover

Can you recall what this included related to the ventilation and heating system?
Prompt: how it works, how residents can operate it to keep home comfortable, maintenance needed

Are you aware now of what the specification and equipment is for ventilation and heating systems at the scheme? What do you know about them?

5 Did you, or the housing association, have previous experience of the type of ventilation system at this scheme or was this new to you?
Prompt: who had experience of it

If this was new to you, how did you learn about this particular ventilation system?
Prompt: training by manufacturer, M&E specialist, on site, off site, online

6 Has any monitoring of the indoor or outdoor air quality taken place at this scheme?
Prompt: indoor, outdoor, humidity, CO2, VOCs, PM2.5

When and why was this monitoring carried out?

What did the monitoring reveal?

What action was taken?

Did this have an effect on the air quality inside the homes concerned?

Just a couple more questions…

7 Has advice been given to residents on ventilating their homes? If so, what and why?
Prompt: how system works, how to use controls, lifestyle

Who has given the advice?

How has this advice been communicated to residents?
Prompt: one-to-one, at a meeting, in newsletter, on website

How often is advice given on ventilation or dealing with condensation or damp?
Prompt: start of tenancy only, as and when problem reported, regularly

In your experience, have residents followed this advice?

If not, why do you think they have not followed this advice?

8 If you could influence the specification or development process for new schemes, what would you specify regarding ventilation?

Why would you specify this?

Finally…

9 Is there anything further you would like to add about ventilation, either in relation to this scheme or more broadly?

Thank you very much for your time today and your willingness to answer my questions.

I will send you a copy of notes from the interview so that you can confirm that you are happy with these. I will aim to send these to you by email within two weeks. Please can you let me know within a week if there is anything that is inaccurate or that you would like me to remove.

Thank you again for your time and sharing your experience with me.
By taking part, you've helped to make this research more complete and therefore more useful.

If you need to contact me for any reason about the interview here are my details. *Give interviewee a business card*

Appendix 6. First cycle coding example

Staff interviews – Descriptive Codes – first cycle

n=16 across 5 schemes

Name	Description	Files	References
Air quality		3	6
Airtightness		4	17
Architect		2	3
Build quality, defects		8	27
Build type		1	1
Building contractors, sub-contractors		7	24
Changes during development		3	8
Commissioning, certificates		4	9
Complaints, disputes, compensation		6	9
Complexity, simplicity, standardisation		4	11
Cooking		1	2
Cost issues for residents		9	22
Cost, funding, tenure		8	26
Data, IT systems		3	5
Design, specification, brief, procurement		12	65
Development process, stages		9	16
Draughts		3	5
Drying laundry		4	5
Eco-exemplar, innovation, flagship scheme		6	9
Energy calculations, SAP, EPCs		2	9
Extra ventilation		1	1
Filters, servicing, cleaning		12	72
Fire safety		1	1
Floors		3	3

Jan 28, 2019

Name	Description	Files	References
Funding		1	2
Future residents		1	1
Handover - first lets		11	18
Handover - re-lets		6	7
Handover to maintenance, hsg manag		9	13
Health, wellbeing, H&S risks		5	17
Heating		6	8
Heating control		4	13
Heating costs		8	19
Housing management, lettings		7	20
Info, advice, education for residents		15	58
Installation, sequencing		7	29
Insurance, warranty		2	3
Knowledge, expertise, learning, forgetting		13	67
LA involvement		1	2
Laundry		2	2
Legal position, challenges		3	6
Maintenance costs		7	10
Maintenance implications, risks		11	23
Maintenance planning		5	5
Mould, condensation, damp, leaks, humidity		14	39
Mutual exchange		2	2
Natural ventilation		1	3
Noise		7	12
Overheating		3	4
Performance, targets, data		5	9
Pests		1	2
POE, monitoring		8	20
Private developers, s106		3	8
Quality assurance		2	3

Jan 28, 2019

Name	Description	Files	References
Rainwater harvesting		1	1
Reactive repairs		8	16
Reputation, customer service		3	4
Resident activity, lifestyle		9	17
Resident control, boost, perception		4	9
Resident feedback, experience		8	18
Resident use of equipment		2	3
Roofs, lofts		4	5
Routine maintenance		3	3
Service engineers		4	9
Site, location, environment		6	14
Solar pv		3	5
Space		1	2
Standards, codes, Bldg Regs, govt policy		8	29
Start of tenancy - sign up		3	11
Switching off		7	21
Training hsg manag staff		3	4
Training maint staff		8	16
Tricklevents		3	3
Turnover of residents		4	5
Turnover of staff		4	7
Use of heating		2	6
Use of ventilation		3	3
Use of windows		10	19
Vent system - demand controlled extract		2	3
Vent system - MEV		1	1
Vent system - MVHR		9	49
Vent system - PIV		4	9
Ventilation strategy		7	20
Ventilation suppliers, manufacturers		5	8
Ventilation systems, faults		10	19

Jan 28, 2019

Name	Description	Files	References
Void works		2	2
Window design		3	6
Working relationships, communication, arrangements, structure		12	43

Jan 28, 2019

Appendix 7. Survey data Q5

Five Quick Questions on Ventilation

Q5 In your view, what are the three biggest problems, and the solutions, for social landlords in maintaining effective ventilation in rented homes? (please describe briefly)

Answered: 33   Skipped: 1

ANSWER CHOICES	RESPONSES	
Problem no.1	100.00%	33
What would solve this?	90.91%	30
Problem no.2	100.00%	33
What would solve this?	90.91%	30
Problem no.3	84.85%	28
What would solve this?	75.76%	25

#	PROBLEM NO.1	DATE
1	Preventing condensation	11/21/2017 11:28 AM
2	who is responsible	11/21/2017 11:21 AM
3	black mould in bathrooms	11/17/2017 2:37 PM
4	tenants understanding the importance	11/17/2017 12:49 PM
5	perceived cost to the resident of running the system.	11/17/2017 12:34 PM
6	resident behaviour	11/17/2017 12:19 PM
7	Resident think running cost	11/17/2017 12:17 PM
8	Residents not being engaged in managing ventilation	11/17/2017 12:15 PM
9	customer behaviour	11/15/2017 3:19 PM
10	Understanding ventilation systems (residents & staff)	11/15/2017 9:25 AM
11	Cost of service	11/14/2017 10:14 AM
12	Tenant Behavoiur	11/14/2017 10:10 AM
13	Understanding maintenance needs	11/14/2017 9:26 AM
14	Fuel poverty (reluctance to let out expensive heat)	11/14/2017 8:52 AM
15	heat loss for tenants so not using	11/9/2017 9:06 AM
16	extract fans turned off	11/8/2017 10:16 AM
17	Fuel Poverty - tenants think they are wasting heat	11/7/2017 5:19 PM
18	Resident does not understand need for ventilation.	11/7/2017 9:13 AM
19	solid wall	11/6/2017 11:51 AM
20	Access	11/6/2017 10:47 AM
21	Condensation and Mould	11/6/2017 10:32 AM
22	Fuel poverty	11/6/2017 9:49 AM
23	Getting customers to use it	11/6/2017 9:45 AM
24	Custeomres not understanding the importance of ventilation	11/6/2017 9:33 AM
25	Poor extraction rate of old extractor fans	11/6/2017 8:58 AM

26	Over-specification in new builds	11/6/2017 8:49 AM
27	Customer buy in	11/6/2017 8:13 AM
28	Tenant awareness.	11/6/2017 8:01 AM
29	Lack of Ventilation strategy for new build	11/5/2017 8:55 PM
30	Resident understanding	11/5/2017 5:58 PM
31	Tenant understanding of the difference between damp and condensation	11/4/2017 8:07 PM
32	Tenants understanding	11/4/2017 3:25 PM
33	Tenant understanding on ventilation	11/4/2017 12:30 PM
#	**WHAT WOULD SOLVE THIS?**	**DATE**
1	Passive ventilation or heat recovery that cannot be switched off	11/21/2017 11:28 AM
2	clear communication and policy	11/21/2017 11:21 AM
3	install low carbon constant running fans	11/17/2017 2:37 PM
4	trying to educate tenants	11/17/2017 12:49 PM
5	better literature supplied by the manufacturer specifically written for the end user (the resident).	11/17/2017 12:34 PM
6	Install low cost fan	11/17/2017 12:17 PM
7	Education	11/17/2017 12:15 PM
8	eduction and advice	11/15/2017 3:19 PM
9	Use practical equipement to measure humidity levels to understand the context of the problem	11/15/2017 9:25 AM
10	making it part of the EICR	11/14/2017 10:14 AM
11	We try to educate on visits	11/14/2017 10:10 AM
12	basic guides for non technical staff	11/14/2017 9:26 AM
13	Affordable energy	11/14/2017 8:52 AM
14	social economic	11/9/2017 9:06 AM
15	remove rocker switch for blank plate	11/8/2017 10:16 AM
16	Better understanding of ventilation requirements for a healthy home	11/7/2017 5:19 PM
17	insulation	11/6/2017 11:51 AM
18	Maintenance free systems	11/6/2017 10:47 AM
19	Install Positive Ventilation Units	11/6/2017 10:32 AM
20	This is beyond our control . Government fuel cap may work.	11/6/2017 9:49 AM
21	We distribute a customer newsletter and add articles on control	11/6/2017 9:33 AM
22	Replacing fans	11/6/2017 8:58 AM
23	a move away from mechanical solutions	11/6/2017 8:49 AM
24	Educating the customers	11/6/2017 8:13 AM
25	Keep information updated and available.	11/6/2017 8:01 AM
26	Fit filter less systems, that are designed, and works for social housing	11/5/2017 8:55 PM
27	Education & monitoring	11/5/2017 5:58 PM
28	Improved literature and awareness campaigns	11/4/2017 8:07 PM
29	Education	11/4/2017 3:25 PM
30	Increased engagement, but this requires requires significant resources and tenants often don't want to be engaged with and habits are hard to break.	11/4/2017 12:30 PM
#	**PROBLEM NO.2**	**DATE**

1	Resident acceptance of lifestyle issues	11/21/2017 11:28 AM
2	residents understanding	11/21/2017 11:21 AM
3	condensation in bedrooms due to residents drying clothes on rads	11/17/2017 2:37 PM
4	correct specification size etc	11/17/2017 12:49 PM
5	frailty/complexity of the system	11/17/2017 12:34 PM
6	access for servicing etc	11/17/2017 12:19 PM
7	Making noise	11/17/2017 12:17 PM
8	Residents switching systems off	11/17/2017 12:15 PM
9	fuel poverty	11/15/2017 3:19 PM
10	Incorrectly specified products	11/15/2017 9:25 AM
11	regular cleaning of products	11/14/2017 10:14 AM
12	Running costs	11/14/2017 10:10 AM
13	Sourcing contractors	11/14/2017 9:26 AM
14	User controlable ventilation	11/14/2017 8:52 AM
15	lack of service set up	11/9/2017 9:06 AM
16	trickle vents closed	11/8/2017 10:16 AM
17	MVHR - often inaccessible, difficult to maintain and tenants do not like 'draughts'	11/7/2017 5:19 PM
18	Resident more concerned about saving energy bills than ventilation (understandably)	11/7/2017 9:13 AM
19	lack of heat and ventalation	11/6/2017 11:51 AM
20	Residents use / non -use	11/6/2017 10:47 AM
21	Tenants switching Posi vent units off	11/6/2017 10:32 AM
22	Tenants understanding link between ventialtion and heating	11/6/2017 9:49 AM
23	Ventilation systems not effective	11/6/2017 9:45 AM
24	Customers isolating ventilation	11/6/2017 9:33 AM
25	Tenants not understanding need to ventilate	11/6/2017 8:58 AM
26	Poor quality installations	11/6/2017 8:49 AM
27	Lifestyle	11/6/2017 8:13 AM
28	Call centre knowledge.	11/6/2017 8:01 AM
29	Education of Tenant	11/5/2017 8:55 PM
30	Turning off fans	11/5/2017 5:58 PM
31	Tired and worn out stock	11/4/2017 8:07 PM
32	In house team knowledge	11/4/2017 3:25 PM
33	Issues with design/install/commission of ventilation systems. Also the approach for new homes with related challenges such as procurement meaning that cheaper options are used.	11/4/2017 12:30 PM

#	WHAT WOULD SOLVE THIS?	DATE
1	Ventilation that can't be switched off	11/21/2017 11:28 AM
2	more accountability for residents and/or better communication	11/21/2017 11:21 AM
3	educate residents not to do so!	11/17/2017 2:37 PM
4	independant caluclation of ventilation requirements	11/17/2017 12:49 PM
5	systems are designed to be maintained by trained operatives. if they were more intuitive to use then residents could clean filters	11/17/2017 12:34 PM

6	looking for less noise fan	11/17/2017 12:17 PM
7	Fitting of dataloggers so this can be proven	11/17/2017 12:15 PM
8	limited to what can be done	11/15/2017 3:19 PM
9	Specify products that will automatically manage the mositure levels. Specifiy filterless fans such as the Envirovent	11/15/2017 9:25 AM
10	Self cleaning devices	11/14/2017 10:14 AM
11	Try to advise that the costs are low	11/14/2017 10:10 AM
12	Installers to ensure maintenance contract set up	11/14/2017 9:26 AM
13	Automatic ventilation	11/14/2017 8:52 AM
14	set up servicing and alocate costing into overall calculations on viabilty	11/9/2017 9:06 AM
15	education of residents or static trickle vents	11/8/2017 10:16 AM
16	Better installation generally and tenant awareness	11/7/2017 5:19 PM
17	education	11/6/2017 11:51 AM
18	We can only try to educate	11/6/2017 10:47 AM
19	Education into running costs v damage to home	11/6/2017 10:32 AM
20	We already produce advice leaflets	11/6/2017 9:49 AM
21	Education.	11/6/2017 9:33 AM
22	Personal expalnation to tenants. Some don't listen.	11/6/2017 8:58 AM
23	readier availability of acredited training	11/6/2017 8:49 AM
24	Educating the customers	11/6/2017 8:13 AM
25	Regular training and good feedback on cases.	11/6/2017 8:01 AM
26	Guidance in multiple forms, con	11/5/2017 8:55 PM
27	Education & monitoring	11/5/2017 5:58 PM
28	Massive house building and or refurbishment building campaign	11/4/2017 8:07 PM
29	Education	11/4/2017 3:25 PM
30	Significant problem which the industry needs to address. Specifically MVHR. Issues have been across different suppliers, companies and products so widespread action needs to be taken by the industry. Training in the form of CPD should be provided to consultants/contractors by independent companies as currently this is often carried out by sales people and focuses on a specific product rather than the appropriate technical solutions.	11/4/2017 12:30 PM

