Business models to accelerate uptake of domestic heat efficiency and decarbonisation measures

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A dissertation submitted by Chris Carus to the Department of Civil & Environmental Engineering, University of Strathclyde, in part completion of the requirements for the MSc Environmental Entrepreneurship.

I, Chris Carus, hereby state that this report is my own work and that all sources used are made explicit in the text.

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Abstract

Decarbonising the heating of existing residential buildings is a key sustainability challenge. Improving building thermal efficiency is a low regrets approach: reducing the capacity and cost of required new renewable sources and reducing fuel poverty. However, retrofitting energy efficient measures in the owner-occupier sector is difficult, facing challenges of low homeowner engagement, high costs and disruption. This dissertation applied case study methodology to consider how business model innovation can accelerate energy efficiency and decarbonisation retrofit implementation in an area of south Glasgow, UK.

Using an established conceptual framework of retrofit business models, this research applied an exploratory case study approach to examine drivers and barriers to retrofit in a specific physical and social context. Findings were synthesised in an outline business model suitable to the case study area. Semi-structured interviews with professionals were used to strengthen the transferability of conclusions.

Current homeowner decision making was found to be focussed on cost and payback. The potential value of improved comfort may be underestimated by homeowners, especially by occupants of traditional constructions. Coronavirus 'work from home' policies have changed younger homeowner attitudes towards home heating improvements. Homeowners indicate interest in advanced, independent and personalised energy assessment. Previous research into the importance of interpersonal trust was reinforced with the discovery of an online social media group with a strong local influence on tradesperson selection.

An innovative business model is proposed in response to the case study findings. Policy recommendations are put forward, with particular relevance to emergent minimum energy efficiency standards for the owner-occupier sector. Further research needs are identified.

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Abbreviations

BWS	Best worst scaling
ECO	Energy Companies Obligation
EES	Energy Efficient Scotland
EPC	Energy Performance Certificate
LHEES	Local Heat and Energy Efficiency Strategy
RHI	Renewable Heat Incentive

1. Introduction

Heating and hot water for buildings account for around 20% of UK greenhouse gas emissions (CCC, 2019). Compliance with the UK Climate Change Act requires the near total elimination of these emissions by 2050 and a 20% reduction by 2030 (CCC, 2019). Some argue that emissions beyond the mid-2030s would not be compliant with international obligations including the 'fairness' aspect of the UNFCC Paris Agreement that places higher expectations on developed countries (Anderson and Broderick, 2017). Research has not yet established the extent to which decarbonisation should be achieved through emissions abatement through efficiencies as compared with investment in low carbon energy infrastructure (Filippidou and Jiminez-Navarro, 2019; CCC, 2019). However, energy efficient investments are described as 'low regrets' climate action options due to their several benefits addressing fuel poverty, the health of occupants and their potential contribution to a green recovery from the COVID crisis (Liebreich, 2020) whilst helping deliver the UK government's 'levelling up' agenda (Allan *et al*, 2020).

The UK's housing stock is amongst the oldest and least thermally efficient in Europe (Filippidou and Jiminez-Navarro, 2019). 80% of the 2050 stock has already been built meaning that almost all homes, including those being built today, will require retrofitting with insulation and low or zero carbon heat sources (CCC, 2019). Strategies to improving insulation and air tightness are not new. However, retrofit of the scale and depth required presents challenges to households in terms of cost and disruption, and to industry in terms of workforce development (Brown, 2018).

Technical innovation is addressing cost and performance challenges (Killip *et al*, 2014) while social science identifies the influence of tradespeople and the supply chain (Wade, 2020; Maby and Owen, 2015). A research question requiring further attention is how to better align owner-occupier retrofit business offerings with the natural progression of households and homes (Galvin and Sunikka-Blank, 2017).

The business model concept came to prominence during the dot com boom at the turn of the century (Amit and Zott, 2001). Zott and Amit (2010) provided a framework for characterising networks of actors, while Osterwalder and Pigneur (2010) provided their 'canvas' approach for business model development. In recent years approaches to understand and advance sustainable transition have pivoted away from transition theory towards business model approaches (Bolton and Hannon, 2016). Boons and Lüdeke-Freund (2013) outlined a research agenda for sustainable business models. In the field of retrofit, Mlecnik *et al* (2019) have shown that business modelling is an effective device for building effective collaborative networks. Frameworks for characterising retrofit business models have been put forward (Brown, 2018; Brown *et al*, 2019).

This research was motivated by a personal desire on the behalf of the researcher to carve out a new, purposive career in climate change mitigation. If one is tackling afresh the problem of residential carbon emissions in one's community, what novel ideas have a chance of making an impact? What challenges are presented by Scottish building archetypes and the views of their occupants? What contemporary issues should have a bearing on business model development, including policy developments and the COVID crisis?

Case study methodology was applied to an urban area of Glasgow, UK and semi-structured interviews with professionals were used to improve the robustness and transferability of findings. The research focusses on the perspectives of homeowners considered 'able to pay' in that they fall beyond the scope of the government energy efficiency grant support programmes.

The remainder of the dissertation is structured as follows. Section 2 introduces key principles of domestic heat efficiency and occupant comfort. Section 3 reviews academic and grey literature relevant to retrofit in the fields of policy, homeowner engagement and business model innovation. The research gap and ensuing research objectives are in section 3.4. Methods are detailed and justified in section 4. Findings are presented and discussed in section 5 before conclusions are summarised in section 6. This report is supported by a separate volume of appendices.

2. Approaches to Heat Decarbonisation and Comfort in Existing Homes

For home heating, complying with government net zero emissions targets means eliminating fossil fuels and replacing them with zero carbon alternatives. Improving the thermal efficiency of buildings reduces both the required zero carbon generation capacity and the ongoing operational cost of the building (Morgan, 2018). Sensitively done, thermal efficiency retrofit of existing buildings can also provide a healthier and more comfortable environment for occupants while preserving heritage features and cost-effectively extending the life of the building (Morgan, 2018). This section outlines the main strategies for improving thermal efficiency (section 2.1) and heat sources (2.2) and introduces some key concepts of assessment (2.3) and comfort (2.4).

This section relies heavily on 'Sustainable Renovation' by Morgan (2018) which describes advanced and architecturally sympathetic retrofit methodology appropriate to Scotland's housing stock and climate.

2.1. Insulation and Airtightness

Heat supplied to the home will escape through the building envelope until internal and external temperatures are equal through conduction, radiation or convection. Rates of heat conduction through walls (or radiation in the case of glazing) are addressed by insulating with materials that have low thermal transmittance. Most insulation materials work by trapping air in their structure (or other gases in the case of glazing).

Convection causes heat loss by transferring air through the building envelope, often through unintentional ventilation, or draughts. As insulation has been added to houses over the years, draughts have become more important and typically account for around 40% of all heat loss in the average building (Morgan, 2018). Improvements in air tightness need to come with improvements in controlled ventilation, such as mechanical extraction, to avoid the accumulation of moisture and toxic gases emitted from synthetic materials and gas cooking appliances.

Figure 2.1 shows that traditional Scottish solid stone wall constructions present both insulation and air tightness challenges. Stone is a poor insulator. Air flow around suspended timber floors and roof eaves (A) are design features intended to prevent structural damage due to any accumulation of moisture. Air tightness layers are now recommended, and synthetic insulation materials are common (B). Increasingly retrofit specialists advocate natural insulation materials, such as wood fibre boards, that have human health advantages and low embodied carbon (C).

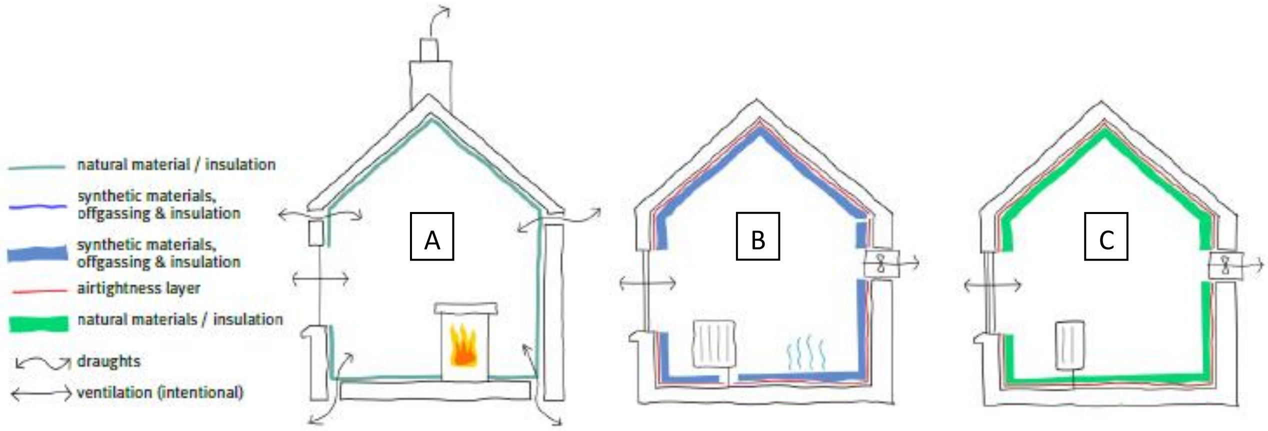

Figure 2.1: Changing approaches to insulation and air tightness. Adapted from Morgan, 2018.