#	PROBLEM NO.3	DATE
1	Residents ability to pay fuel bills	11/21/2017 11:28 AM
2	using an array of contractors/sub contractors and/or not adequate contracts set up	11/21/2017 11:21 AM
3	maintenance of filters etc	11/17/2017 12:49 PM
4	costs	11/17/2017 12:19 PM
5	Fan cost	11/17/2017 12:17 PM
6	Cold air produced by some MVHR units when on boost (usually because resident has switched off previously)	11/17/2017 12:15 PM
7	lack of techncal knowledge by RSL managers	11/15/2017 3:19 PM
8	Knowing the significance of the problem?	11/15/2017 9:25 AM
9	awareness of use	11/14/2017 10:14 AM
10	access	11/14/2017 10:10 AM
11	Tenants switching them off	11/14/2017 9:26 AM

12	Incorrectly vented tumble diers	11/14/2017 8:52 AM
13	tenants not cleaning out trickle vents or painting over	11/9/2017 9:06 AM
14	Not removing excess condensation	11/8/2017 10:16 AM
15	Resident expectations of condensation control - drying clothes inside, not ventilating and assuming condensation mould is due to a building defect.	11/7/2017 9:13 AM
16	lack of heating due to expense	11/6/2017 11:51 AM
17	Availibility of contractors	11/6/2017 10:47 AM
18	Tenants not using fans/extractors provided	11/6/2017 9:49 AM
19	air bricks and vents blocked up	11/6/2017 9:45 AM
20	Noisy system	11/6/2017 9:33 AM
21	Tenants understanding difference between condensation and penetrating damp.	11/6/2017 8:58 AM
22	Tenant lack of understanding	11/6/2017 8:49 AM
23	Consistentcy across stock to have extractor fans and means of ventilation.	11/6/2017 8:13 AM
24	Lack of understanding of the subject area	11/5/2017 8:55 PM
25	Continued poor lifestyle	11/5/2017 5:58 PM
26	Non use of adequate heating systems	11/4/2017 8:07 PM
27	Cost	11/4/2017 3:25 PM
28	Meeting new energy standards in the best way - MVHR pushed by most designers now. Also, other standards such as Passive House will heavily rely on MVHR.	11/4/2017 12:30 PM

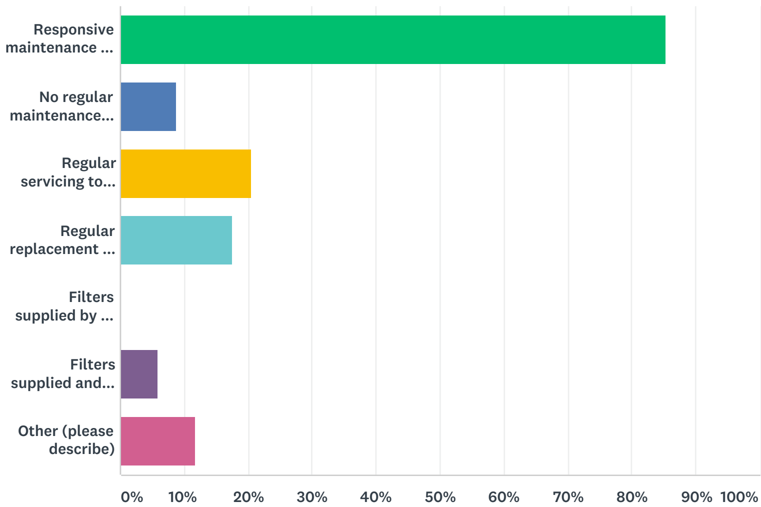
#	WHAT WOULD SOLVE THIS?	DATE
1	Cheaper tariffs and support when residents are in debt	11/21/2017 11:28 AM
2	suitable qualified one stop shop and/or robust contracts that identify exactly each system	11/21/2017 11:21 AM
3	we know use filterless fans	11/17/2017 12:49 PM
4	Get the best value on the fan price	11/17/2017 12:17 PM
5	Consider positive input fans instead.	11/17/2017 12:15 PM
6	better staff and training	11/15/2017 3:19 PM
7	Understand the data! What is your expenditure on ventilated related issues and what budet do you need to address the problem?	11/15/2017 9:25 AM
8	Maintenance details and records visable	11/14/2017 10:14 AM
9	we try to advise at least twice before visits	11/14/2017 10:10 AM
10	educating tenants on benefits	11/14/2017 9:26 AM
11	Provide external vents for tumble driers	11/14/2017 8:52 AM
12	better information for tenants on sign up. regular checks when any staff visit	11/9/2017 9:06 AM
13	education, education, education!	11/8/2017 10:16 AM
14	money	11/6/2017 11:51 AM
15	Longer term contracts	11/6/2017 10:47 AM
16	Continue to reinforce the need for extraction of moist air	11/6/2017 9:49 AM
17	Overhaul exiting system or replace with something newer and quieter	11/6/2017 9:33 AM
18	Personal explanation to tnenants. Some don't listen.	11/6/2017 8:58 AM
19	simpler controls, standardisation of stock	11/6/2017 8:49 AM
20	Planned investment works	11/6/2017 8:13 AM
21	Continues training	11/5/2017 8:55 PM

22	Education & monitoring	11/5/2017 5:58 PM
23	Low cost technology to improve heating systems	11/4/2017 8:07 PM
24	Reduction	11/4/2017 3:25 PM
25	Further training and in-house knowledge to challenge consultants. I believe there is a knowledge gap within social housing and we rely too heavily on consultants. It would be good to see wider Govt support and funding to support this area for social housing.	11/4/2017 12:30 PM

Appendix 8. Survey data Q1-4 See tables below charts for full text

Q1 How do you keep ventilation working well in your rented homes? (please tick all that apply)

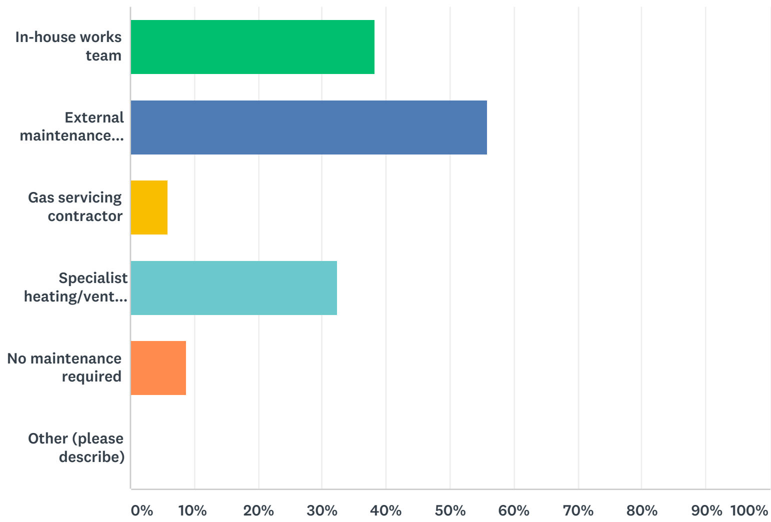
Answered: 34 Skipped: 0



ANSWER CHOICES	RESPONSES	
Responsive maintenance as and when problems reported	85.29%	29
No regular maintenance required for means of ventilation used	8.82%	3
Regular servicing to replace filters, balance system, check controls, etc	20.59%	7
Regular replacement of filters by the landlord	17.65%	6
Filters supplied by the landlord and fitted by the resident	0.00%	0
Filters supplied and fitted by the resident	5.88%	2
Other (please describe)	11.76%	4
Total Respondents: 34		

Q2 Who carries out maintenance of any ventilation technology in your homes?(please tick all that apply)

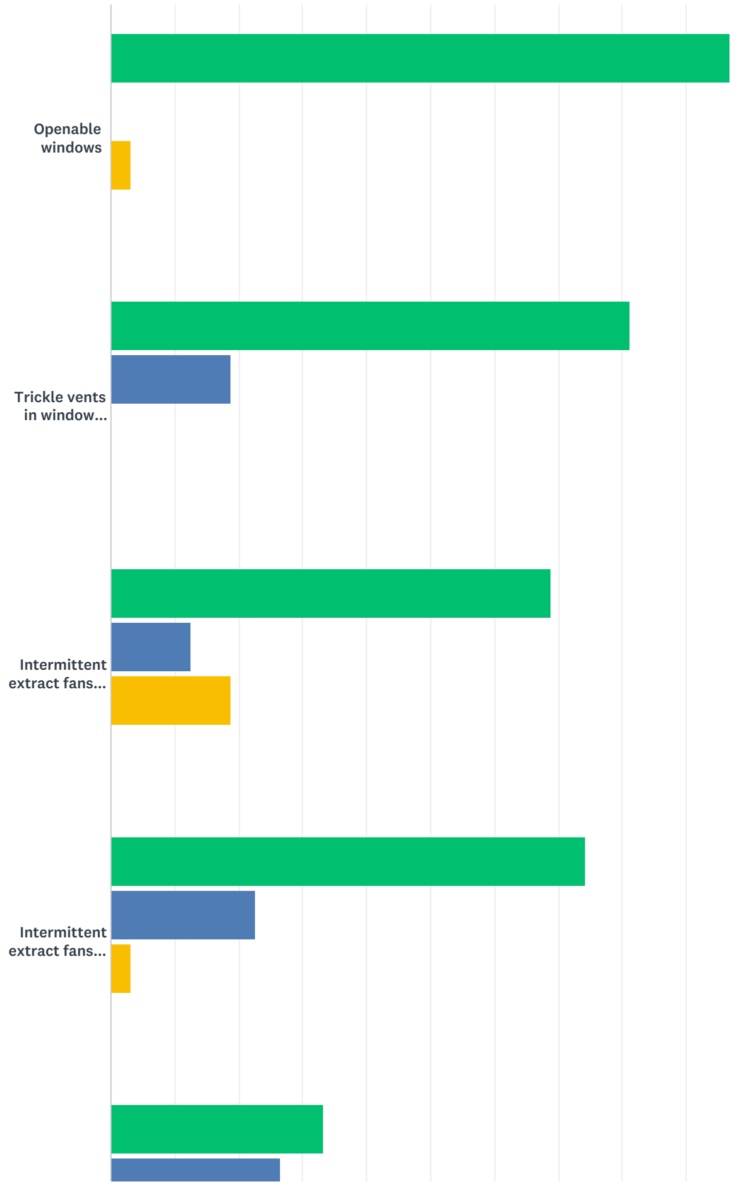
Answered: 34 Skipped: 0



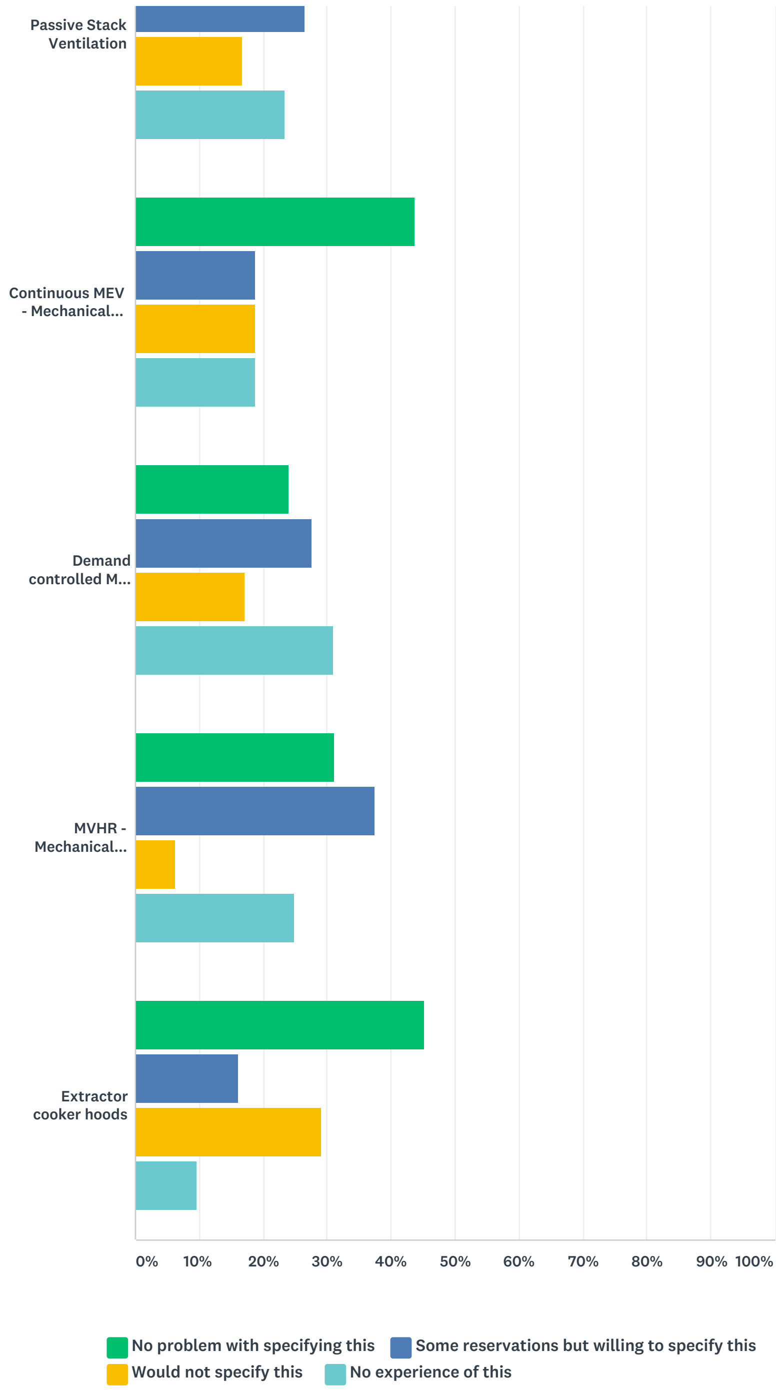
ANSWER CHOICES	RESPONSES	
In-house works team	38.24%	13
External maintenance contractor	55.88%	19
Gas servicing contractor	5.88%	2
Specialist heating/ventilation contractor	32.35%	11
No maintenance required	8.82%	3
Other (please describe)	0.00%	0
Total Respondents: 34		

Q3 From your experience of these means of ventilation, given the choice, which would you specify - or not specify - in future new homes?(please tick one response for each option)

Answered: 34 Skipped: 0



Five Quick Questions on Ventilation



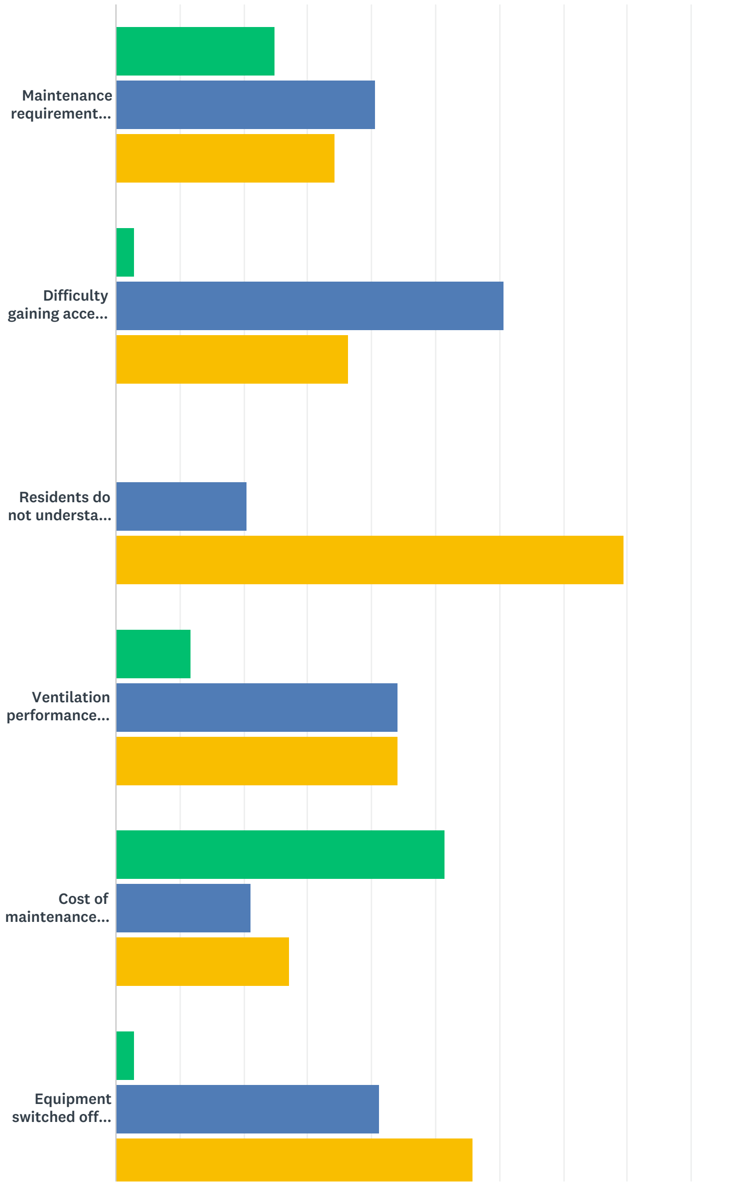
4 / 9

Five Quick Questions on Ventilation

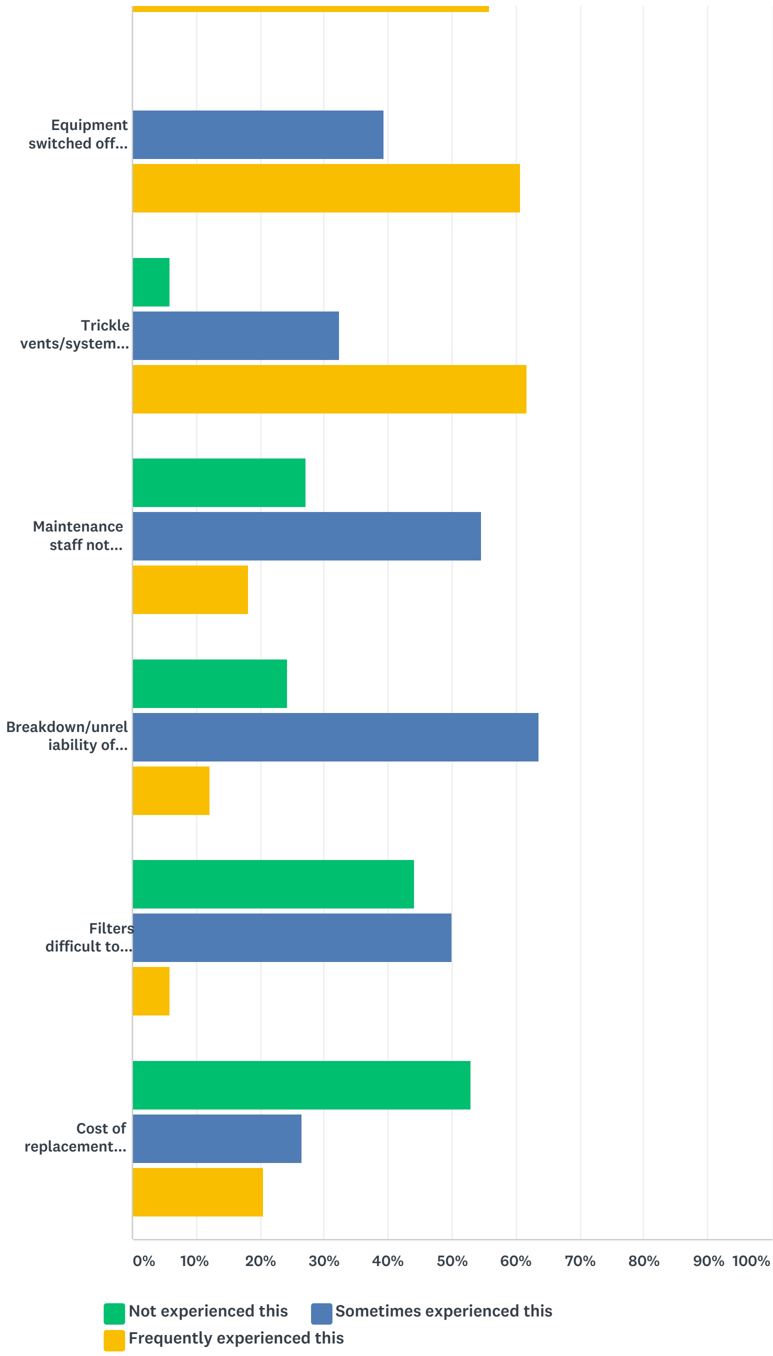
	NO PROBLEM WITH SPECIFYING THIS	SOME RESERVATIONS BUT WILLING TO SPECIFY THIS	WOULD NOT SPECIFY THIS	NO EXPERIENCE OF THIS	TOTAL
Openable windows	96.88% 31	0.00% 0	3.13% 1	0.00% 0	32
Trickle vents in window frames	81.25% 26	18.75% 6	0.00% 0	0.00% 0	32
Intermittent extract fans in kit/bath - manual/light switch operated	68.75% 22	12.50% 4	18.75% 6	0.00% 0	32
Intermittent extract fans in kit/bath - sensor activated	74.19% 23	22.58% 7	3.23% 1	0.00% 0	31
Passive Stack Ventilation	33.33% 10	26.67% 8	16.67% 5	23.33% 7	30
Continuous MEV - Mechanical Extract Ventilation	43.75% 14	18.75% 6	18.75% 6	18.75% 6	32
Demand controlled MEV - sensor activated	24.14% 7	27.59% 8	17.24% 5	31.03% 9	29
MVHR - Mechanical Ventilation with Heat Recovery	31.25% 10	37.50% 12	6.25% 2	25.00% 8	32
Extractor cooker hoods	45.16% 14	16.13% 5	29.03% 9	9.68% 3	31

Q4 What obstacles have you experienced to maintaining effective ventilation in your rented homes?(please tick one response for each issue)

Answered: 34   Skipped: 0



Five Quick Questions on Ventilation



7 / 9

Five Quick Questions on Ventilation

	NOT EXPERIENCED THIS	SOMETIMES EXPERIENCED THIS	FREQUENTLY EXPERIENCED THIS	TOTAL
Maintenance requirement unclear	25.00% 8	40.63% 13	34.38% 11	32
Difficulty gaining access to homes	3.03% 1	60.61% 20	36.36% 12	33
Residents do not understand the need for ventilation	0.00% 0	20.59% 7	79.41% 27	34
Ventilation performance given low priority	11.76% 4	44.12% 15	44.12% 15	34
Cost of maintenance contract	51.52% 17	21.21% 7	27.27% 9	33
Equipment switched off by resident due to noisy system	2.94% 1	41.18% 14	55.88% 19	34
Equipment switched off by resident to save running costs	0.00% 0	39.39% 13	60.61% 20	33
Trickle vents/system vents blocked to prevent draughts	5.88% 2	32.35% 11	61.76% 21	34
Maintenance staff not familiar with technology installed	27.27% 9	54.55% 18	18.18% 6	33
Breakdown/unreliability of equipment/controls	24.24% 8	63.64% 21	12.12% 4	33
Filters difficult to replace/inaccessible	44.12% 15	50.00% 17	5.88% 2	34
Cost of replacement filters	52.94% 18	26.47% 9	20.59% 7	34

Appendix 9. Focus Group transcript

Transcript of Focus Group held on 23 January 2018 at the National Housing Maintenance Forum conference

Facilitator: Jenny Brierley, Researcher, University of Sheffield (JB)

QUESTION 1
HOW DO YOU KEEP VENTILATION WORKING WELL IN YOUR RENTED HOMES?

F14 The question is whether ventilation is maintained more effectively through responsive or planned maintenance? If you've got planned, what do your regular service contracts include? What triggers a response maintenance request? What causes this? How reliable is this as a predictor of unacceptable air quality or inadequate ventilation?

F4 We're local authority, don't do a routine maintenance thing, we're just responsive. Units fitted do have a certain protocol where they store certain information if the customer switches it off. Basically what we do, if there's a problem with it we'll go and have a look at it but we don't particularly have, every 12 months or whatever, a routine thing. Don't check that information regularly.

Units pretty good. Got some really dated ones that we replace, but the new units we don't tend to have much problem with.

The problem is more the education of the customer, to try to explain how to prevent condensation and stuff. That's basically what mostly sinks in. My line manager here and I take it all the way to Sec11, the court stuff. It's always the same thing driving us down, year after year.

F13 I'm from a local authority, pretty much in your position. We install things, I don't know, I just assume the installer does regular servicing if needed, we just respond to problems.

A lot of the problems are things that are out of our control, even as my job is tenant services manager, so I'm responsible for the whole landlord function.

A lot of it is due to overcrowding, and that's not going to be solved. A lot of it is due to space standards, tiny rooms, a living room 10x10 for a family of 5.

A lot of housing doesn't have much space for storage, so we have a lot of clutter building up. People do have furniture against external walls, with the best will in the world, in a room that's 10x10, you're bound to be having stuff against external walls. You go into bedrooms and they are floor to ceiling with black bags or cardboard boxes, there's just not enough space. You've got a family of say 5 or 6 in a 2 bed flat, you're going to have problems, regardless of whatever you do.

F15 I agree with both of those comments.
I think it depends on what level of ventilation you install depends on whether potentially you go down the responsive route or whether you go down the planned route. Obviously with things just like basic extractor fans and things like that we would expect the tenant to contact us if there is an issue with them because obviously we've provided them in a good working condition, but if it's something like a standalone unit where obviously we have filters to change then that's registered, and then that goes through our planned department, to make sure that if it's on a 5 year filter change then obviously that filter is then looked at at that point, so again it can depend on the individual product.

But one of the things we've started to do just recently, and this is in order more to combat condensation, but obviously ventilation is a huge part of that, is we've devised an electronic survey sheet that if we get a conversation with a tenant that's relevant to black mould, condensation, etc. we will now instead of just sending someone to constantly respond to treat it we've now adapted a 1-2-3 approach. The idea is that we'll go out on the first time and survey your property and see exactly what we need to provide you from, and more often than not it's the ventilation parts that we've been missing in the past, because we've sealed all these homes but then not necessarily looked at how we allow that air to escape.
So we then put our landlord's responsibilities on that, that's Step 1, where actually we're saying, d'you know what, we need an order to deliver our part of this side of the bargain, we need to do x, y and z and then from that also that survey is looking at your lifestyle while in that home, and we raise a report of what we have seen, where the actual tenant has aided that condensation increase etc and what they can do to help support that. We will visit again next year if necessary but actually once we've done two educational visits it is a case of about you have to adapt your lifestyle as we've done all the things that we can do as a landlord to help support you through that journey.

F13 A lot of tenants don't want to hear it's a lifestyle issue. They want to know what we are going to do about it not what they can do about it

F4 Recently done one like this, sent letter out yesterday, where we did a survey, the gentleman wouldn't have it, yes there were 3 people, 2 adults and a child sleeping in one big flat, and it's all mould and everything. Adamant mould is in his bones, it's our fault, it's affecting his urine. Just could not get through to this guy. He won't heat it, won't have the heating on, won't open windows because it's electric, the cost of heating, they don't work, in the flat all day.

That's part of the problem, educating people. They will go on line and research the effects of mould, but won't research how to prevent it. They skip across that down to mould is going to cause breathing problems.

QUESTION 2
WHO CARRIES OUT MAINTENANCE OF ANY VENTILATION TECHNOLOGY IN YOUR HOMES?

F2 I think a lot of it will depend on what type of ventilation system you're talking about. Extractor fan in a bathroom is probably a relatively simple day to day maintenance job, but if you're talking about a more robust system in new build…or in a sheltered or supported scheme, for example an extra care scheme, you'd expect to see more specialist contractors brought in to do that type of thing…different strategies for different technologies...

F15 But most providers of ventilation services are pretty good these days and will offer you, even if it's only to a contractor, free training on fitting, so you're getting the best of both worlds, you get to increase the skill set of your operatives but it's not costing you any additional other than the cost of the fact that you've gone with that supplier for the product.

F10 We're a housing association but we've transferred from a local authority. I think for us it's the quality of the data that we have got as to what units are in there and fitted and also it's the lack of communication between something comes in as a complaint of damp or whatever, so someone goes out and fits something that's just standalone. I think we're bad as an organisation at knowing exactly what we've got, where, how old it is, when it was fitted, who is responsible for it. It's just down to knowing exactly what it is, identifying it and then being able to put in place some kind of maintenance programme. I think we just respond like everyone else, if it breaks we fix it.