Retrofit specialists recommend a 'fabric first' approach because repairing and insulating the building envelope often has a faster rate of financial and carbon savings than measures focussed on energy generation. Furthermore, efficient buildings require smaller heat sources that require lower capital investment. Fabric first approaches can be augmented by taking a 'whole house' or 'deep retrofit' approach in which plans for each element of the building envelope are integrated from the outset reducing the risk of leaving uninsulated gaps in the building envelope (called 'thermal 'bridges') which are a common cause of the 'performance gap' between designed and actual efficiency.

In Scotland, loft, wall and suspended timber floor insulation are important to improving thermal efficiency, as well as high performance windows and doors. Finished stone exteriors are usually preserved by applying internal wall insulation (see A in figure 2.2), while other solid walls can be externally insulated (B) and cavity walls, common since the 1930s can be infilled with insulation (C).

Figure 2.2: Forms of wall insulation: A internal; B external, C cavity fill. (Source: NIA, 2020).

Suspended timber ground floors, which are common in the area studied in this research, can also be insulated from above after removing floorboards (see A in figure 2.3) or from below if the solum space is sufficiently large (B in figure 2.3).

Figure 2.3: Underfloor insulation can be applied to suspended floors from above after removing floorboards (A) or from below (B). (Bragg, 2012; MacKay, 2015).

Building Standards regulations apply when elements of existing buildings are removed or replaced and define, for example, the maximum permissible thermal transmittance of insulation (Scottish Government, 2019a).

Costs of energy efficiency retrofits can be high. The Scottish Government (2018a) estimates the median cost of bringing all Scottish homes to Energy Performance Certificate band C to be £3500 per home, although consumer advocates argue this is an underestimate (CAS, 2019). Deeper retrofits to reach 50% or 80% energy reductions may cost £15k to £90k (Innovate UK, 2014).

The energy savings associated with retrofit are often negated if occupants increase the internal temperature, which is referred to as the rebound effect. The term ‘prebound effect’ is ascribed to the observation that thermally inefficient homes often consume less energy than is technically determined to be required meaning that, prior to retrofit, temperatures are uncomfortably or even unhealthily low (Sunikka-Blank and Galvin, 2012).

2.2.Heat Sources

Natural gas, a fossil fuel, is the most common primary fuel in Scottish homes with 91% of urban homes within the coverage of the gas grid (Scottish Government, 2020b). In urban areas most of the remainder of homes use resistive electrical heating. The mandatory requirement for all newly installed gas boilers to be ‘condensing’, i.e. capable of recovering heat by condensing combustion vapour, has increased efficiency to 88% (HMG, 2018). However, for this level of efficiency to be achieved, boiler and radiator sizes as well as heating circuit flow rates need to be carefully designed (CIBSE, 2013).

Electrification provides the main decarbonised alternative to gas in the form of heat pumps, either through domestic units or centralised through heat networks (CCC, 2019). Heat pumps can use air, ground, water, mine water or deep geothermal heat sources. They operate most efficiently at low heating circuit flow temperatures which require thermally efficient buildings and large radiators (CIBSE, 2013, in Wade, 2020). Optimal design requires accurate assessment of the buildings' heat demand on the coldest days (Cantor, 2020). The cost and risk of laying extensive pipe networks is a major barrier to the development of heat networks in low density housing areas (Chaudry, 2014).

An alternative to electrification is hydrogen produced either from water using renewable electricity or from natural gas using steam and carbon capture and storage which is currently an experimental and expensive technology (Agora Verkehrswende *et al*, 2018). The Committee on Climate Change (2018) remains sceptical of the potential future role of hydrogen in heating because of the cost of production and the challenges of appliance and grid conversion. It has recommended large scale pilots to support decision making (CCC, 2019).

2.3. Efficiency Standards and Assessment

The measure of energy efficiency with which most people in the UK familiar is the Energy Performance Certificate (EPC) as it has been required as part of all property sales and rental contracts since 2007 (MHCLG, 2014). EPCs are intended as a regulatory compliance tool and use a simplified assessment method. Now commonly missed a measurement of energy demand, the EPC is an important driver of the performance gap (Morgan, 2018). It is important to note that the 'energy efficiency rating' quoted in relation to EPCs is in fact a measure of cost efficiency not energy efficiency.

The simplified EPC methodology has the advantages of simplicity, accessibility and low training requirements for assessors. However, EPCs are often assessed incorrectly due to human error (Hardy and Glew, 2019) and the simplified assumptions can place properties in the wrong banding as shown in the histogram of actual property energy consumption vs EPC estimates in figure 2.4. Furthermore, dependency on outdated assumptions of grid electricity carbon intensity and the efficiency of heat pumps mean that EPCs can have a deterrent effect on renewables adoption (Rosenow, 2019). Nevertheless, EPCs have been shown to influence property valuations (Fuerst *et al*, 2016).

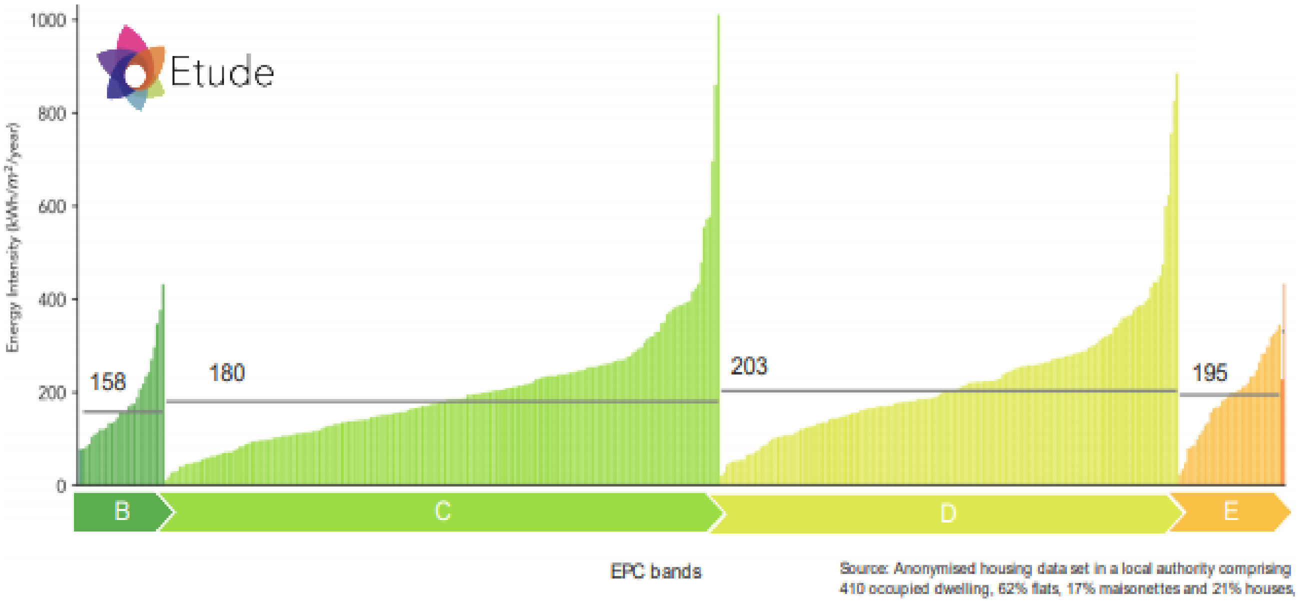

Figure 2.4: Histogram of actual property energy consumption vs EPC estimates showing that the simplified EPC assumptions can place properties in the wrong banding. Source: (Passivhaus Trust, 2020).

Advanced tools provide more accurate estimates and explanations of heat loss including Standard Assessment Procedure, Passivhaus planning package (PHPP) and dynamic modelling (Passivhaus Trust, 2020).

2.4. Perceptions of Comfort

Advanced understanding of human comfort in buildings goes beyond simply temperature levels and into the field of psychology and human development (Morgan, 2018). For example, heat from radiant surfaces is thought to have a disproportionate influence on sense of comfort because from the earliest time humans evolved to absorb heat from the sun. Figure 2.5 shows six interacting parameters influencing comfort, of which temperature is only one. Clothing and physical activity reduce the need for higher temperatures. Warm dry air can be uncomfortable and trigger coughs. Importantly, humans prefer warm feet and cool heads.

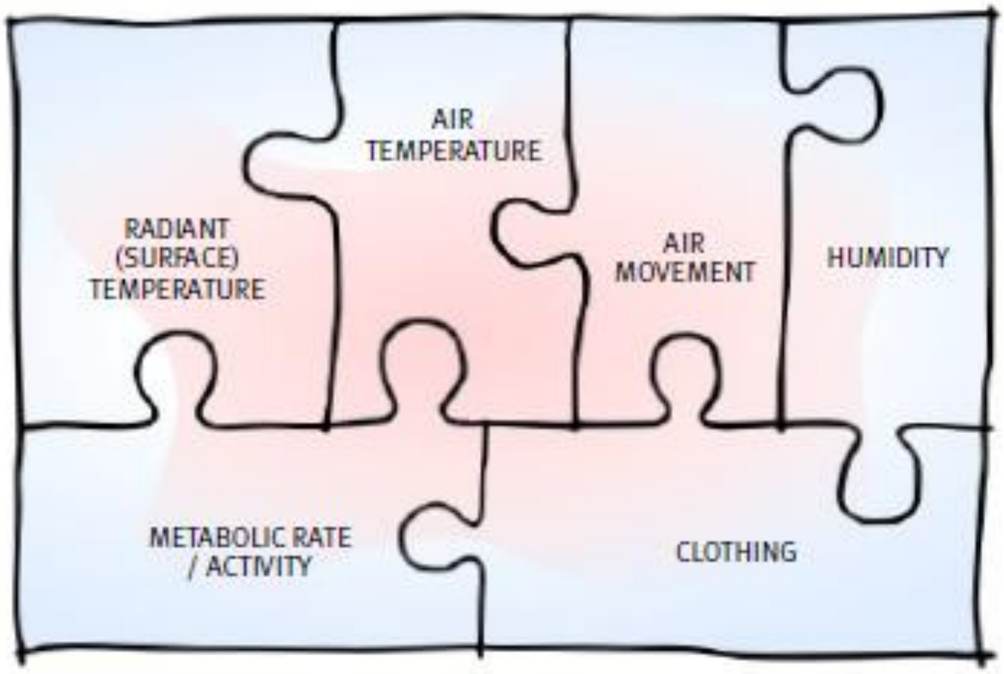

Figure 2.5: Six interacting factors of human comfort in dwellings. (Source: Morgan, 2018)

3. Literature Review

This section reviews relevant policy (section 3.1) and relevant previous work in the fields of homeowner engagement (section 3.2) and business model innovation (3.3). The research gap addressed by this research is presented with the research goals in section 3.4.