F8 We're getting there. We do stock condition surveys and know approximate ages but we don't know a lot that has been fitted as standalone to combat a problem.

F7 In our case, a council, the extractor fans we put in are the positive input units, we get a 7 year warranty, so actual responsive maintenance on those units is carried out by the specialist contractor. Our in-house team will then take over maintenance on expiration of the warranty. Get training to do that? Yes.

F14 Does your approach differ depending on what the controls are? If there are, say, humidistat controls, do you still see that as a simple maintenance job? If it's wired into the light fitting? If you're collecting data about what equipment you've got there do you know what triggers the thing as that might make a difference?

F2 Part of that goes back to the customer though in the first place…the call to us for a repair via the request to the call centre. Most customers will say that the fan's gone or…or this control panel's gone but they probably wouldn't know the difference.

I think it all comes back to your point of knowing what's in your properties and being able to set a strategy around that. Because as an industry… all the time…have we got a strategy in place? There's a complaint or a sec 11 has come in, we respond to it. Joining the dots up to have a proper strategy and a solution to what is an issue…

F7 Our problem is a tenant might report a mould or condensation problem and then when our surveyor goes to investigate it they notice that the extractor fan is not operating correctly. But the tenant wouldn't actually report the extractor fan. They wouldn't link it to the mould or condensation problem in the first place. But obviously looking at mould or condensation one of the key points on your checklist would be to check that the extractor fan is operating correctly.

F10 I would say from a responsive repair point of view you never have a conversation with a tenant about being worried about the ventilation in their property, you always have an outcome, normally the black mould is appearing or cold spotting etc. It is those elements that you go out and look at, obviously ventilation as part of that three-way mould triangle.

QUESTION 3
FROM OUR EXPERIENCE OF THESE MEANS OF VENTILATION, GIVEN THE CHOICE, WHICH WOULD YOU SPECIFY – OR NOT SPECIFY – IN FUTURE NEW HOMES?

F8 We have problems with the positioning of the kit sometimes, often it's in a loft. Many people don't actually go in their lofts at all so when you say you've got to go up there once a year to clear a filter they don't know how to go, don't want to. If it could be brought downstairs say where there's a bedroom that would be better. But I know that space is needed there and space is always at a premium.

F10 For us we've got quite a diverse stock. As with anything…try and use the experience of who is out and about in the properties to recommend things. I think it's difficult because if you try and use one product across all different types of stock that is not necessarily going to be the right approach to take. So I think we have to consider what type of property it is….probably one of our problems is trying to have a blanket approach…possibly more from maintenance.

I mean, I don't know about anybody else but development sometimes can be a little bit out on their own, someone will put something completely different in, whereas as maintenance side of things would tend to stick with the same type of thing… not so joined up with our thinking, so maybe our own misfortune we don't tend to communicate well, one side of the business and another…again, it's not necessarily right for each type of property.

F13 With that as well, from a maintenance perspective, one of the reasons you go for the same product is that actually your lads carry the spares on the vans and the vans are only so big, so in an ideal world you do sometimes compromise slightly in order to say actually this one product would do 90% of our needs and therefore we'll use that.

I think as well it's a little bit around we're all very familiar with the things at the top and quite comfortable with it, the knowledge is there. I don't necessarily think with some of the other areas of ventilation that there's enough specialised knowledge within the councils and therefore you're worried about specifying something that is quite an expensive piece of kit with some of the full house solutions. You don't want to take responsibility for that when you're not 100% sure about what else is there on the market, the comparisons. Whereas if you're talking about damp, mould and condensation you could probably have 15 people in your organisation that could spout chapter and verse. It's one of those areas that I think it's still a little bit unknown.

F10 And obviously you're always pushed to show value for money so you can buy a certain amount of things and get a better rate so that's a reason.

QUESTION 4
WHAT OBSTACLES HAVE YOU EXPERIENCED TO MAINTAINING EFFECTIVE VENTILATION IN YOUR RENTED HOMES?

F5 Prior to joining the ALMO I worked for a housing association. Lot of MVHR systems installed in new properties and the main issues that we had was installation faults. The unit had never been installed properly in the first place. The worst case scenario I came across was the tenant said, oh yes this system it does this, that and the other, but when we looked in the loft we found it had never been wired up so it wasn't actually doing anything.

Filters is a main issue because a lot of the manufacturers say filters should be changed 6 weeks after the property is occupied to get rid of all the builder's dust and that's never ever been done. We've come across filters that have actually been ripped because they've been put under that much pressure and are just completely blocked.

But then we decided to do all that work in-house. So it was in-house electricians that were going out to do the maintenance because we just weren't getting the service from the contractors.

F2 Why this has a low priority – we've done a lot of retrofit works, insulation, and priority has been affordable warmth. Quite often the quality not good or work has not been specified correctly. Works across the stock in the past, in the glorious days of CESP when everything was 100% funded. 6 or 7 years down the line we've inherited many, many problems, due to lack of understanding what we were doing in the first place.

But still today, if there's an opportunity for funding I think probably sector-wide we grab it with both hands, the likes of EWI etc. and then the additional cost of suitable ventilation or even reviewing the specs in the first place, I'd say probably, well I might be alone, would probably be pretty low on the priority list, unless you learn the lessons when you've had those experiences previously.

QUESTION 5
IN YOUR VIEW, WHAT ARE THE THREE BIGGEST PROBLEMS, AND THE SOLUTIONS, FOR SOCIAL LANDLORDS IN MAINTAINING EFFECTIVE VENTILATION IN RENTED HOMES?

F13 One of the issues - staff understanding you call it. I'd also say, while hating to criticise my colleagues, it's also an attitude, when a surveyor is asked to go out and inspect a property because a tenant is complaining about condensation, damp, mould, there's an immediate assumption before they even leave the office that it's lifestyle. When they come back and I say I've got an MP's complaint and they say it's lifestyle. I ask if they have spoken to the tenant about the lifestyle and they say they have told the tenant not to put clothing on radiators etc.
I think there has to be better communication and information given to the tenants about what aspect of their lifestyle it is, but there also has to be an attitude, an open-minded attitude, that it isn't necessarily lifestyle. I think that some staff are going out with the automatic assumption that it is a lifestyle issue.

I've got an estate, lovely, landscaped, lots of slopes and hillocks. I had two surveyors go out to the same property and both of them said it was lifestyle, so we used our private sector surveyor to go out and she just said no, it's the water-table is higher than the flat. So I think it's getting staff to look beyond the immediate environment and what else could be causing these issues as well.

(JB: Experience that this takes a long time and you're at a stage 3 complaint before that kind of stuff ever gets uncovered?)

Yes and by then everyone's had enough, the tenant is then in emergency decant and you're doing lots of work. I mean the properties are going to require lots of work anyway but it's taken the tenant probably 12-18 months, young children, with health problems, that we could have dealt with earlier, could have prevented or treated earlier.

(JB: What do you think we can do to change those attitudes?)

I don't know because a lot of the time it IS lifestyle.

F8 Surveyor's got to look for the exception rather than the norm.

F7 I manage the surveying team that does these inspections. Everyone has got to follow the same process. You've got to eliminate the possible technical issues before you move on to assuming lifestyle. Even if it is partially contributed to by lifestyle, those technical issues may exist in conjunction with the lifestyle issues so you've got to eliminate those things and everyone has to follow the same process. Process has got to be made clear to the staff who are doing those inspections.

On the other side, I can see why, like you say 90% of the time it is lifestyle issues and it does become quite soul-destroying when you're out all day, every day, having people have a go at you, criticise you. I suppose people become a bit demoralised, a bit demotivated, start being a bit complacent, making assumptions about people which is quite dangerous. I think that's what it is, having a clear process for people to follow is important.

F13 I've never been a responsive repairs surveyor but I do get the impression that it's probably one of the worst, one of the most thankless tasks in housing. I don't envy them their job at all.

F8 I used to do the job myself, now I manage the people who do it, so I do have some sympathy.

There's also the fact that some people want to move and they are using that, they are overcrowded, they know that it's categorised as a class A health & safety hazard under HHSRS, or category 1 I should say, so they are using that, they don't want to help themselves…

F13 They don't want to co-operate with remedial action.

F8 …their ticket to move is gone as soon as the problem is solved.

F2 I think it's accurate…responsive repair surveyors day to day life…you do get a little bit scarred by what you go through on a day to day basis…a trigger for being harsh… you almost go in with the blinkers on.

I've argued with a surveyor who has now left our organisation, told me once that the damp was being caused in the property because the tenant had a dog water bowl, without looking at anything on the repairs history. When you look back at it there had been a lot of damp over 4 different tenancies over 12 years. But this person argued that action was held down to lifestyle and the dog water bowl in the bedroom was causing literally damp black spots right the way up. I argued that was just like having glass of water on the bedside cabinet at night, but he would not have it. But because that person was seeking a move. To be frank I'd be seeking a move if I lived in that property. It's almost chicken and egg, we make decisions based upon people's frustrations and complaints, but a lot of the time at some point there has been causation for that.

F6 We've experienced the same sort of thing. A lot of the tenants are using it, to potentially want to move, We've adopted a two stage process. We'll go in, we'll work with them, we'll leave the ventilation leaflets, we'll do everything we can to work with them, but we've also got other people who are blinkered and assume it's lifestyle and sometimes it's not. When we eradicate the issue they're downhearted because they can't move but we resolve the issue, try to do it working with them, get them on board.

F15 Another thing is that 20 years ago a building surveyor was a building surveyor, he'd been trained in all elements of building fabric, whereas nowadays a building surveyor is someone who understands the schedule of rates, understands basic maintenance, and actually it's more about how we develop and train them. In the organisation I came into they didn't really even want to look at mould and condensation, they would go out every year and spend all those thousands of pounds doing it. Whereas we've come from a very different angle. We've come from an angle of actually let's get our landlord responsibilities right first. With that piece we'll do first line education and from that we'll give it another opportunity to give that education if it didn't sink in the first time, but actually it is about taking a stand and passing it back to the tenants but being very, very sure that you have ruled out everything that relates to you having the landlord responsibilities. So our first port of call, our first pages, are nothing at all to do with lifestyle. It's all questions about the fabric of the building, about ventilation, and goes through all those processes, the windows, all that sort of thing, the insulation, the lot, before we start to even look at the lifestyle element.

F10 I'm not a surveyor, I'm more of a data person. I think for us we realise the importance of looking at trends looking at repairs. It could be because you've got an area where there's poverty, low income, it could be lifestyle as you say. If you see that trend where you constantly get the same type of repairs you need to use that data and go just a little bit deeper.

We have one estate where over the years people noticed and maybe mentioned this one person but never really recorded it anywhere, it had gone on and snowballed into a huge scheme, like the comment about the water-table. It had been passed off probably because it was a deprived area, they're not using the heating, not ventilating the property correctly. However if you had actually looked at the data we already had, or had it all in one place to look at, we would probably have put a red flag earlier and dealt with it. Now the work is being done the tenants don't want to move, the issues, the property is now better.

Within asset management. Just trying to use what we've got. Responsive surveyors do tend to move around quite a lot, probably because it's not an easy job to do. So if you've got someone at least capturing data and putting it into one place you can then look at it…gives you a little bit more to work with, just flags something up you may otherwise ignore.

F3 Building services and fan manufacturers as well. Key thing – last seminar talking about change, emphasised thinking outside the box, which we've been doing for the last 20 years. Maybe this is the opportunity to start to embrace ventilation manufacturers. Get them in to help you guys, your teams, to actually improve their skill sets. One thing that the industry is very up to now is following regulations, building regulations for instance, so there are legal requirements about what ventilation you put in. A lot of products that you have had installed in properties, inherited from development teams, or that you've picked up from other housing associations or local authorities, you don't know how effective those ventilation systems are. The ducting may be causing problems, it may be blocked, it may be that the ducting was not considered, how it will affect the performance of the extract fan for instance, but if you have collaborations with the ventilation manufacturers you use it would certainly help you guys to have a better understanding how to approach things moving forward and probably have a better cost effective approach as well and maybe even expediate the problem from the outset, because some of the systems we talked about with MVHR they are very complicated. You may have inherited a design of an MVHR system that isn't that effective anyway and it will naturally cause the problems. Airtightness, with extra insulation in the properties, is creating a need for extra ventilation so there's a lot more that can be done, I believe, with collaboration whereas before ventilation was ventilation and nobody gets involved with it too much, assumes just replace like for like but perhaps there is a different solution now that can be picked up from a collaboration with the ventilation manufacturers to come in and do some proper training.

F14 Looking through the questions there, the comment about using data, probably data you've already got, it's just a question of someone collecting it, might actually help you to improve either the ventilation performance or the way that you improve your remedial works without increasing cost, something already starting to do, looking a bit outside the box.

We've talked about what and where the gaps in staff understanding are, the prejudices that people may come with when they are looking at properties. I can recall this back in the '80s as well when people realised that heating and insulation was such an important part of avoiding condensation and mould growth, research coming out then.

Speaker F15 mentioned three step approach, explaining how you as a landlord would do as much as possible…when you've done your bit what is best way to get the residents to understand, to be on side, to play their part?

F15 I think it's about how you approach the education. We're not saying the approach is perfect. Some residents just don't want to listen but just explaining the basics of heating, ventilation, and water, and just actually getting them to understand how they play their part with it.

Normally we've increased our survey time by 45 mins purely because rather than just sending an inspector in to have just a quick whizz round that house and see what you think, we actually want them to spend that time going through it at a real dumbed-down level. They get an hour and 15 mins currently in the property to go and have a look, whereas before it was very much a whistlestop tour. It's about investing that time and if he runs over, to be honest, we're not really that worried if we feel he's walked away feeling there's been some acknowledgement of understanding, but more importantly the leaflets we leave them with are about what they can do to support it. It's about have that real basic conversation about what happens when you're cooking, what happens when you shower, or even if it's about actually we're going to put this extractor fan in, talking about the actual cost of it, talking about what they expect to see, the fact that it will be on all the time on trickle, and this is why it needs to be that way, however it will go into boost, and this is what it costs per annum, so that actually it's not a case of you must be careful, don't block it or it will bring on black mould, talking through the whole of the what, the why and the how, in order to make sure in an ideal world we don't walk away and the first thing you do is (a) not turn it on, (b) disconnect it or (c) block it up. Having that open conversation with them. With new or existing tenant. More often than not we are reactionary, we react to the fact that somebody's rung up about mould and then we go out and do it. In an ideal world I'd like to have a condition survey done of all the properties but at the moment we're just starting with what has been rung through to the call centre.