3.1. Energy Efficiency and Decarbonisation Policy and Progress to Date

Standards for thermal efficiency in buildings were first introduced in the 1970s in response to concerns regarding energy security and energy prices driven by the oil crisis (Bardi, 2009). Building energy efficiency is now a national infrastructure priority in Scotland, driven by government goals to address fuel poverty and climate change (Scottish Government, 2015).

The question of how much energy efficiency is enough is a ‘wicked problem’ in that there is no obvious end point (Rittel and Webber, 1973). Scenarios on a global level foresee efficiency accounting for 40% of the abatement of carbon emissions by 2040 (IEA, 2018). Optimisation for lowest total cost of decarbonisation of the EU housing stock finds that different balances in spending on efficiency retrofit versus renewable energy infrastructure are merited dependent on latitude (Filippidou and Jiminez-Navarro, 2019). In central European latitudes, deep retrofit is merited, whereas in southern Europe investment should focus first on energy infrastructure. The Scottish Government efficiency goals are conditioned on household-level cost-effectiveness in that ‘measures should pay for themselves over their lifetime’ (Scottish Government, 2018b, p6).

Regardless of the required end point there is consensus that progress is too slow (Rosenow *et al*, 2017). Compared with an indicator guideline of 545,000 loft insulation installations in 2019, only 27,000 installations were completed (CCC, 2020). Figure 3.1 shows the slow rate of progress in Scotland as measured by average EPC banding. Observers remark that climate policy is stagnating in a vicious cycle (Mitchell, 2019). Policy makers, fearing public reaction to disruptive legislation, postpone difficult decisions which increases the scale of action required later to meet international obligations. An example is the abandonment of the zero-carbon policy for new homes in England due to a lack of positive reinforcing results at an early stage (Edmondson *et al*, 2020). In relation to residential heat, UK policy makers fear, or are opposed in principle, to intrusive interventions into the private homes of citizens (Lowes and Woodman, 2020). In contrast with the other nations of the UK, Scotland has a policy to legislate for minimum energy efficient standards in the owner-occupied sector (CCC, 2020).

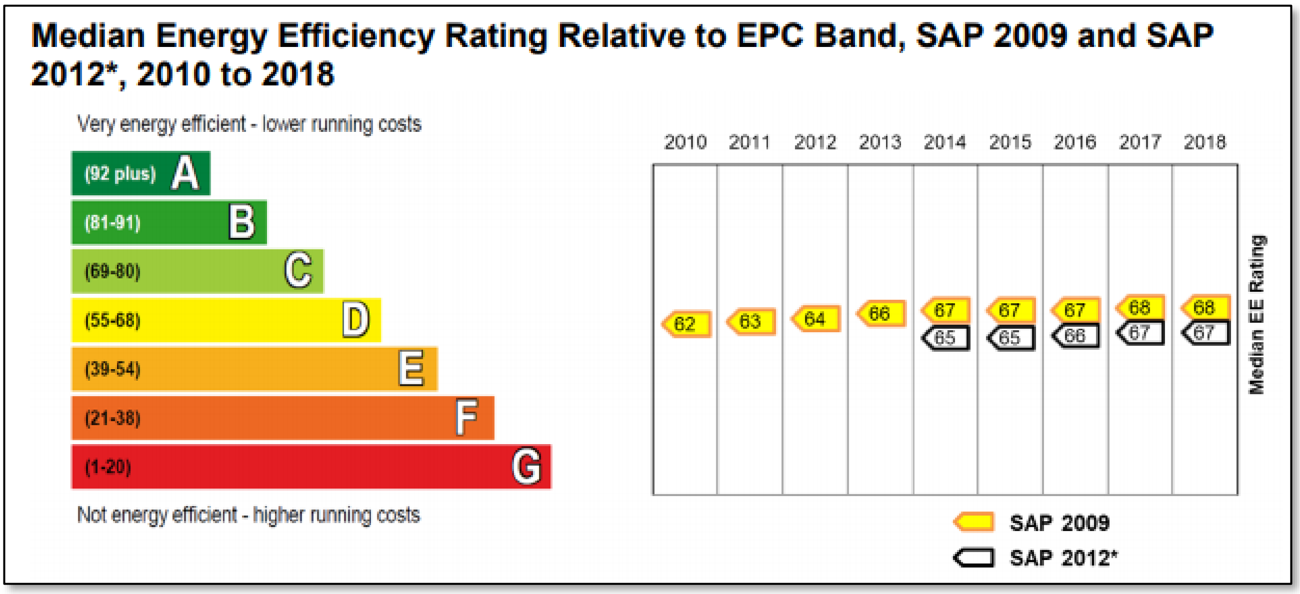

Figure 3.1: Average Scottish home Energy Efficiency Rating 2010 - 2018 (Scottish Government, 2020a)

The Scottish Governments policy for the owner-occupied sector, part of the Energy Efficient Scotland (EES) programme, targets all homes reaching EPC band C by 2040 (Scottish Government, 2018b). Up until 2030 the government will ‘encourage the adoption of EPC C’ (Scottish Government, 2018b, p13) and if necessary at that point, introduce legislation to mandate compliance at the point of sale or major renovations. After adopting the Committee on Climate Change’s recommendation of a 2050 net zero carbon target in 2019, the government has consulted on advancing the 2030 checkpoint to 2024 but has not yet published updated policy (Scottish Government, 2019c). Critics remark that the proposal lacks ambition both in terms of efficiency outcomes and timings (Wade and Webb, 2020) and that the EPC is not a reliable measure of either energy efficiency or environmental impact (Rosenow, 2020).

Arguments have been put forward in the international academic literature for local interventions because higher level actors are too far removed from homeowners’ motivations (Gram-Hanssen *et al*, 2018). The signal failure of the UK Governments national Green Deal scheme for home retrofit is attributed in part to its top down approach (Rosenow and Eyre, 2016). Similarly, the associated Green Deal Communities programme was found to have missed opportunities to develop local networks of competent retrofit tradespeople (Ince and Marvin, 2019). In contrast, EES envisions a local-authority lead approach to ‘hand-holding’ support for able to pay homeowners (Scottish Government, 2018b). Evaluation of pilot projects in the social housing sector has shown some success in developing ‘linked ecologies’ (Wade, Bush and Webb, 2020).

Based on examples in London and Manchester, Hodsen *et al* (2013) show that local government and other intermediaries can work around the policy stagnation at national level. The city of Glasgow, UK, the location of this case study research, has committed to net zero carbon by 2030 – fully 15 years ahead of the national target (GCC, 2019). Glasgow's 2014 carbon action master plan (GCC, 2014), which had a focus on heat networks, is to be replaced shortly with a Local Heat and Energy Efficiency Strategy (LHEES) (GCC, 2020a).

The high potential cost of retrofit, as outlined in section 2.1, makes finance a core consideration for retrofit policy and efficiency installations are sensitive to shifts in government policy. Figure 3.2 shows that the number of cavity wall insulations installed in Scotland dropped dramatically due to a change in UK funding support (Kerr and Winskel, 2018). A major reason for the very low uptake across the UK of the domestic renewable heat incentive (RHI) support, a core UK decarbonisation strategy, has been the cash flow challenge of having to pay upfront for the installation and then claiming the funding over seven years (UK Public Accounts Committee, 2018). By contrast, the Scottish Government provides an up-front interest free loan for renewables and insulation (EST, 2020). Despite this, only 36 RHI installations have been completed in the city of Glasgow between 2014 and 2019 (BEIS, 2019b).

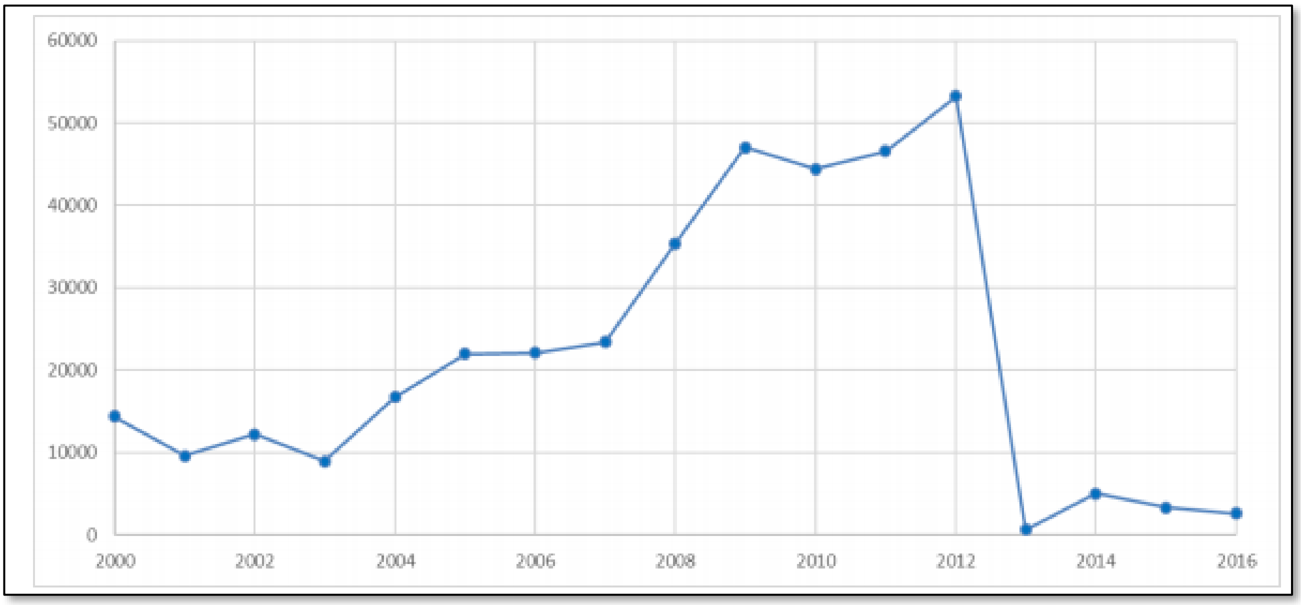

Figure 3.2: Cavity wall insulation installations in Scotland, 2000 to 2016. (Source: Energy Saving Trust, cited in Kerr and Winskel, 2018.)

The main financial and advisory support for home energy efficiency and decarbonisation available to owner-occupier homeowners such as those considered in this case study research are summarised in Box 3.1.

Box 3.1: Summary of the principle government support for energy efficiency and decarbonisation for owner-occupiers in the case study area.

Energy Company Obligation (ECO)	Payments towards insulation and gas boilers paid by large energy providers. Only households receiving social security payments eligible (BEIS, 2019a)
Renewable Heat Incentive	Tariff payment over seven years on heat generated from low carbon sources including biomass and heat pumps. (BEIS, 2020a)
Interest free loans	Provided for eligible measures (EST, 2020)
Equity loans	Scottish government takes a stake in the property until the loan is repaid when the property is sold (EST, 2020)
Home Energy Scotland advice	Online and telephone advice on home energy conservation and renewables. (EST, 2020)

Despite progressive development of government policy over many years, the depth and rate of energy efficiency and decarbonisation implementations remain low.

3.2. Homeowner Engagement with Retrofit

This section reviews research into the drivers and barriers of retrofit from the perspective of the homeowner (section 3.2.1) and into the challenges of engaging with the retrofit supply chain (3.2.2).

3.2.1. Drivers, Barriers and Windows of Opportunity for Retrofit

Besides the often considerable cost, as shown in section 2.1, homeowners face a range of barriers to effective retrofit. Homeowners are often unaware of the benefits of fabric retrofit (Mallaband *et al*, 2013). The challenge of organising complex interventions is often exacerbated by the lack of competent providers (Mahapatra *et al*, 2013; Gillich *et al*., 2018). The sheer hassle and mental effort required to understand needs, evaluate benefits, manage risk and engage contractors can be overwhelming for all but the most motivated and capable of households (EST, 2011).

A review of studies into homeowner decision-making found that economic and comfort reasons were found to be most significant drivers of major home energy-relevant interventions including efficiency retrofit (Kastern & Stern, 2015). Demographics were not found to be useful determinants of propensity towards retrofit. Impacts beyond the home, particularly environmental impacts, were also found to be important. However, UK polling suggests that the power of environmental concerns may be undermined by low levels of public understanding with only a minority (49%) of survey respondents identifying gas central heating as a cause of climate change (ESC, 2020).

Frederiks *et al* (2015) have shown home energy decisions are distorted by cognitive biases including risk aversion and 'satisficing' which is being satisfied with a sub-optimal outcome provided it exceeds a minimum standard. Furthermore, economic rationales are undermined by fixation on sunk costs and expectations of rapid paybacks in bill savings. Risk aversion has been found elsewhere to deflect homeowners from local government schemes (Sperling and Arler, 2020).

Research into homeowner decisions around deep, whole house retrofit in Norway revealed that finding the right opportunity in time for works was a significant barrier (Klöckner and Nayum, 2016). In the UK it has been proposed that deep retrofit can be effectively pursued in incremental fashion, rather than as a single comprehensive intervention, and that renovation, maintenance and improvement (RMI) interventions provide underexploited windows of opportunity (Maby and Owen, 2015). Integrating retrofit with RMI can also make the cost of retrofit easier to rationalise (Brown *et al*, 2019). Life course transitions such as having children or retiring also provide important opportunities for retrofit (Burningham and Venn, 2017). Galvin and Sunikka-Blank (2017) compare such integration of retrofitting into the natural course of a household with the 'desire line' principle in landscaping in which paths should be laid where people naturally want to walk rather than at awkward right angles. However, incremental interventions can lead to sub-optimal outcomes for energy consumption. Wade (2020) has shown through ethnographic studies that gas engineers may sometimes perpetuate the inefficiency of a heating system through oversizing replacement gas boilers or retaining the poor location of a thermostat in order to reduce the need for disruption to décor or user habits.

Innovative retrofit businesses may seek to target their launch offering at a market segment upon which to form a 'beachhead' (Moore, 2014). One approach is to characterise homeowners using 'personas' based on traits including life stage, bias towards do-it-yourself, amenity and aesthetic priorities and the degree to which the homeowner is distracted by other pressures (Haines and Mitchell, 2014).

3.2.2. Interaction with the supply chain

De Wilde (2019) has shown that three modes of trust have important influence on retrofit decision making. Interpersonal trust arises through participation in social networks; impersonal trust is linked with independent trade accreditations and government standards; and professional trust develops from perceptions of the professionalism and ethics of service providers. In the study of 40 low carbon measure adopters in the Netherlands, interpersonal trust was most important in the early stages of orientation and information gathering. Professional trust was influential in the final stage of installation and commissioning.

The importance of interpersonal trust in engaging homeowners is echoed in the UK (Maby and Owen, 2015). US studies highlight the importance of community based social marketing, a method that builds on networks and workshops within a locale (Gillich *et al*, 2018). Social marketing is a central strategy in the pioneering People Powered Retrofit programme operated by Carbon Coop in Greater Manchester, UK (Carbon Coop, 2020).

The 'Each Home Counts' review was commissioned by the UK government to make recommendations to support energy efficient retrofit in the areas of consumer protection, quality standards and enforcement (BEIS, 2020). Conclusions built on the government Trustmark supplier standard (Trustmark, 2020) and advised renewal of the PAS2030 standards for insulation installations, which are both examples of impersonal trust mediators. The review also led to the creation of publicly available standard PAS2035 (BSI, 2020), which defines standards for the retrofit customer journey. PAS2035 defines roles including 'retrofit coordinator' and 'retrofit designer', which may in time come to mediate some level of professional trust.

3.3. Business Model Innovation for Retrofit

Osterwalder and Pigneur (2010) define business models as "the rationale of how an organisation creates, delivers and captures value". Zott and Amit (2010) take a perspective that goes beyond a single organisation to consider networks of activity. Williams and Lewis (2008) argue that value may not only be economic and that public sector organisations can be engaged through business modelling to consider concepts of strategic importance. Through case studies in energy, energy conservation and transport, Sovacool (2020) has shown that innovative business models can emerge from incumbent industry players as well as from new entrants.

Rather than being about simply producing a document, business modelling should be seen as a process with an inherent value of its own. The business model canvas is provided as a tool for building shared understanding and insights through multi-disciplinary workshops (Osterwalder and Pigneur, 2010). Boons and Lüdeke-Freund (2013) argue that modelling can act as a vehicle for communication between both business and non-business actors.

Killip *et al* (2014) found that novel supply chain configurations are required for effective retrofit. Reviews of local authority-lead pilot schemes within the Energy Efficient Scotland programme found that configurations do not yet fully integrate in terms of communication, trust and distribution of risk (Myers *et al*, 2019). While 'one-stop shops' would reduce complexity for homeowners, they have been found to be difficult to establish in the face of uncertain demand (Mahapatra *et al*, 2013).

Several conceptual frameworks have been put forward to support business model development and analysis (Brown, 2018). All of these frameworks take a 360 degrees approach to characterising networks of actors: the value offered to the customer; the downstream and upstream supply chain interfaces; and the key defining intellectual, physical or financial resources. The nine-element business model canvas is specifically designed for practitioners (Osterwalder and Pigneur, 2010). Zott and Amit (201) identified three design elements central to their activity network perspective. From these two frameworks, Boons and Lüdeke-Freund (2013) identified four key characteristics central to sustainable innovation. Bolton and Hannon (2016) highlighted the importance of governance in business models that combine energy generation and conservation in energy service companies. Brown (2018) merged that insight with the Boons and Lüdeke-Freund framework to provide a five element framework for characterising retrofit business models, shown in table 3.1. Brown's framework is central to the method of this research project.

Table 3.1: Brown's (2018) framework for characterising retrofit business models.

Business model characteristic	Description
Value proposition	The value presented to the customer by the product and/or service.
Customer interface	The channels through which customers are engaged and the means by which the customer relationship is nurtured.
Supply chain	The design and management of relationships with suppliers and delivery partners.
Financial model	The arrangement of cash flow, capital investment, expense and income streams including pricing and finance.
Business model governance	The distribution of activity and responsibility between actors and the overarching organisation for service delivery.