F2 What we're facing in a lot of the big cities where we work is that the first notification that we have of damp or alleged damp or condensation is accompanied by a solicitor's letter. If you haven't got experience of the door-knockers brace yourself because it will be coming. Quite how we get ahead of the curve on that is a massive challenge. So having a strategy in place, I completely subscribe to everything you say, but I'm not sure how we get to it…door -knockers are having a field day…quite often it comes to nothing…resource needed to deal with that…door-knockers encouraging this. It amplifies the prejudice automatically, because you're going to deal with what in some cases WILL be a genuine issue but you get very claims conscious and it's such a challenge.

F5 Presentation at Direct Works Forum last June solicitors saying you have to be so careful when you record information because if you go to court all that information can be disclosed. Looked through our system and there was a repair inspection put on 'whole house full of damp', basically it will be a case of 'you said it yourself'.

F14 M3 have produced interesting little book called Hattie the House, could this be a useful resource for families, could be done in your own branding, slightly creative thing.

Appendix 10. Anonymised maintenance practitioner interview transcript

Interviewee: Alex, Maintenance Manager at Eco HA, developers of Barn Close case-study scheme
Interviewer: Jenny Brierley, Researcher, University of Sheffield (JB)
Interview took place at the area office of Eco HA in June 2018

JB: Are you aware of any problems that residents have with ventilation at this scheme?

Alex: Nobody has complained at all, no. But I do notice they all have their windows open just like any other tenant would, so I don't think they appreciate, I think there are only two original people in there, but I don't really think they appreciate they're living in something different. I don't think their lifestyles are any different to they would be if they were living in a normal house. I don't know whether that's because we didn't tell them properly in the first place or they just didn't listen, I'm not sure.

JB: How many of these homes have you been in? (JB: Alex has been in post 2 yrs)

Alex: Three of the Barn Close ones. No-one's ever complained about it at all. I'm not saying they've never reported it, but they haven't reported it in my time. I'd know, I quite often take the phone call as well, so I'd really know!

JB: What kind of routine maintenance do you do on the ventilation system?

Alex: Only changing the filters and washing them. They were being serviced once a year but the guy that was servicing them has retired and I cannot find anyone to service them. I'm really struggling at the moment. I've been to all sorts of companies. I don't know why, because I mean there's quite a few properties across our stock. I've been to loads of companies and no-one's interested. So we had that set up with that one guy, like a one-man-and-his-dog type approach, and he was going in once a year and servicing it but no, we should have serviced them this year and so far I haven't found anyone to do it. He seemed to have been employed just to do this. I think he's a heating engineer by background, from talking to him, but he's been doing it ever since the properties were new, and not just here, everywhere. He retired and that was it.

I just went on to the internet and put servicing MVHR and blasted everyone on the internet and said this is what we've got, would you be interested, filled in all their on-line forms, rung, nothing. I just had no response back. So I've been to, we've got a group called the Beech Group, so I thought easy then, so when Eira (Chief Exec) went I said could you ask there who does theirs and she came back with one company and I went to them and they said no, we don't service MVHR. Goodness gracious! So I need to go to that meeting I think or email round and ask people. There's Oak, there's Ash, no they're not Ash they're Birch now. They're big people.

I even asked, they've got a consultant working for them, Gwilym, who was like, locally, when I was working in Shropshire he was the guy we always went to if we wanted advice, he was miles ahead of the rest of us twenty-odd years ago, so I went to him because he now works for CN, no, he didn't know anybody. I'm just thinking, this is so simple, it's everywhere, so it's quite frustrating actually, and it's not something that I have particular knowledge of so I'm, you know, struggling a little bit. So yes, it's an interesting one. I mean I'll find someone in the end.

JB: Are you training your own staff to do this?

Alex: Well that was what I was thinking. I use our electricians, they're not our electricians but they're a company that are very closely allied with us and do all our work. What I've done when I've had bits breaking down, I've gone to the manufacturer myself in Ireland, ordered the part, got it to my desk, and then asked them to fit it. It's not ideal, I mean it works, but it's not good, and I'm not an expert. So far I've ordered the right part each time. They're very helpful this company, Goodvent, they're really helpful. When I ring him or send him a picture of what's broken, he's really good and he's helped me out, and that's how we've managed it, but again, it's not good. Goodvent's the Ashford Road ones and they're the oldest and they're the ones that I'm having most problems with on the breakdowns, so fortunately this guy's really good and I just, but again it was by ringing around everybody. Nothing's easy on this.

JB: What do you expect an annual service to cover?

Alex: Well that's my problem you see I don't really know, and that's where I feel a real weakness in my knowledge, because I've never dealt with them before I came here, never had them anywhere.

We had a lady in post that used to do it all the time, Anwen. She was the energy whatever, she left in March so she went with all the knowledge and so I don't know. So I've got to find out and that puts me in a bit of a, normally I'm pretty good on things, I know my way around a boiler, I know my way around, so. That was her full time job, that was all she did, just sustainability and Ecohomes and EPCs and that sort of thing. (JB: Green Doctor?) Yes she was, that was just her job, that was all she did. It wasn't really, I mean I think Eira, to be fair to her, thought this is silly now, because you can't justify this person any more, but with her she took some knowledge. She didn't always get it right, because she did some stuff down in the Church Lane, that actually, it was an absolute nightmare. So she wasn't technically very sound, but I think she just got in with the right people and knew the people to, so yes.

Ashford Road is more simple. I think we got more complex as we went on. We did Ashford Road and then Church Lane, the last one, is a nightmare. That's much worse and in fact even some of the people, we had a company down there who were specialists in it and they were locals, so brilliant, and Anwen took them on, but they didn't know what they were doing at all. They've got the solar, which they haven't got in, they've got a really weird system, it's a bit like a megaflow system, but it's quite complex and the piping, if you send a normal heating engineer they don't understand it, sent specialists but they didn't really understand it either.

JB: Do you have a brief for servicing? Anything apart from changing filters?

Alex: No, well I need something, that's why I'd really like to go to an expert who does it a lot and find out someone else who did it.

JB: Did you know some tenants at Barn Close are cleaning filters themselves?

Alex: OK, I wasn't aware that they were because we're going in and doing it as well. Well I haven't (JB: given them instructions) but then they might have had it before. I think, I understand when they first moved in they had quite a good handover pack with lots of instructions in, which I have found a copy of now, so I guess if you were that way inclined you may well do that. Some tenants are more able than others as well.

And if we didn't tell them, what I've picked, when I came here, it was almost a shock to some people that they would be any different, because the staff had changed since the beginning. So, what do we tell a tenant when they move in then? What do you mean, what do we tell them? But they're in an Ecohome, so what are we telling them? Well, we're not telling them anything. Well, shouldn't we be? Well, why would we be? And that's quite, so I think staff changes over time has meant that that's gone. At the time we knew a lot. And we've got Zoe back on board now which is nice because she was involved from the beginning, she might be a help to me. Although she's not found anyone to service them either. I'll find someone she said, oh ok I can't she said.

JB: Do you employ your own staff to carry out routine maintenance?

Alex: Yes we do, in-house. (JB: So is it feasible to train staff to service MVHR?) Yes, if it's not complicated, yes, especially if it was a two-day course, that could be easily done. We don't have electricians in-house, but then I could persuade the others. If there's any problem with the fan our electricians do go and look at it, and that's how we got to this, they said oh that's gone so I said right, leave it with me, I'll find the part, you fit it.

JB: So where you worked previously was there no MVHR in the stock?

Alex: Nothing at all, no. What did we have? Oh yes we had some heat pumps and they didn't even know they had them when I arrived there. So I said what are we doing about those? What do you mean? We're not servicing them? No. We should be. And then I did find a bit of a ventilation system, a bit different, but again we weren't doing anything with that.

JB: How are you involved in the handover of a new scheme?

Alex: I haven't had one since I've been here yet. Where I've worked before, well actually I've managed development before at the same time which is absolutely perfect, it's no better than managing all three, but that was my perfect role, but I've been in another role where I've been doing this with development. I'm not involved that much here, which surprises me really, at any stage, because I've always been used to being involved through the design process as well, whereas here, so far, I've had no experience of that. I was asked to look at some house types on a s106 but that's a bit different. So with the Westbridge development for instance, which is our own scheme, I would have expected to be involved quite a lot more than I have, so no, I'm not here, and I think that's a bit disappointing, because a couple of years down the line, when the building's been handed over and I'm saying why have we done that. But no, there's no sign of that, it's quite separate. I think, to be fair, Andrew is a consultant who isn't based in the office, so a lot happens away from the office. I'm hoping now Zoe's on board it might make a bit of a difference. She might be the link, but no, at the moment I'm not involved at all.

JB: Would you say it's ideal to be involved at briefing/specification stage?

Alex: Absolutely, yes.

JB: And then at handover?

Alex: Yes, I mean, again, where I've worked before I've been on the site as well. I know it's different here, but it's, people in development are not always very technical. I don't mean that in a (JB: Alex hesitates), but they're not always. They don't always have a technical qualification so on site they don't always stop things happening that somebody who has a technical qualification would stop, like why are you doing that, that's wrong. Development people are a different breed I think. But I couldn't be on site as well because there's only so much I can do in a day, I do appreciate that. But that would be my ideal, to be out there on site once a month just checking that everything's going right as well.

JB: From a maintenance point of view, what would you be saying about ventilation, heating and cooling at the briefing/specification stage?

Alex: How's it maintained? Is it a product that everyone's using already? How often does it have to be serviced? What happens? All those sort of things, because you're always thinking ahead aren't you, what happens once the building comes, whereas development people are sometimes thinking that's nice, that's pretty, there we are. She said, who used to do development as well. But I think because I've got that broad range I'm very lucky, because I'm always thinking, if we do that no, what about cleaning that later, that won't work, the scaffolding won't reach there, I'm always thinking about things like that whereas development people aren't always. So yes, when I was at Bristol I had the perfect job, I had the whole lot.

JB: Given the range of systems for ventilation, what would be your preferred system?

Alex: I don't know enough. I know the three we've got, that's all I know. I'm sure there's better things out there that I don't know about.

JB: What reservations have you got about the systems you have?

Alex: The Church Lane one definitely, yes. What we've done in Church Lane is too much, too complicated, nobody understands it and it's not a good thing that we've done. I think the Ashford Road, which was the first scheme, is the best actually. I think we've actually got worse. We've probably tried to over-complicate it. And Barn Close sits somewhere in the middle. So I said that to Zoe and she said you surprise me. I said well that's from a maintenance point of view that's how it's worked. That's an unusual way round. You usually learn and get better, but then she did say yes, I think we've possibly over-complicated the last one.

JB: Is this complicated for residents as well?

Alex: Yes, definitely. The whole thing, I mean Church Lane looks very nice, but all the pipework's behind boxing, if there's a leak you've got to take the whole of the bathroom wall out, no-one ever thought, it looks nice, but no-one ever thought about what would happen if something went wrong. We've had two floors we've had to take up, where there's been a leak under the floor and the timber's got wet and no-one thought about that, and that's obvious but. And that's happened at Barn Close, if you've been into no.6, so exactly the same thing's happened there.

JB: So you would have spotted that in the specification?

Alex: I hope so. Definitely on site. And when's it going to happen again?

JB: Have you come across much discussion or concern about IAQ in the maintenance sector?

Alex: Not even been raised. That's what I say, it's almost like you haven't got Ecohomes in the stock. Nobody, I don't even think that, I think most of the tenants don't even know they live in one.

In fact I went to an interesting presentation this week on the WELL standard and, wow, I was just thinking, if that's coming, that's going to change everything around so much. It's not something I'm particularly aware of but I was listening and thinking, this is coming, it's got to be the next thing. And rightly so, when you're talking about the impacts of air on people's health and lifespan and ability to concentrate. And when you see those sort of statistics you start to think, my goodness, how have we not thought about this before. It was a bit of a, yes it was only Wednesday this week, funnily enough, I just went 'ting'. It was a bunch of crusty old surveyors she was talking to as well and we're always hard to, even some of the old guys were going umm. It was the RICS CPD day, so I thought that was interesting.

JB: What about legal standards?

Alex: No, nothing. And I guess with all the Brexit thing going on no-one's even going to think about bringing anything in, you know, we've got a few years before anyone's going to start thinking about proper things again.

JB: Have you been involved at all in advising residents on how to ventilate their homes?

Alex: No, not really, no, because that was what Anwen was doing all the time and of course she's gone now.

JB: What advice did she give?

Alex: I don't know. Zoe would know probably, she and Anwen set it up together I think.

JB: Do you give advice to residents, through a newsletter for instance?

Alex: Yes, when I first came here we had quarterly ones, but this year we've gone to twice a year. So for example, I did an article on condensation, you know, how to prevent condensation, just the bullet points, just six, seven points what to do and I'm pretty sure it was about September newsletter, coming up to that time of year, time to you all start thinking about, because people don't. I've created a little condensation leaflet as well so if I'm going out and I find somebody with condensation problems I've just created a little leaflet that I just give to them if I think they're not really listening or not. Some people are really good, oh I didn't know that, and others you can just feel the blank, so I'll just give the little leaflet out as well.

JB: Is there anything else you would like to add about maintenance and ventilation in particular?

Alex: The only problems we ever have with this is if they make a noise and that's when people tend to ring us up. They're noisy, and that's when we go out and find something wrong. Otherwise nobody ever complains about the air but whenever I go there all their windows are open, so they're really not. And people like fresh air I guess, at the end of the day, and you're not going to change that.

JB: What about long-term maintenance plans?

Alex: I'm starting to. There wasn't one here when I came. I'm now working towards a 30 year proper, costed, but I'm not there yet. I'm trying to go to all the properties and survey them so I'm about half-way through that. (JB: Is there a line in the plan for ventilation systems?) Definitely, I've got the line there. I've got to work out yet what I've got to do with it, yes definitely the line's there. Where I've worked before I've always had that, I'm used to working with, everything, anything that needs doing to that building, in my view, should be in that budget and it always shocks me when I go places and they're not. Actually, to be fair, I don't think it was here when I came, it's only been the line has been there and I've just chucked money in it, not knowing what I'm really doing. I think I assumed 10 (JB: years life of system) but I don't know. A boiler's 15 but, having said that, some of the new condensing boilers didn't last 15, they only went about 11, so whilst the RICS say that it's 15, I always bring it back to 11 for the condensing boilers. They're back to 15 now, they've developed them and we're back up to 15, in fact we're going 16, 17 now. But yes, I've allowed 10 for anything that I don't really know in that sort of area, just because I don't know. It will be interesting to see whether the RICS have given it a lifecycle actually, I'm going to have a look at that. Last time I printed it off it hadn't, but it was quite a few years ago. I think some of them are a lot more complex than others and I can see that the simpler ones have probably got a longer life.

It’s like having a boiler and not servicing it isn’t it. It’s the most contact that tenants have is with us. And reputation.

I’ve always been, wherever I’ve been I’ve been quite lucky. I’ve been in start-ups twice with new housing associations, so right from scratch, and there’s nothing nicer than a blank sheet of paper, you get involved in the set up so therefore you carry quite a lot of weight so it’s a nice position to be.

It’s changed a lot. When I first started out in, 30-odd years ago, it was all middle-aged men who didn’t really care, and tenants were a nuisance, awful attitude, I don’t like this, I’m not having this, but over the years it’s really changed. People are a lot more compassionate and empathetic and it’s much nicer actually.

JB: Eco HA led the way with Ecohomes, how are these homes now regarded?

Alex: Yes, it’s a danger it just becomes a normal house, with a few bits of kit in it that no-one really knows what they do.

I feel a bit negative really and I don’t like that but I sort of feel, because I don’t know enough about it. I will find out. I don’t want to come across as negative because I don’t understand some of it. I like to be ahead of it all really. I don’t like to be on the back foot.

All names of individuals, places, projects and organisations have been changed.

Appendix 11. Anonymised site observation notes

Site Checklist

Attach site plan and location plan
Observations – note on checklist, indicate relevant issues on plans
Photos – take photos, indicate position/direction on plans

Day/date of visit	Tues 5 June 2018
Time	10.00
Weather	Cool
Scheme name	
Address/ postcode	
Housing assoc	
Observer	Jenny Brierley

		NOTES
EXTERNALS	Windows/trickle vents ext. metal coating	High quality triple glazed timber windows, treated not painted, good condition
	Doors/porches	Porches formed by canopy, extends over bin/bike store, not in good condition
	Extract/intake vents	on gable walls at high/low level
	Ventilation cowls None	
	Solar PV/Solar Thermal/other renewables None	
	Indicators of damp – gutters, downpipes, walls, DPC, ground level	No evidence of problems except at back where pergola joins house
	Well maintained/neglected	External render, natural coloured, looks worn. Intended to be left unpainted to save maint. Is this acceptable?

Should be ventilation slot at base of walls – not always present and sometimes overgrown.

and cover has been fixed over pergola

Extract vent in kitchen does not have filter – wrong type fitted? Does not match part specified.

7-12

		NOTES
SCHEME	Orientation Exposed/sheltered Open/shaded Overlooking/privacy issues Clothes drying space Well maintained/neglected	Road runs NW-SE Kitchens face road Livingrooms face back i.e. SW or NE Sheltered on SW side by thick tree boundary, adjacent to road Open on NE side to fields surrounding village hall & children's playground Private gardens, no o'looking space for outside drying Fairly well maintained but not exceptional
LOCATION	Urban/rural Built up/open Residential/commercial/ industrial/agricultural Main road/side road/ cul-de-sac Safety issues Air pollution sources – dust, dirt, pollen, smells Noise sources Security issues Radon area – postcode check at www.ukradon.org although several residents complained about dust	Edge of village (exception site) with large houses around. Doctors surgery and village hall adjacent All residential village. Fields around & woods. Cul de sac off well-used drive to village hall. Busy road to SW, used by lorries as a cut-through, although narrow residential road No safety issues Houses overlook each other, kitchen to kitchen, giving security. No dust, dirt sources Pollen from fields Noise from road audible to houses on SW sides (nos. 7-12)

1-6

Dust from agricultural land/grassland?

Appendix 12. Anonymised resident interview transcript

Interviewee: Alison, tenant, in her 50s. Alison's daughter Claire, in her 20s, lives with her
Interviewer: Jenny Brierley, Researcher, University of Sheffield (JB)
Interview took place at Alison's home in May 2018, Claire was also present

JB: Could you tell me about the heating in your home?

Alison: Mainly it's only in the winter isn't it really, we have the heating on downstairs. You've got your control downstairs and there's one for upstairs, which is quite nice, because you haven't got to have it on all throughout the house, and the majority of the time we only have it on downstairs, because it does keep quite warm. To be quite honest with you, even in the summer, it's too warm sometimes as well.

JB: What about cooling if you are too hot, how do you do that?

Alison: Just by opening windows really or keeping curtains closed so that it's cool inside, the sun's not getting in, that's the only way we can do it, or have the fan on obviously. Sometimes in the summer, we have to use it quite a lot, because there's just no air (JB: electric fan).

Claire: More of a night, upstairs it really is warm at night, even with the windows open.

Alison: It gets ever so warm, doesn't it, I mean throughout the year we only ever have our summer quilts on, because it's just too warm in here. You can't always have windows open because of all the insects that fly in. And it's not even if you can put them on halfway then close it and lock it, you can't do that.

The heating I think meets our needs.

Claire: Yes, they heat up quite quickly.

Alison: You don't have to have it on a timer, you can come in, put it on and within five minutes it's warm. I've got no complaints there. Yes, the gas boiler.

JB: What about ventilation, how do you air the house?

Alison: The only way we can do it is by having windows open, that is the only way. We do have this ventilation system in. I still don't know, no, we've never ever been told how it works, there was no booklet here when we came to show us how it works, nothing here whatsoever, nothing here. Obviously, you get this cool breeze, but only, obviously, if you go into the bathroom or the toilet and you put the light on, then it woofts up and you hear the motor going but that's the only time.

Claire: We ignore it, we wouldn't know exactly what…

Alison: …how to operate it, because when you put it on, you hear the motor running, so you couldn't have that on. When we first moved in, you just had this motor running the whole time and they actually came down and they turned it down because you could hear it. You'd have to have the bathroom light on or the toilet light on, you'd have to have a light on all the time for that to be going.

JB: Does the house usually feel well aired?

Alison: Not always in the winter, because I have damp traps down because the condensation is really bad.

Claire: We get mould on the upstairs windows.

Alison: Yes, if they're not wiped. You should really be having to wipe them every single day because in the winter they are so wet.

I think sometimes the ventilation could be better in the kitchen as well, because even though the windows are open, if you're cooking, something's boiling, the cupboards, and inside, are wringing wet. So I don't think that's very good. I don't know if it's because it's such a small space.

But you could say that about the bathroom, couldn't you Claire. Because if you're in the shower, I've tried it with the door closed, window closed, window open, door open, with the fan on, the ventilation system on, and it still gets very steamed, steamed up in there. It doesn't seem to be taking it away, and the sides are wet.

JB: Is it the same in the winter?

Alison: Same. It could even be like this, this morning when we got up, when we showered it would still be, like, damp, on the sides once you've finished.

JB: Do you get cooking smells lingering?

Alison: No, because I have to have my kitchen door shut. We don't do smells around the house. No matter what you're cooking the door has to be shut.

Claire: And we leave the door shut after we've cooked as well.

Alison: Yes, to make the smells go away.

JB: Do you get smells from outside?

Alison: Sometimes you do.

Claire: We've had a smell recently haven't we. A couple of mornings we've come in here and it stinks of pot.

Alison: It's terrible.

Claire: And that's no windows or doors open. And we've also had the smell of smoke in here before, as if something's burning, and it has come through them (JB: MVHR input vents in livingroom ceiling), haven't we. We've not had that for a while, that one. But the last, when was it, a couple of weeks ago, we came in here from work one evening and you opened the door and you could literally smell pot in here.

Alison: You said it was a good job we didn't have visitors or they'd have thought it was us. All I can assume is neighbours.

Claire: It was just like, there was no windows open, no doors open, the house was sealed up and it still stunk in here.

Alison: It was awful.

JB: Do you get any problems from the open land at the back?

Alison: That's just derelict. No-one ever goes on there. You don't get no smells from there at all, no.

Claire: Just bugs.

JB: How do you deal with the condensation?

Alison: On the windows we've got a big damp trap down there, that I have all year round. I have that there, and that's normally when it's really bad. And then in all the bedrooms I keep a smaller one and collect it. Then I wipe the windows, wipe the window sills.

Claire: They're always full.

Alison: Yes, it's quite surprising.

Claire: More in the winter, but you still have to change them over throughout the summer.

Alison: In the winter, I would say every other day, definitely every other day. Because the things inside are supposed to last three months and they don't, they only last a month. Even the lock, on the main front door, there would be condensation on the lock as well in the winter.

JB: Have you contacted the housing association about the damp?

Alison: I can't remember if I have. I phone them about so many things. They just say, it happens, it just happens in all homes. All they'd say is keep a window open. But that's not always feasible to do.

JB: Did they mention the ventilation system?

Alison: No. No-one's even ever been to service it, so that's six years it's not been serviced for, so I assume it would need new filters. Because not so long ago actually, I took a picture of it, googled it on-line and then contacted the suppliers, the manufacturer, and they emailed me an instruction thing, but it was really how to install it and how to change the filters, not what is it for, how you should use it. And they said I should phone them and when I last spoke to my housing officer about it, he said what I should do is phone up and report it as a repair. And I said well it's not technically a repair. He went no, you need to report it as a repair, and get someone come out and they will decide then if they're going to change the filters and what's what. I haven't done that yet. I'm never around in the daytime, because I'm at work, and I can only be here when it's school holidays, so I have to contact them nearer school holiday time so that I can get an appointment. I'm definitely going to do that, believe me.

JB: What advice did you get when you moved in?

Alison: I actually signed for the house where I used to live. I used to live in a West Homes property, I know it's North & South now, but it was West Homes at the time, and the area was being regenerated. So I signed for my keys there. We did come and view it but the lady that was here didn't really know, because she told me I had a south-facing garden, I'd have sun, which I don't. So then she told me I could have a dishwasher.

Claire: We spent a year fighting for it.

Alison: Fighting for it to be plumbed-in because there was no plumbing for a dishwasher. So she wasn't very well informed.

Claire: It was a couple of months old, wasn't it, because there was already people moving in. A couple of properties were empty, this being one of them.

JB: What response do you get when you report repairs?

Alison: It depends. It depends, sometimes it's a hit and miss, if they come.

Claire: I think they fob you off though. Remember you had the leak in your bedroom and they took, what, a good few months to get that even resolved.

Alison: Ages yes. It turned out it was the flat above me and their balcony part hadn't been sealed so they had to take the lady's tiles up off the floor and the part hadn't been sealed. But sometimes they tend to fob you off a lot. They seem to think that you don't know anything, and I do, and yes, they just fob you off.

JB: How does this property compare with your previous homes?

Alison: I think we could keep it aired better in our old property.

Claire: We never had no condensation in our old house.

Alison: No condensation. We lived in a maisonette. We had PVC windows installed. I don't know if it had to do with the fact that we were above a croft, so it was open. I don't know if that had anything to do with it. But saying that, it's warmer here than what it was in our old property. Even with no heating on, sometimes it just gets so warm in here. We can't sleep with the bedroom door shut because you'd just die.

JB: Are the fuel bills reasonable?

Alison: I think they are, yes. I think in total we pay £60-£65 a month and that's gas and electricity. I think that's quite…and sometimes it could be less on the electricity, so £65 is the most I would say that we pay.

JB: Do you do a lot of cooking?

Alison: Not if I can help it. I always have to have the windows open. Mind you, I do always open a window when I get up in the morning, in any case, windows always open. It could be in winter and I'd have a window open and she'd moan.

But I can't stand the bugs that come in (at night) and the noise of the trains. Sometimes it can shake, if a really heavy freight one goes past. It does, yes.

Claire: You do kind of block off the noise, with the windows and doors closed you block off, but when they're open you can really hear it.

JB: What about the laundry, how do you do that?

Alison: Chinese laundry. Don't have a tumble dryer. So it's basically the washing, obviously in the winter, the heating's on in here, so I will dry washing near the radiator in here, on a rack, just like that. I won't put my washing out in case it rains. In the summer the rack is there and upstairs it's just like a Chinese laundry, over the doors…

Claire: We do use it (JB: outside line) on a Saturday when we're here, but I work and don't get in until gone 7 normally of a night, and by then it's dark out there and you start getting the bugs out there, and it might have rained.

Alison: So normally we keep the washing in in the summer, unless we're here. And also if people have barbeques, can't be doing that either. It smells of that.

Claire: Sometimes in the summer, as soon as the weather's nice…

Alison: …you put the washing out and someone lights a barbeque, you think, really, you could have said. We have the sun till about half past two or three o'clock, then you get the sun out the front. It's not too bad.

Discussion during walkthrough of house:

JB: How do the windows open?

Alison: So that's how the windows open. In our other place the windows tilted in. So these'd be open like this. Upstairs you have got another lock on there now, because of the children, in case you've got children it locks. I'd like a window where you can half shut it and it'd lock, then you could go out and leave your window like that then. The kitchen one, I have to stand on a stool to reach it.

They're nice looking, but I think they could have been triple-glazed. Because even sometimes I go upstairs and I think Claire has left her bedroom window open because the train sound is so near, but it's not. I don't know, because sometimes we do get draughts through the windows, obviously through the sides of the windows still, and it's just crazy sometimes, you can just hear people talking outside your bedroom window of a night, can't you.

JB: How do you use the heating controls?

Alison: I just turn it on when I want it on. It only takes five minutes. Switch it on at the control here. Just put it on manual there. Then turn it off, normally about an hour before we go to bed to let it cool down. When it reaches a certain temperature, that you've got it set at, it'll turn off.

JB: Did you add the cooker hood?

Alison: That was already here. Some of these were part buy, part rent. The properties that were part buy, part rent have got different features to the social housing. Though I'm social housing, I don't part buy, part rent, it's different to social housing.

Claire: They had to buy this for us to move here, but we're not part buy, part rent, we're just social housing. This was originally a property for part buy, part rent.

JB: What do you do with the cooker hood filter?

Alison: I just wash it down.

JB: Do you use the fan boost switch in the kitchen?