Examples are used below to illustrate each of the five business model characteristics.

Innovative ***value propositions*** can include advanced understanding of building physics. Parity Projects uses sophisticated computer modelling of sensor data to determine the operational cost impact of switching from gas boilers to heat pumps (Parity Projects, 2020). Innovation in delivery can reduce disruption such as the 'room in a day' approach provided by Pouget in France (Fawcett *et al*, 2014).

Novel approaches to ***customer interface*** can be as simple as open home days to allow potential customers to view completed installations (Berry, 2014). As described in section 3.2.2, social marketing can be a powerful form of engagement.

Competent ***supply chains*** need to be built up simultaneously with growth in customer demand. Cooperative approaches have demonstrated success in the UK. Case study review into Retrofitworks in southern England, which is founded as a friends provident society, has shown that that form of constitution lends itself to the patient approach required to ‘warm up’ a local supplier network (Ince and Marvin, 2019). Carbon Coop in Manchester, UK provides a similar example (Carbon Coop, 2020).

Supply chain costs can be reduced through economies of scale and through offsite production. The Dutch Energiesprong (energy leap) model leverages both through offsite production of entire insulated facades and plug-and-play energy units (see Figure 3.3) to retrofit social housing blocks (Brown *et al*, 2019). However, an effective intermediary in the ***customer interface*** is necessary to build demand for the necessary scale.

Figure 3.3: A plug and play energy unit combining heat pump and battery storage being lowered into place in social housing in the Netherlands. (Source: Energiesprong, 2020).

Supply chain costs can also be controlled by providing surety of demand and reducing the cost of customer acquisition and this has been observed in the pilot stage of the Energy Efficient Scotland programme (Bush *et al*, 2018). Suppliers have made progress on cost innovation where they have been allowed the necessary resources by customers to experiment (Killip *et al*, 2014; Killip, 2013).

The retrofit business model archetype with which most UK homeowners are familiar is the ‘atomised’ model characterised by the non-integrated contracting of independent tradespeople (Brown, 2018). In this model the ***governance*** role is carried out by the homeowners deciding on measures, selecting contractors and arranging finance. ***Governance*** can be disrupted by intermediaries and system builders (Bolton and Hannon, 2016). For example, energy service companies disrupt both ***governance*** and ***financial models***. Here, customers pay for a guaranteed service level, typically indoor temperature, and providers are therefore incentivised to provide energy conservation measures (Hannon *et al*, 2015; Nolden *et al*, 2016). Mlecnik (2019) reports case studies where business modelling was an effective means of building the new collaborative networks. Community based intermediaries, such as low carbon communities, can provide a catalyst for retrofit supply and demand growth (Gupta *et al*, 2014). However, examples show there is a risk that the priorities of customers and intermediaries can become misaligned (Grandclément *et al*, 2015).

The conventional 'atomised' model of siloed trades dominates the UK renovation and efficiency retrofit industry. Frameworks for conceptualising innovation in this field have been developed and there is an emerging body of case study research into innovative retrofit business models.

3.4. Research Gap

The UK and international literatures reveal a homeowner perspective of retrofit as being *difficult*. Barriers of low awareness, cost, complexity and disruption need to be overcome if retrofit rates are to meet policy goals. The dominant 'atomised' business model is not equal to the task but promising alternatives are emerging.

Scottish Government policy places accountability on local authorities to play a 'hand holding' intermediary role to support able to pay customers (Scottish Government, 2018b) but the practical form of this strategy has yet to be developed. The Scottish private housing stock presents unique challenges including its age and form of traditional wall construction. While there is a developing body of international literature on retrofit approaches for owner-occupiers, recent research in Scotland has been largely limited to programme evaluations in the social housing sector (Wade, Bush and Webb, 2020). This dissertation addressed this gap in understanding of business model innovation to support owner-occupier retrofit within the Scottish context.

The research objectives were as follows:

1) Undertake a review of academic and grey literature on retrofit domestic heat efficiency and decarbonisation measures to establish current knowledge on:
    a) Consumer preferences around domestic retrofit
    b) Business model innovation
2) Undertake questionnaires and interviews to understand owner-occupier perceptions of barriers and drivers to retrofit in a case study area centred on Langside, south Glasgow, UK.
3) Undertake interviews with relevant professionals to increase the robustness of conclusions.
4) Synthesise outcomes from objectives 1 to 3 to assess the merits of business model innovations in relation to the case study area.

4. Methodology

This project considered the opportunity presented by retrofit business model innovation in consideration of homeowner views within the context of a specific urban area of Glasgow, UK. The method chosen was a case study comprising an online questionnaire, document analysis and semi-structured interviews. Case study is suitable for research into 'how' and 'why' questions in relation to contemporary phenomena (Yin, 2014). Semi-structured interviews with relevant professionals were then used to provide additional context and strengthen the validity of conclusions.

The research methods are informed by Brown's (2018) conceptual framework for residential retrofit business models, described in section 3.3, which consists of five components: value proposition, supply chain, customer interface, financial model and business model governance. This framework was used in the coding of survey and interview comments, and in the structure of analysis and discussion.

The research was carried out in line with University of Strathclyde's ethics code of conduct (University of Strathclyde, 2008) and received departmental ethics approval. All participants were granted the right to withdraw or correct any or all of their contributions, although none took advantage of this. Also, all participants were assured of pseudo-anonymity with homeowners to be described in terms of their home archetype and professionals described in terms of their role and the nature of their organisation. All research was carried out online or by telephone to comply with coronavirus social distancing requirements in force at the time.

The case study design choices are described further in section 4.1. Section 4.2 describes how interviews with professionals were used to strengthen the validity of conclusions. Strategies to mitigate bias and error are presented in section 4.3.

4.1. Case Study

The case study, carried out in July and August 2020, comprised three methods listed below.

- Home-owner questionnaire to identify the range of attitudes and issues.
- Document study to provide context in terms of building archetypes, energy use and energy efficiency recommendations.
- Home-owner interviews to further explore the issues raised and the attractiveness of different potential business model characteristics.

The area chosen for the study, shown in Figure 4.1, was loosely based on the local government electoral ward of Langside. It has an area of 9 km^2 and is located 4 km to the south of the centre of Glasgow, UK. The 2011 census recorded a population of 53442 across 26499 households, giving an average of 2.0 persons per household (Scottish Government, 2020b). This area was primarily chosen because the researcher was already familiar with it, having lived there for nine years, and had good links to local communities. It makes a good case for the research question because of its high level of owner-occupiers – 55% in Langside, compared to 45% in Glasgow as a whole (GCC, 2020b) - and the low rates of eligibility for social support for retrofit with 3.4% on income support or other benefits compared with 5.0% across Glasgow (GCC, 2020b).

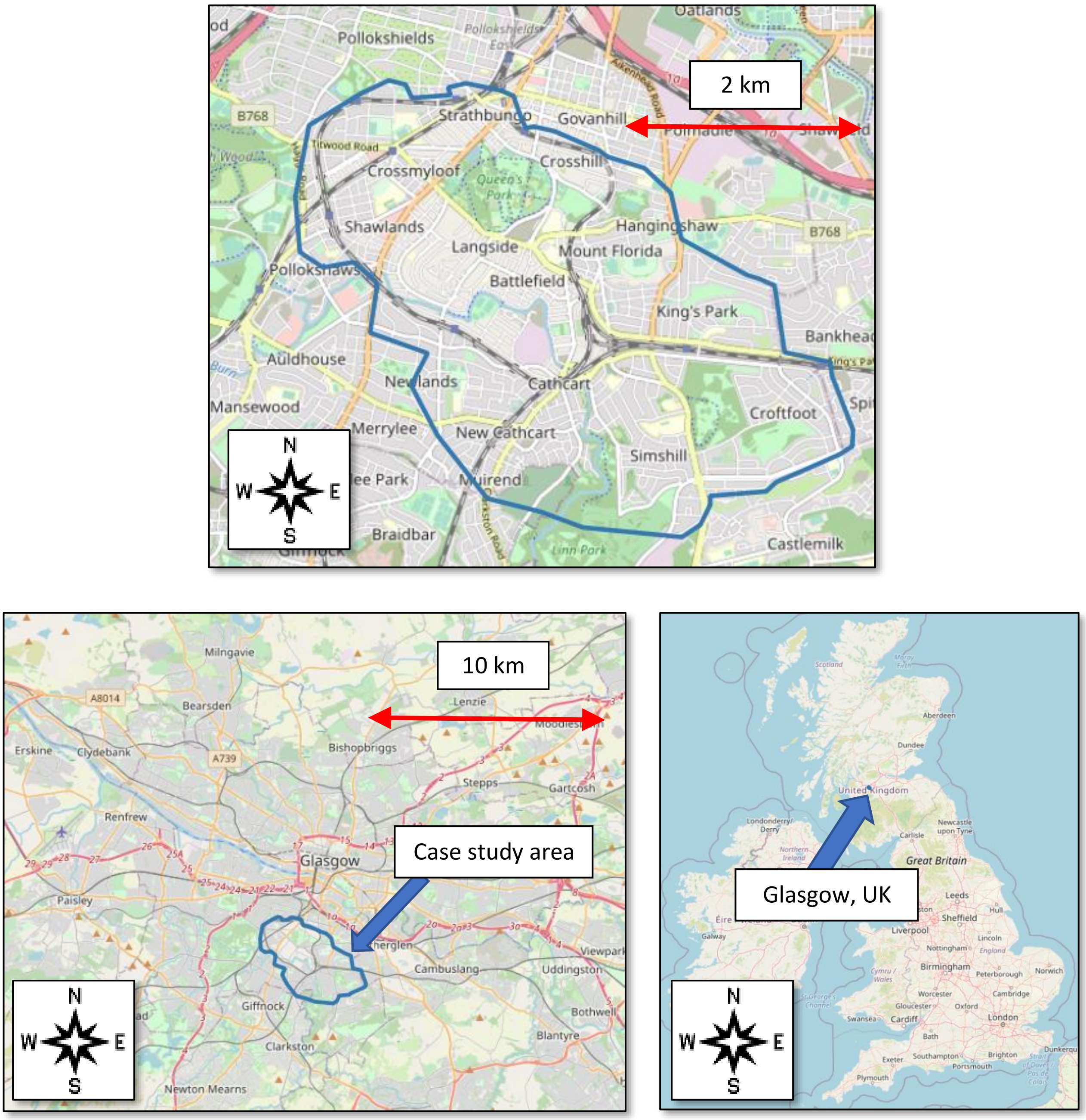

Figure 4.1: Outline and location of the case study area in south Glasgow, UK. (Source: OpenStreetMap, 2020).