Alison: Very rarely we touch that one. If the smells are in here, obviously the window's always open or I have the cooker hood on.

JB: How do you open the kitchen window?

Alison: I can't reach it. I have to stand on a stool. I did mention that to them when they came round to do the snagging. That's why the stool's there, so that I can stand on the stool to open and close it.

JB: How do you operate the MVHR?

Alison: That is on all the time. And if I turn this on you'll hear the noise, that's the noise when you turn this light on, and the toilet light, and that's how it was continuously when we moved in, and they came and turned it down, because we couldn't sleep. You know if someone's left the bathroom or the toilet light on because you can hear this. If you get up in the night it's so bright you don't need a light on. Or the majority of the time, because it takes so long to come on, the light, we use the little light, this is brighter, and it's quicker. Eventually it runs down (JB: the boost noise). But it's strange because if someone's in here in the toilet and you're in the bedroom, wherever, you can feel that breeze coming through. But when you're in the shower and it's on you don't. So I don't know if it doesn't work properly.

JB: I see you have child locks on windows?

Alison: They came round and put those on. They said that by law they had to even though we didn't have children here. They had to fit them all so they went round and did everyone upstairs.

JB: Is there anything that deters you from opening windows?

Alison: I just think the only thing that deters us really is the bugs, especially where you've got all those trees and everything, the bugs that come in. We've also got, as you can see there, a water butt, which is a pain, because it attracts all the mosquitos, so of course you have the window open and you get all the mozzies coming in. That's just a nightmare that it's there.

I think sometimes the front, you don't like your window open do you, because anyone could climb up.

Claire: So you can reach my bedroom window, if you was able to get up onto the glass panel it's easy, my bedroom window's just there. If you know how to stand on it properly you could stand on the bins. I just watch too many scary movies I think. It can be noisy at the front, especially like a Friday or a Saturday night, with people coming in. Not so bad now our old neighbours have gone but it used to be quite…

Alison: And it's the same, if we're not sitting in here, I won't leave my door open because of the rats. We have a problem with rats, especially because you've got the railway line, you've got that land there, people have seen them.

Claire: It's never been a problem to us, never seen one.

Alison: We've never ever seen one. They've never come in. But the fact, even if we go in the kitchen, I would shut my living room door. Someone said they had them in their shed, we never have done, but late of a night we don't even have that door open because of that. Which is a shame, because some evenings are so nice we'd like to sit out there but we don't, for that reason isn't it.

JB: Do you usually agree on the temperature in the house?

Alison: She's a chilly mortal. I like fresh air.

Claire: I like, right now, I'm freezing. Normally we go with you. I just go and put blankets on, dressing gown and stuff. I just freeze but not fun.

Alison: The highest we have it is about 25 in the winter.

Claire: That's like, when it was snowing it was 25.

Alison: We have it up to 25 but you have to have the door open because it gets too hot.

Claire: I'll have the door shut, even though you can't breathe, it's stifling. I might just put an extra blanket on.

All names of individuals, places, projects and organisations have been changed.

Appendix 13. Anonymised home walkthrough notes

Interview 4pm after work
Hot sunny day! Airless!

QUESTIONS	OBSERVE PHOTO VIDEO
How well does ventilation work here? Any particular issues? How/when do you ventilate in here? How do you boost if needed?	Feel of room Hot! Windows open/closed Patio door open, window closed Heating Off Fans Use fans in livingroom & bedrooms, not on
Do you open windows here? How often? How easy? Anything stops you? Do you use tricklevents? If needed from area behind [illegible] from window but [illegible]	Window type Catches — Don't open them. Bugs Obstructions Fear of rats so don't leave door open unattended Tricklevents from [illegible] line
Any condensation or damp? Where? When? How long? Use condensation catchers, see photos	Crowded furniture etc Full, not overcluttered Under door gaps carpets fill gaps
Bathroom extract?	Working Clean MVHR boost when main light on – noisy so ~~tend to use light over~~ mirror instead
Kitchen extract? Use MVHR boost switch but not effective Cooking amount? Cooker hood? Filter?	Working Clean Yes Cooker hood type cookerhood fitted as designed for sale, recirculation type *
Laundry wash & dry. Where? How?	Tumble dryer vent No tumble dryer Outside line Not used much Dry on airing rack in living room or hanging around house
Ventilation controls. Where? How? Who? On/off in cupd boost in kit	Type of controls Complexity, usability
Maintenance of ventilation? Filter change?	Filters No maint/servicing in 6 years
All in house agree on temp and vent? Who takes charge?	Daughter cold / mother hot blankets

MVHR boost switch?
Humidistat control?
What is MVHR fixed to?

* House designed for sale but switched to affordable rent so some differences in spec

Htg has 2 circuits – controls in livingroom & ~~main~~ bedroom rear double

Glossary: terminology and definitions

AECB Building Standard

Developed by the Association for Environment Conscious Building (AECB) this standard (previously the AECB Silver Standard) utilises PHPP methodology (see Passivhaus), taking a similar fabric-first approach. The airtightness target is less onerous than the Passivhaus standard, specifying <1.5ACH_{50} where an MVHR system is used for ventilation or <3ACH_{50} where an MEV system is used.

Affordable Rent

Rent (including service charge) set at up to 80% of local market rent (including service charge).

Airey house

A type of pre-fabricated house built in the UK in the 1940s and 1950s, particularly by local authorities, constructed of concrete ship-lap panels and columns, with little or no insulation.

Airtightness

Two metrics are typically used to quantify the uncontrolled exchange of air between the inside and outside of a building through cracks, porosity and other unintentional openings. These metrics do not have a direct relationship with each other.

- UK Building Regulations methodology measures **air permeability**, i.e. the amount of air leakage per square metre of building envelope. This is a measure of building envelope airtightness. For example, $10m^3/hr/m^2$@50Pa means that $10m^3$ of air leaks from the building per hour for each m^2 of building envelope, measured at a pressure difference across the building envelope of 50 Pascals.
- Passivhaus methodology measures the **air change rate**, i.e. the number of times the volume of air within the building is changed in an hour. This is a measure of the volume of air that needs to be heated and thus the heating energy cost of the building. For example, 1 ACH_{50} means all the air in the building is replaced once an hour, at 50 Pa pressure difference.

Arms-Length Management Organisation (ALMO)

A not-for-profit company set up by a local authority to manage and improve all or part of its housing stock. ALMOs have been set up since 2002 as a way of increasing investment in local authority housing, with the stock remaining in the ownership of the local authority. In recent years, a significant number of local authorities have disbanded the ALMOs they created, reverting to direct management of housing services or transferring the stock to a housing association.

Assured Tenancy

See tenancy types.

Building Performance Evaluation (BPE)

The process of evaluating the performance of a building at all stages, from inception to occupation, with Post-Occupancy Evaluation being one element in the process.

Building Regulations

Mandatory requirements prescribed by Government applying to the construction and alteration of buildings. The regulations are supplemented by Approved Documents giving guidance on compliance with the regulations. Approved Document F: Ventilation and Approved Document L: Conservation of fuel and power are the two documents most relevant to the research topic.

The current regulations were set in 2010, with substantial reviews in 2013 and 2016, and apply to England only, being a matter devolved to UK national governments. The Ministry of Housing, Communities & Local Government is currently carrying out a fundamental review of the regulations (see Future Homes Standard).

In the current building regulations, four ventilation systems are allowed, with a further option allowable as an alternative strategy (see ventilation systems).

CO_2

Carbon dioxide, the principal greenhouse gas driving climate change by retaining heat in the atmosphere. Emissions of CO_2 arise primarily from burning fossil fuels. Reducing carbon emissions in order to slow down the rise in global temperatures (see Paris Agreement) therefore requires a reduction in the use of fossil fuels for domestic heating and generating electricity.

Code for Sustainable Homes (CfSH)

A sustainability standard introduced in 2006, based on nine categories of building performance. Dwellings received credits or points in each category, contributing to an overall rating from Level 1 to Level 6 (highest). Achieving specified code levels was mandatory for housing association schemes funded by the Homes and Communities Agency up to 2015. The standard is now voluntary.

EcoHomes

The version of BREEAM (Building Research Establishment Environmental Assessment Method), introduced in 2000 for new build homes. Credits were available in eight categories, contributing to a sustainability rating of pass, good, very good or excellent. EcoHomes was replaced by the Code for Sustainable Homes in 2007.

Energy Performance Certificate (EPC)

An EPC provides details of the energy and carbon performance of a property and how this can be improved. EPCs have two metrics: a fuel cost-based Energy Efficiency Rating (£/kWh/m^2) and a carbon emission Environmental Impact Rating (CO_2/m^2), calculated using the Standard Assessment Procedure (see SAP). Ratings are banded A (highest) to G. An EPC is required when properties are built, sold or let. Government strategy for increasing the energy efficiency of homes requires an improvement in EPC ratings to band C for all rented homes by 2030, recommended to be brought forward to 2028 by the Committee on Climate Change (2020b) in the latest Carbon Budget report.

Energy Performance of Buildings Directive (EPBD)

A European Union measure designed to tackle climate change by reducing the carbon emissions produced by buildings. The requirements of the EPBD have been embedded in UK legislation, including the need for Energy Performance Certificates (EPCs). The EPBD set a deadline for all new buildings in member states to be Nearly Zero Energy Buildings (NZEBs) by the end of 2020. Following the UK's exit from the EU, future changes in building standards in the UK will be the responsibility of the UK Government.

Fuel poverty

Fuel poverty (also referred to as energy poverty) is defined in England by the Low Income High Cost indicator (LIHC), which takes account of the cost of heating the dwelling adequately, compared to the median cost, as well as household income and fuel costs. Based on this indicator, 2.4m households in England, 10.3% of the total, experienced fuel poverty in 2018 (Department for Business Energy & Industrial Strategy 2020c).

Future Homes Standard

The UK Government launched a consultation in 2019 on proposed changes to the Building Regulations, to apply to new homes in England from 2020, as a stepping-stone to a Future Homes Standard in 2025. This standard will require 75-80% less carbon emissions from new homes than the current Building Regulations, paving the way to the UK achieving its legally-enforceable target of net-zero emissions by 2050. The Future Homes Standard will require new build homes 'to be future-proofed with low carbon heating and world-leading levels of energy efficiency' (Ministry of Housing Communities & Local Government 2019e:16). Heat pumps are expected to become the primary heating technology, making new homes 'zero carbon ready'.

Home

In this practice-based research, the term 'home' is generally used, in preference to dwelling, property or house, taking the view that 'a house is a device we interact with directly when building and renovating, whereas a home is a background for the performance of our everyday practices' (Mechlenborg and Gram-Hanssen 2020:6). However, house, property or dwelling, the legal term used in the Building Regulations, is generally used when referring to the building as a material 'thing' in ventilation practice. The impersonal term 'unit', in common use in the housing sector, is purposely avoided. See also (Mallett 2004; Ellsworth-Krebs, Reid, and Hunter 2015; Coolen and Meesters 2012).

Homes England

Non-departmental public body that, among other functions, allocates grants from public funds to reduce the loan funding required by housing associations developing new homes, enabling rents to be set at affordable levels.
This role was previously carried out by the Housing Corporation (to 2008) and the Homes and Communities Agency (2008-18).

Homes (Fitness for Human Habitation) Act 2018

This Act gives tenants the right to take legal action against their landlord for breach of contract on grounds that the property is unfit, without requiring local authority intervention. This right applied to new and existing tenants in England from March 2020, with some exceptions. 'Fitness for human habitation' includes fitness as defined in the Landlord and Tenant Act 1985 (including adequate ventilation) and freedom from serious hazards prescribed in the Housing Health and Safety Rating System.

Home User Guide (HUG)

Part L of the Building Regulations in England requires that developers of new homes provide handover documentation to the first occupants, explaining how to operate systems in the home efficiently, including ventilation systems. Housing associations usually provide this information in a Home User Guide, but the format and contents are not prescribed and can vary widely. The proposed changes to the Building Regulations include a 'national template with minimum requirements' for HUGs (Ministry of Housing Communities & Local Government 2019a:62), with the aim of improving the quality of information provided to residents.

Household Reference Person (HRP)

The person in whose name the home is rented or owned, or whoever has the highest income (for joint householders), or the oldest (where incomes are the same). HRP replaced 'head of household' in Government statistics from 2001, no longer defining householder in relation to gender.

Housing associations

Also known as Registered Social Landlords (RSL) or Private Registered Providers (PRP or RP). Non-profit distributing businesses, typically, but not universally, having charitable status. They vary widely in history, geography, size, structure and activities, but all include among their objects the provision of affordable, good quality homes for households on low incomes. There are currently approx. 1400 housing associations registered in England, although approx. 1100 of these are defined as small, managing less than 1000 homes. Mergers in the sector are gradually reducing the overall number of associations. Only a few hundred associations are actively developing or acquiring new homes, increasingly buying homes from private housing developers, creating mixed-tenure schemes as a condition of planning consent (see Section 106).

Housing Health and Safety Rating System (HHSRS)

The HHSRS is a risk-based tool for assessing housing standards, in any tenure, introduced in 2006 in England and Wales. The likelihood and severity of harm to occupants from 29 hazards is assessed, using a scoring system. Local authorities are required to take action where a serious hazard, Category 1, is found. See Homes (Fitness for Human Habitation) Act 2018.

Housing Ombudsman Service

A non-departmental public body set up to investigate complaints about landlords and provide a dispute resolution service for tenant and landlords. Social landlords are required to be members of the service and expected to act on the findings of the Housing Ombudsman, which are published and taken into account by the Regulator of Social Housing. Private landlords can be voluntary members of the service.

Indoor Air Quality (IAQ)

The quality of indoor air in a home can deteriorate due to a mixture of pollutants generated inside the building from building materials, furnishings and the activities of occupants, pollutants generated outside the building that migrate indoors, natural radon gas that enters from the ground (particularly in some geographical locations), and excess humidity in the dwelling.

Domestic air quality in the UK is unregulated and no single Government body has ownership of this issue. Despite the evidence of damage to health, the risks of indoor air pollution have been largely overshadowed to date by the attention focused on external air pollution related to industrial and transport emissions.

Low-energy building standards

A range of voluntary standards, exceeding the building regulation requirements, for dwellings intended to be low-energy in use. The principal standards relevant to this research are the Code for Sustainable Homes, EcoHomes, Zero Carbon Homes, Passivhaus and AECB Building Standard (see separate descriptions).

Low-energy home definitions

A plethora of different terms and metrics are used to define low-energy homes, relating to energy usage or carbon emissions, including zero-net energy, energy-plus, zero carbon, carbon neutral and climate friendly (Lützkendorf and Frischknecht 2020; Williams 2011). For the purpose of this research, the definition of a low-energy home is a dwelling with a design air permeability (airtightness) less than or equal to $5m^3/hr/m^2$ @ 50 Pa (see Airtightness).

Low rent homes

Defined for this research as homes let by housing associations at an Affordable Rent or Social Rent (see separate entries).

Maintenance practitioner

Defined for this research as operational and managerial staff responsible for maintenance services in rented homes. The definition of maintenance practitioner encompasses a spectrum of roles, from directors, managers and heads of service to roles closer to front-line service delivery, such as engineers, supervisors and surveyors, irrespective of the specific job title. In the context of this research, maintenance practitioner does not include maintenance operatives or tradespeople carrying out maintenance work in tenants' homes.

Mechanical Extract Ventilation (MEV)

A whole-house ventilation system using a centrally located fan to draw stale or moist air from high humidity rooms through ducts, extracting this to the outside. This creates negative pressure in the property, which draws fresh air into the property through the envelope of the building.

Mechanical Ventilation with Heat Recovery (MVHR)

MVHR supplies filtered fresh air, and extracts stale air, through a system of ducts and room vents, with air flow driven by one or more low-power fans in the MVHR unit. As air passes through the unit, it recovers heat from the outgoing air, transferring this to the incoming air. Filters for the incoming and outgoing air require changing at approx. 3-12 month intervals.

Mutual Exchange

Process for two or more tenants in social housing to move house by swapping homes. The landlord's consent is required but tenants themselves agree the exchange, accepting their new home 'as seen'. Landlords may inspect the properties and carry out safety checks and are required to provide an EPC to the incoming tenant.

National Housing Federation (NHF)

Membership body representing housing associations in England.

National Housing Maintenance Forum (NHMF)

Membership body representing the maintenance sector in social housing organisations in the UK.

Noise standards

The noise from domestic building services is not regulated in the UK, although guidance in Approved Document F of the Building Regulations specifies that continuously running ventilation systems should not exceed 30 dB(A) in living rooms or bedrooms. Evidence indicates that poor design, installation and commissioning of MVHR systems (NHBC 2017) can lead to noise exceeding this level at handover. Based on considerable research on this issue, Harvie-Clark (2019) recommends a more prudent limit of 24-26 dB(A) for mechanical ventilation systems to ensure that adjusting systems in reaction to noise does not lead to unacceptable air quality. Proposed changes to the Building Regulations strengthen the guidance on ensuring that ventilation systems are not ‘unduly noisy’, but do not propose mandatory in-situ noise testing of new dwellings or reduce the advisory maximum noise level.

Paris Agreement

Increasing international concern about the impact of global warming led to the 2015 Paris Agreement to intensify action to limit the global temperature rise in this century to well below $2^{o}C$ above pre-industrial levels, for the first time bringing ‘all nations into a common cause’ (United Nations 2017). The Agreement requires all signatories to take the necessary action to achieve this target. The UK Climate Change Act 2008 enacted a legally-binding target of reducing greenhouse gas emissions by 80%, from a 1990 baseline, by 2050. Triggered by the UK’s commitment to act on the Paris Agreement, and mounting public pressure regarding the Climate Emergency, this target was amended in 2019 to zero carbon emissions from all sectors by 2050.

Passive Stack Ventilation (PSV)

PSV is a natural whole-house ventilation strategy using a combination of cross-ventilation, buoyancy (warm air rising) and the venturi effect as wind passes over the terminal of ducts at roof level causing suction.

Passivhaus

An energy performance standard developed in Germany in the 1990s, based on a ‘fabric-first’ approach to construction, having ultra-high levels of insulation and airtightness. The standard sets limits for heating energy (15 $kWh/m^2/yr$) and for primary energy consumption. An airtightness target of $<0.6ACH_{50}$ generally requires the dwelling to have an MVHR system. Dwellings are designed to meet the targets using PHPP (PassivHaus Planning Package) software.

Positive Input Ventilation (PIV)

PIV supplies filtered fresh air to the whole house through a central diffuser in the landing ceiling, driven by a PIV fan unit in the loft. The positive air pressure in the property causes stale air to escape through air leakage points in the building. There is no heat recovery in a PIV system. A filter for the incoming air requires changing at approx. 3-5 year intervals.

Post-Occupancy Evaluation (POE)

Systematic and rigorous evaluation of the performance of a building after it has been in use for some time, including feedback from occupants or users of the building. The RIBA Plan of Work 2019 expects designers to carry out at least a 'light-touch post-occupancy evaluation' (Stevenson 2019). This approach, or the more formal BSRIA Soft Landings process on which it is based (BSRIA 2014) is now regarded by the RIBA as essential to delivering its 2030 Climate Challenge (RIBA 2019).

Regulated and unregulated energy/emissions

Regulated energy is energy consumption from fixed building services and fittings, i.e. space heating and cooling, water heating, ventilation and lighting. Energy efficiency in the Building Regulations, SAP calculation and EPC only takes regulated uses into account.

Unregulated energy is energy consumed by appliances and equipment in the property, often referred to as 'plug loads', that is not included in the SAP calculation.

The reduction of domestic carbon emissions clearly requires action on both regulated and unregulated emissions.

Regulator of Social Housing (RSH)

Non-departmental public body that oversees the financial performance, governance competence, and service delivery of housing associations and has extensive legal powers to intervene where associations are failing to meet the standards that it sets.

This role was previously carried out by the Housing Corporation (to 2008), Tenant Services Authority (2008-12) and the Homes and Communities Agency (2012-18).

Repairs and maintenance service

A housing association repairs and maintenance service will typically be divided between 'responsive repairs' and 'planned and cyclical maintenance'.

Responsive repairs, usually initiated by a report from a resident, will be carried out in accordance with a timescale related to the urgency of the repair. Typical categories and timescales are 'emergency' (respond in 4 hours and complete in 24 hours), 'urgent' (respond and complete in 7 days) and 'routine' (respond and complete in 30 days).

Planned and cyclical maintenance includes annual programmes such as gas servicing, cyclical works such as external decoration and planned programmes for replacing kitchens, heating systems, etc. in accordance with the component's expected life.

A repairs and maintenance service is typically managed in-house and delivered by a mix of directly-employed maintenance operatives and external contractors. In some cases the entire service will be outsourced to a subsidiary of the housing association or to an independent private company.

Management of the service may be a separate directorate within the association or, more typically, part of the development or housing management directorate.

Resident

In this research, the term 'resident' is generally used, as is common in practice in the housing sector, in preference to occupant or inhabitant, although each of these terms refers to the relationship with a particular home or place. The term 'tenant' is generally used where the legal relationship with the landlord is pertinent.

A simple count of terms used by respondents to the scoping survey (maintenance practitioners in UK social housing organisations) showed that 45% referred to tenants, 42% to residents and 13% to customers. None referred to occupants. It was noted at a recent housing sector 'roundtable' including landlord and tenant organisations that 'new terms like "home provider" and "resident" could encourage respectful relationship-building between both parties' (24housing 2019).

Room-based ventilation systems

Domestic ventilation using extractor fans or combined intake/extract fans in individual rooms, supplemented by windows and tricklevents.

Schedule of Rates (SoR)

Schedule defining the work and cost of each maintenance job for residential buildings, updated annually. Housing associations typically use a SoR (such as the M3NHF version) to control maintenance costs.

Section 106 Agreement

A legal agreement under the Town and Country Planning Act 1990 requiring a developer to mitigate the impact of new homes on the local community and infrastructure as a condition of planning consent. Section 106 agreements are commonly used to require developers to make affordable homes available, by the sale of properties to housing associations at below-market prices.

Social housing

Homes owned or managed by a housing association, ALMO or local authority and let at below-market rents, usually Affordable Rent or Social Rent. Low-cost home ownership or shared ownership is sometimes also defined as social housing.
For the purpose of this research, social homes are homes managed by a housing association and let at Affordable Rent or Social Rent.

Social Rent

Rent calculated by a formula set by the Regulator of Social Housing (RSH) that takes into account the relative value of the property, the property size and local income levels. Rent increases are regulated by the RSH.

Standard Assessment Procedure (SAP)

The methodology prescribed by the Government for calculating the energy and environmental performance of dwellings. The SAP score (scale of 1-100) is the basis for Energy Performance Certificates and for establishing compliance with the Building Regulations. A SAP score of 92-100 equates to an EPC rating of A, with a score of 100 indicating zero energy costs.

Starter tenancy

See tenancy types.

Tenancy types

Most social housing tenancies in England are Assured Tenancies, with no time limit. New tenants may be given a Starter Tenancy for a 12-month trial period, which is then converted to an Assured Tenancy if the tenancy conditions have been met. Fixed-term Assured Shorthold Tenancies are usual in the private rented sector, but used by social landlords only in specific circumstances, such as when the landlord only has a short-term lease of the property.

Tricklevents

Trickle ventilators are commonly installed devices designed to provide controllable background ventilation, usually manually controlled. They are typically fitted through or above the window frame, at a height intended to prevent draughts causing discomfort. Tricklevents are intended normally to be left in the open position but can be easily closed if weather conditions require this.

Ventilation effectiveness

As defined in the Building Regulations 2010 Approved Document F, ventilation effectiveness is a measure of how well a ventilation system works in terms of delivering the supply air to the occupant of a building. If the supply air is mixed fully with the room air before it is breathed by the occupants, the ventilation effectiveness is 1. If the supply air is extracted from the room before it mixes with any room air, the ventilation effectiveness is 0. If the supply air reaches the occupant without mixing with any room air, the ventilation effectiveness tends towards infinity. A higher ventilation effectiveness achieves acceptable pollutant levels at the occupant’s breathing zone for a lower air supply rate and offers potentially significant energy savings.

Ventilation rates

Required ventilation rates are set out in the Building Regulations Part F for new homes in England. The rates comprise an extract ventilation rate (litres/sec/m2 floor area) for kitchens and bathrooms, a whole house rate (based on number of bedrooms) and a 'purge' ventilation rate (air changes/hr to rapidly dilute pollutants or moisture). The whole house rate is based on two occupants in the main bedroom and one occupant in each other bedroom, an occupancy rate that is frequently exceeded in social housing, particularly if residents are in receipt of Housing Benefit and are affected by the under-occupancy charge, also known as the Bedroom Tax. The proposed changes to Building Regulations significantly increase the ventilation rates required, relative to the number of bedrooms, reflecting potential higher occupancy.

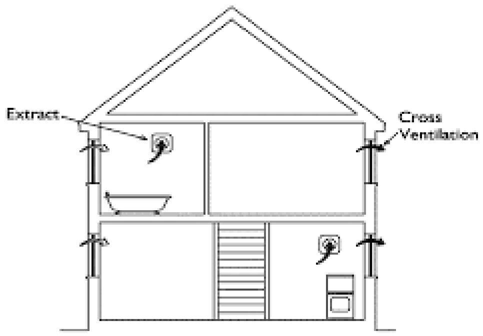
Ventilation systems

Four ventilation systems for domestic buildings are set out in the Building Regulations, plus an alternative allowable system, as illustrated.

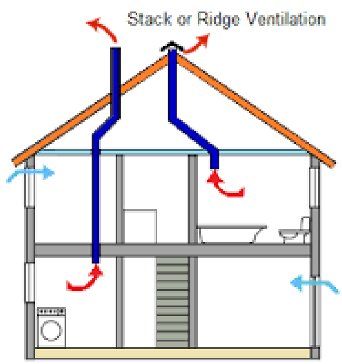
System 1	Background ventilators and intermittent extract fans (as in scheme A)
System 2	Passive stack ventilation (PSV) (not used in case-study schemes)
System 3	Continuous mechanical extract (MEV) (not used in case-study schemes)
System 4	Continuous mechanical supply and extract with heat recovery (MVHR) (as in schemes G, L and R)
Alternative	Positive Input Ventilation (PIV) (as in scheme H)

The system selected must allow for effective ventilation, taking account of the air permeability of the building, achieving the air flow rates specified in the regulations.

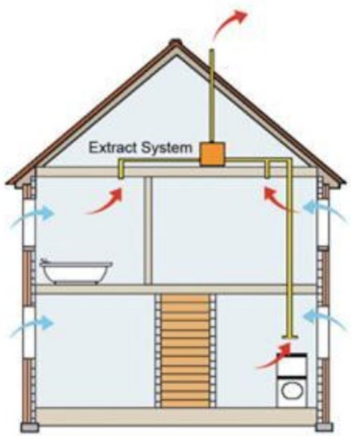
System 1   Background ventilators and extract fans



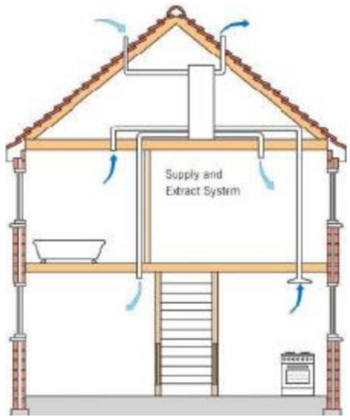
System 2   Passive Stack Ventilation



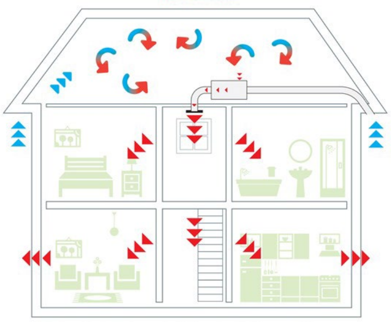
System 3   Mechanical Extract Ventilation



System 4   Mechanical Ventilation with Heat Recovery



Alternative system   Positive Input Ventilation



Whole-house ventilation systems

See MVHR, PIV, MEV, PSV

Zero Carbon Homes

Code Level 6 of the Code for Sustainable Homes was intended to define a zero carbon home. A more comprehensive definition subsequently evolved, combining a Fabric Energy Efficiency Standard (FEES) for space heating and cooling and limits for on-site regulated emissions. Where the combination of fabric efficiency and zero carbon technologies does not result in zero emissions overall, off-site solutions are allowable to offset remaining emissions. Definitions continue to evolve, taking into account carbon embodied in construction of the building as well as operational carbon emitted during use of the building.

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