The range of common build archetypes is shown in figure 4.2. The wall constructions were confirmed through review of a sample Energy Performance Certificates using the EPC database (EST, 2020).

Legend:

A. House – semi-detached/terraced – traditional construction
B. House – semi-detached/terraced – cavity wall construction
C. Bungalow – solid wall construction
D. Bungalow – cavity wall construction
E. Flat – traditional construction
F. Flat – post war and modern
G. Flat – 'Four in a block' cottage flat or maisonette

Figure 4.2: Building archetypes common in the case study area. © Google.

The following sections describe the case study methods in more detail: questionnaire (section 4.1.1), document study (4.1.2) and semi-structured interviews with homeowners (4.1.3). Section 4.1.4 describes how data was coded for analysis.

4.1.1. Online Questionnaire

An online questionnaire was used to understand homeowners' attitudes to home heating efficiency and decarbonisation. The questions and the rationale behind their inclusion are laid out in table 4.1. In summary, there were seven questions concerning the homeowners' context to support respondent segmentation, three questions concerning drivers, a set of seven questions about barriers and two issue elicitation questions. The full questionnaire is included in appendix 1.1.

Table 4.1: Online questionnaire design choices

	Ref	Question	Form	Rationale, reference
Context/ clustering	1	What is your age?	**Multiple choice:** select one of 6 age bands	Different life stages influence retrofit (Burningham and Venn, 2017)
	2	What is your postcode?	**Text entry**	Allows verification of building archetype and correspondence with datazone data – SIMD and local average energy consumption.
	3	What kind of building is your home?	**Multiple choice:** Select one of four options: flat/house, cavity/ traditional wall construction.	In the absence of postcode this allows comparison based on building archetype.
	4	Is your home owned or rented?	Multiple choice	Double check to screen out renters.
	5	How is your home heated?	**Multiple choice**: select from gas boiler; electric or heat pump.	To provide context and support segmentation.
Drivers	6	Thinking about your home in winter, which of the following phrases apply?	**Select as many as apply** from a list of twelve randomly shuffled descriptions relating to comfort, cost of heating and health risks.	Relates to value proposition (Brown, 2018).
	7	If you were to make additional improvements …, what would be your reasons?	**Rank** a randomly shuffled list of five drivers into priority order.	

	Ref	Question	Form	Rationale, reference
	8	Have your ideas about home comfort and improvement priorities changed since the coronavirus lockdown?	Select yes or no	Based on the researcher's speculation that the 2020 lockdown and increased working from home may present a trigger for retrofit
(Screening)	9	Has your household implemented, or considered implementing, any of the following measures: loft/wall/floor insulation, replacement windows/doors, heat pump, efficient gas boiler?	Select yes or no	Ensures responses relate to prior decision-making processes. Sets the context for the subsequent questions.
Barriers	10	Out of the five options below, based on your experience, which is the most and least important barriers to implementation of efficiency measures. Repeats for 7 sets of 5 objects selected from a list of 14 barriers.	**Best worst scaling:** In each set, select the barrier that was most important and the barrier that was least important to implementation decisions.	Prioritise the barriers to be eliminated by innovative business models. Options based on literature review including Klöckner and Nayum (2016). See explanation of method in appendix 1.2.
Context/ clustering	11	Which of the following statements comes closest to your view of climate change	Select one item from a list of five views on the severity and urgency of climate change	To allow comparison with the Scottish national population based on propensity towards sustainable actions (which include efficiency retrofit), based on the Scottish Household Survey (Scottish Government, 2019b)
	12	To what extent do you agree with the following statement: "It's not worth me doing things to help the environment if others don't do the same."	Five-point Likert scale from strongly agree to strongly disagree, plus 'don't know'.	

	Ref	Question	Form	Rationale, reference
Issue elicitation	13	What one thing would make it easier for you to implement heat efficiency or decarbonisation measures	Free text	To elicit further homeowner contributions to be explored in interviews. See description of coding method in section 4.1.4.
	14	If you would like to share further reflections on home insulation, decarbonisation or the impact of lockdown, please comment below.	Free text	

As the research question relates to homeowners' decision-making processes around retrofit, questions were designed with reference to discrete choice experiments (DCE) methods (Louviere *et al*, 2015). In particular, the best-worst scaling method was used in question 10 to force prioritisation of 14 barriers. This method and the rationale behind the chosen barriers are explained in appendix 1.2. Similarly, question 7 required respondents to rank motivations for improvement in priority order. The questionnaire was tested and clarified to ensure consistent understanding with the help of family members.

Participants were recruited non-probabilistically through self-selection, primarily in response to posts on Facebook (see an example ad in appendix 1.4). The questionnaire was delivered using the Qualtrics platform and was online between 17th July and 9th of August 2020. Around this time the Scottish Government had started to relax some aspects of coronavirus lockdown guidelines that had heavily restricted citizens' movements outside their homes since 23rd March 2020 (BBC, 2020).

4.1.2. Document Study

Document study was used to provide further context to support analysis and to further inform homeowner interviews. Google Streetview was used to verify questionnaire respondents' building archetype based on the postcode provided and with reference to the archetypes depicted in figure 4.2. Wall constructions and typical efficiency recommendations for interviewees' homes were verified by reviewing at least three Energy Performance Certificates of homes in the same postcode (EST, 2020).

Additional data was gathered to support respondent segmentation analysis. Census datazones were identified from postcodes (Scottish Government, 2020c), then the position of each datazone in the Scottish Index of Multiple Deprivation was identified (Scottish Government, 2020b). Lastly mean household gas and electricity consumption was mapped for each datazone (UK Government 2020a, 2020b)

4.1.3. Semi-structured interviews with homeowner

Five questionnaire respondents were interviewed using a semi-structured approach to deepen case study understanding. Project resources denied the possibility of holding the nine or more interviews suggested to be enough to reach 'code saturation' (Hennink *et al*, 2017), far less taking a statistical approach to reaching a statistical confidence level (Galvin, 2015). Rather, 'purposeful' non-probabilistic sampling was used to construct 'theoretically significant contrasts' (Henry, 2009, p81). Interviewees were selected to cover a range of ages, respondents' drivers and barriers, building archetypes and social deprivation datazones.

A semi-structured interviewing approach was used to provide a mix of deep, standardised questioning while providing the opportunity for more free-ranging discussion on the situation, motivations and frustrations of the interviewee. Questions were included in the interview guide based on preliminary analysis of the questionnaire. For example, questions regarding contracting reliable tradespeople were included. Also, ideas raised in the questionnaire of community intermediaries and neighbourhood group purchases are explored further. Table 4.2 shows the outline of the key questions and the rationale behind their conclusion. To avoid excessive reactivity, or influence of the interviewer on the interviewee (Maxwell, 2009), standard questions were always asked in the same way and in the same order, and leading questions were avoided. The interview guide is provided in appendix 2.

Table 4.2: Summary outline of homeowner interview guide, and the supporting rationale.

Section	Questions	Rationale or link to Brown's (2018) framework for retrofit business models
Home	How long have you lived in this home? Who makes decisions about improvements? Plans to move out.	BM customer interface: Ascertain the position of the interviewee in relation to decision-making process for improvements and trigger opportunities.
	Recap building archetype and heating already determined from questionnaire and document study.	Background: to confirm the kinds of efficiency measures likely to be appropriate.
	Recap views on perspective of home in winter, improvement priorities and impact of COVID.	BM value proposition: Give opportunity to expand views on motivations for retrofit.
Improvements	Discuss the kinds of improvements relevant to this property.	Background: establish level of prior awareness of measures.
	Discuss experience of having work done.	BM Customer interface: Give opportunity to expand on views already shared in questionnaire regarding frustrations and barriers.
Business Model	Questions about value proposition	BM financial model: Seeking deeper understanding of where businesses may be able to extract revenue.
	Discuss and compare business model archetypes.	Brown's (2018) archetypes provide a framework for comparing key business model characteristics, for example, 'one-stop shop'.
	Questions of trust	BM customer interface: evaluating predispositions to trust various potential intermediaries.
	Views on community cooperative purchasing	BM Governance: exploring topic raised by questionnaire respondents.
	Views on performance guarantee	BM Value proposition: evaluating views of key characteristic of energy service agreements (Brown, 2018).
Policy	Seeking views on the Scottish Government's policy to introduce minimum standards for owner-occupied home energy efficiency	How does the main policy in development affect business model elements?

Interviews lasted around 40 minutes and were carried out between 28th and 30th July 2020 by telephone or internet video call, according to the preferences of the interviewee. Interview data was coded according to the strategy is given in section 4.1.4.

4.1.4. Coding of comments

Homeowner interview data and questionnaire questions 13 and 14 were coded to emergent substantive groups and organised under topical headings. Responses were also linked to the research conceptual framework by coding each substantive group to one of the five elements of the retrofit business model, examples of which are shown in Table 4.3.

Table 4.3: Examples of coding of comments to conceptual framework elements

Business model framework component	Description	Examples of substantive content
Value proposition	"What value is embedded in the product/service offered by the firm" (Boons.and Lüdeke-Freund, 2013)	What homeowners are looking for or would be attracted to: 'holistic advice'; 'advice on environmentally friendly replacement for my gas boiler' Unsolved problems: 'how to insulate combed roofs', 'Company that could clear my loft space in a professional careful manner prior to roof insulation works.' Help with new problems: Compliance with energy efficiency standards.
Customer interface	"How are downstream relationships with customers structured and managed" (Brown, 2018)	Issues of trust: 'I don't trust cold calling insulation companies' Markets: 'help to address efficiency in renovation when moving in' Recommendations for contractors: 'I need help to find reliable contractors'
Supply chain	"how upstream relationships with suppliers structured and managed" (Boons.and Lüdeke-Freund, 2013)	Comments related to assessors, designers, installers, experts, consultants, manufacturers. Accreditations (e.g. Trustmark, PAS2035). Supply chain cost efficiency: e.g. scaled, off-site production of retrofit elements.
Financial model	"constitutes the combination of an organisation's capital and operational expenditures with its means of revenue generation from business activities" (Brown, 2018) .	Issues of government subsidy and finance. Private finance. Financial justification for works. Cost of goods and services.
Business model governance	"governance involves both the control and management of the individual components and the organisational form of the BM" (Brown, 2018)	Independent tradespeople, one-stop shops, energy service providers, community organisation, central/local government programmes.

Perceptions of the home in winter (questionnaire question 6) were categorised according to an order of precedence where responses that included references to fuel poverty and health took priority over other issues. This coding method is explained fully in appendix 1.3.

4.2. Semi-structured Interviews With Professionals

Five professionals with expertise in the fields of domestic building energy efficiency assessment, retrofit or home valuation were recruited for interview. The purpose of the interviews was to add some balancing perspective to increase the robustness and external validity of the case study conclusions. Interviews were 'problem-centred' (Döringer, 2020), focussed on the issue of accelerating heat efficiency retrofit for owner-occupied houses with reference to themes emergent from the case study.

Sampling was purposeful and intended to detect heterogeneity in views across different professional sectors (Maxwell, 2009). For example, the views of professionals with deep appreciation of building physics were contrasted with the practical experience of experienced insulation installers. Selection was made either by identifying leading retrofit designers and firms in the grey literature, or through checking insulation trade accreditations such as the Green Deal database (Green Deal ORB, 2020) or by finding firms with physical presence in the case study area through internet search or personal networks.

The semi-structured interview form allowed for starting questions borne out from the case study themes to be followed up with broader discussion of the concerns raised by the interviewees. For example, in one interview an opener about group purchase of measures lead onto a deep description of how this might address the challenges of purchasing double-glazed windows suitable for conservation areas. The interview guides are provided in appendix 3.

Interviews lasted around 30 minutes and were carried out between 4th and 10th August 2020 by telephone or internet video call, according to the preferences of the interviewee.

4.3. Mitigation of Bias

Issues with recall are common in survey methods (Floyd and Cosenza, 2009). This research concerned issues of comfort and heating in winter but was carried out in summer and is therefore expected to be impacted by poor recall. It was not possible to mitigate for this impact and this should be addressed in further research.

Internet recruitment strategies can lead to samples that are not representative of the population (Henry, 2009), which in this research is all homeowners in the case study area. To counter this bias, some additional homeowner recruitment was made by email targeted at older residents who are not active on Facebook. Bias was assessed with reference to age distribution, and by using propensity scoring based on attitude to climate change. Bias was addressed by triangulating the findings from the different research methods.

Social desirability can also influence answers (Floyd and Cosenza, 2009). In this research, respondents that considered action to address climate change to be socially desirable may have ranked 'reduce environmental impact' more highly in their list of heat efficiency motivations (question 7) than may be the actual case. To assess the size of this impact, questions 11 and 12 about attitude to climate change were replicated from the annual Scottish Household Survey (Scottish Government, 2019b) to allow comparison with national estimates.

5. Results and Discussion

This section describes the results of the case study and considers their importance for retrofit business model innovation, balanced with input from the professionals interviewed. First, section 5.1 provides an overview of the research participants. The analysis is then structured according to the five elements of Brown's (2018) framework for retrofit business models in sections 5.2 through 5.5. Methodological issues are considered in section 5.6. Section 5.7 brings findings together in a discussion of implications for business models for the case study area.

5.1.Profiles of Participants

Case study homeowners are profiled in section 5.1.1 (questionnaire respondents) and 5.1.2 (interviewees). The professionals that were interviewed are profiled in section 5.1.3.

5.1.1. Case Study Questionnaire Respondents

188 responses to the questionnaire were received. As the vast majority provided full postcodes it was possible to verify which fell in the geographical scope and discount 51 responses. 26 of the remaining 137 responses (14% of all responses) were abandoned during best-worst scaling (question 10) but their answers to the earlier questions were included in the analysis.

The 137 respondents represent a cross-section of the case study population. Figure 5.1 shows the broad spatial distribution of respondents across the case study area and that most census data zones were represented in the data. Figure 5.2Figure 4.1 shows that both houses and flats and most age groups were well represented. Few 18-24 year olds were expected to be owning property. Table 5.1 shows that all building archetypes common to the area were represented except for archetype C, solid wall bungalows.

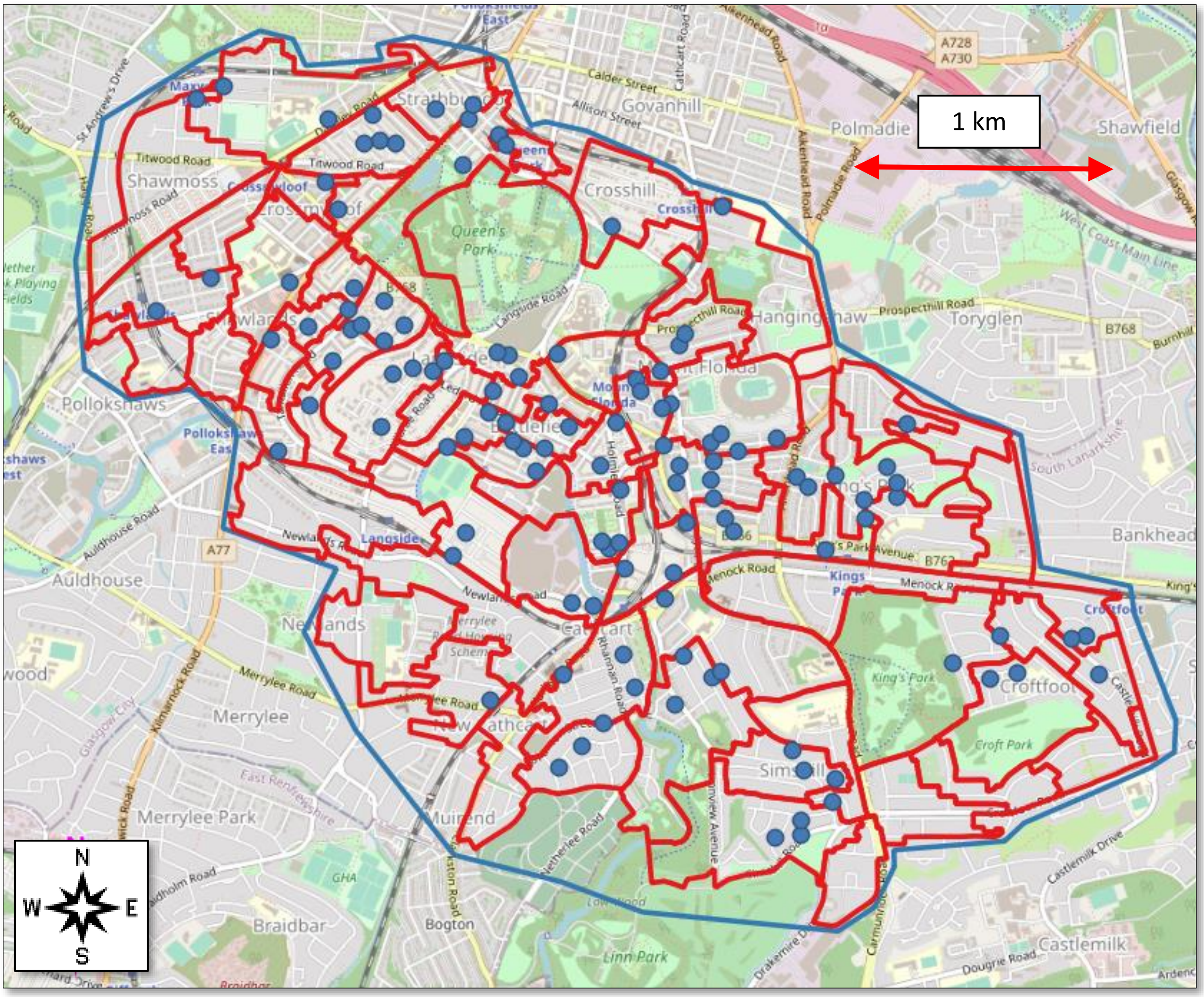

Figure 5.1: Distribution of respondents across the case study area (blue dots) with a blue line indicating the boundary of the case study area and red lines indicating data zones (Scottish Government, 2020b; OpenStreetMap contributors. (2015) Retrieved from https://planet.openstreetmap.org; postcode geocoding by Doogal (2020)).

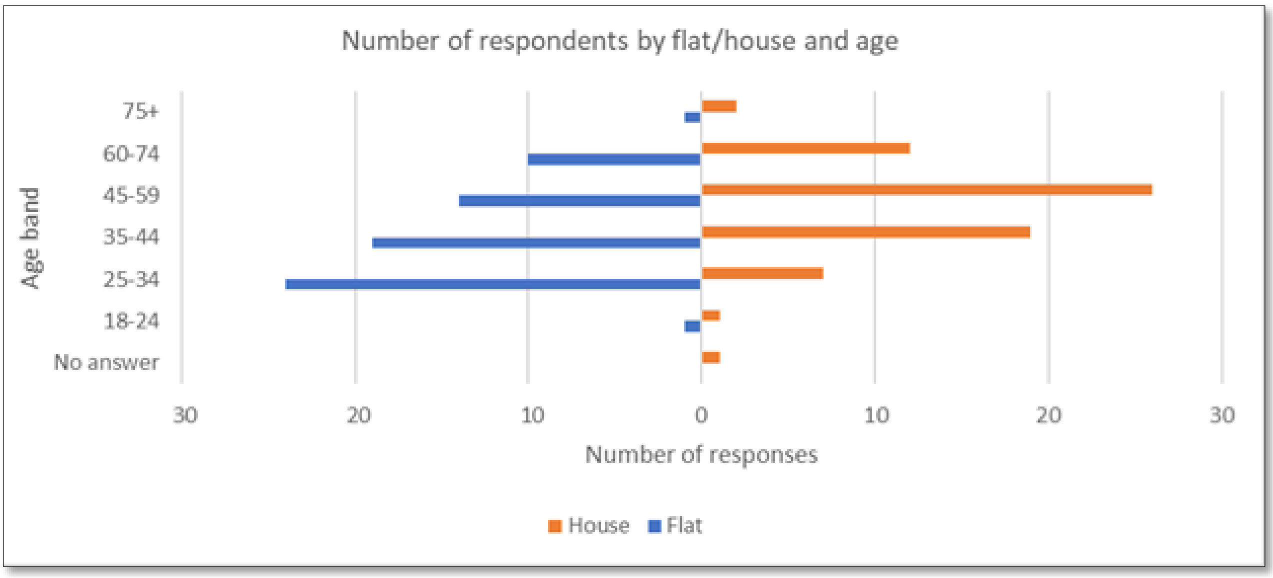

Figure 5.2: Distribution of questionnaire respondents by age band and flat vs house occupancy.

Table 5.1: Number of questionnaire responses per common building archetype

Building archetype	Number of questionnaire responses
A: House – semi-detached/terraced – traditional construction	42
B: House – semi-detached/terraced – cavity wall construction	20
C: Bungalow – solid wall construction	-
D: Bungalow – cavity wall construction	6
E: Flat – traditional construction	46
F: Flat – post war and modern	11
G: Flat – 'Four in a block' cottage flat or maisonette	8
Other (conversion flats, mixed construction types)	4
TOTAL	137

Figure 5.3 shows that by comparison with the most recently published Scottish Household Survey carried out in 2018 (Scottish Government, 2019b) respondents reported themselves being more concerned with climate change than the 2018 national average. It is worth noting that the 2018 polling was carried out before the 2019 Extinction Rebellion protests (Barasi, 2019) and the revised net zero Climate Change Act (Scottish Parliament, 2019) so the sample may be no more inclined to action than the average Scottish homeowner.

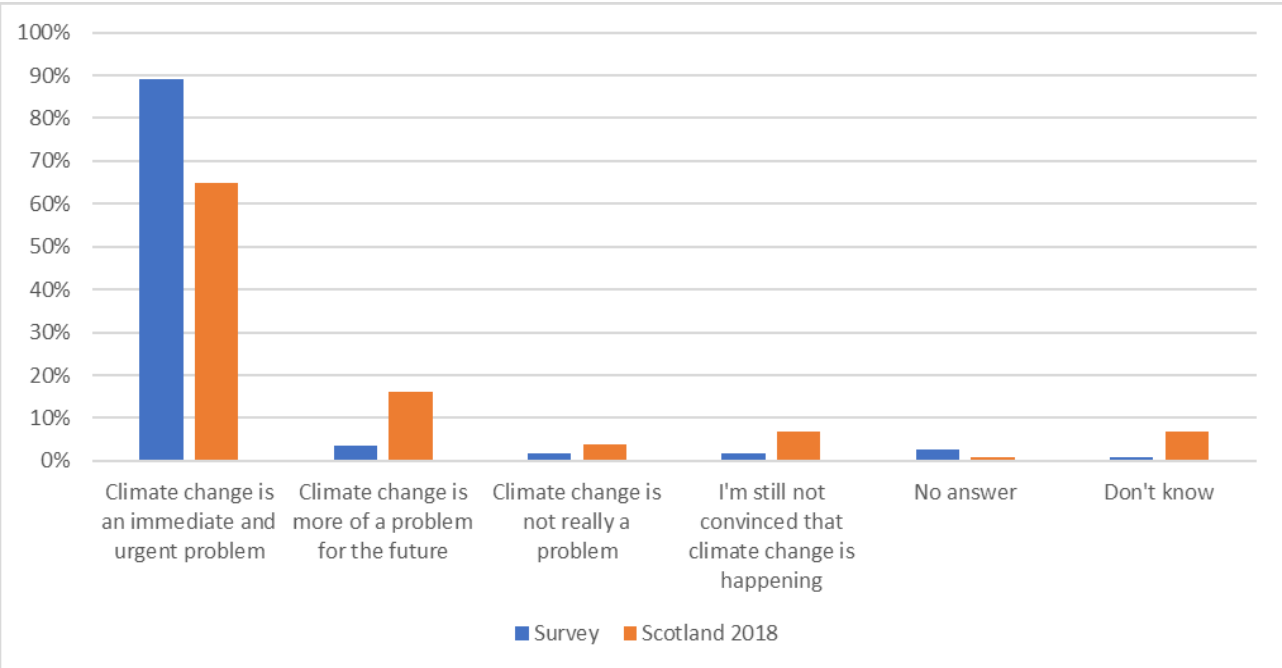

Figure 5.3: Comparison of questionnaire respondents' perception of climate change as a problem (Q11) with the results of national polling carried out in 2018. Respondents indicate greater concern than the Scottish average. Question: 'Which of the following statements comes closest to your view of climate change?' (Scottish Government, 2019b)

5.1.2. Homeowner interviewees

Table 5.2 gives an overview of the five interviewees selected from among the questionnaire respondents, showing a contrasting range of buildings, ages, perceptions of home, drivers and barriers.

Table 5.2: Overview of interviewees showing a contrasting range of homeowners.

Reference	H1	H2	H3	H4	H5
Building type	E – Flat, traditional	B - Semi-detached house – traditional	D - Interwar bungalow with room in roof - cavity wall	G - Interwar cottage flat	A - Terraced house – traditional
Heating type	Gas boiler				
Age	35-44	60-74	45-59	25-34	35-44
Home perception category	Comfort	Heating too costly	Discomfort	Heating too costly	Discomfort
Perception changed since lockdown?	No	No	No	Yes	Yes
Top reason for improvement	Reduce energy bills	Reduce environmental impact	Reduce environmental impact	Improve comfort	Reduce energy bills
Top barrier to improvement	Up front cost, finding contractors.	Difficulty finding contractors	Plans to move out	Up front cost	(Never considered measures for current home)

5.1.3. Professionals

Table 5.3 gives an overview of the five professionals recruited for interview. P1 and P2 are highly trained professionals with deep understanding of building physics. P3 has extensive experience in insulation installation as director of an SME. P4 was able to provide perspective borne out from supporting households to tackle energy problems. P5 provided a view on the considerations in the property valuation and sale process. Interviewees had experience of a range of housing sectors which supported discussion on transferring and scaling practice between sectors.

Table 5.3: Overview of professional interviewees.

Reference	P1	P2	P3	P4	P5
Role	Architect and retrofit coordinator.	Consulting engineer	Director, specialist insulation contractor SME	General manager, place-based sustainability charity	Estate agent in the case study area.
Housing sector	Mainly social housing retrofit	Private: high end one-off projects subcontracted by architects.	Mostly private residential in public-sector programmes.	All: private rental, owner-occupied, social.	Owner-occupied
Activities	Assessment and evaluation	Advanced building physics modelling.	All forms of insulation. Specialist in internal wall insulation.	Energy advice. Housing stock surveys.	Valuing property and negotiating sales.
Energy skills, training, tools	PAS2035 retrofit coordinator SAP, PHPP	Dynamic modelling.	Quantity surveyor, site manager.	Energy performance certificates, energy awareness.	None

5.2. Value Proposition

An understanding of the value of retrofit, as seen by homeowners in the case study area, was built up from questions concerning the perception of the home in winter and drivers for improvements. Furthermore, the most important barriers were identified, as their elimination may provide differentiating value in an innovative business model, as compared to conventional approaches (Brown, 2018). The following sections highlight key findings. Raw data is provided in appendices 4 and 5.

5.2.1. Comfort as a retrofit rationale may be undervalued by homeowners

Financial considerations appeared to dominate homeowners thinking in relation to retrofit. Questionnaire respondents indicated that their top reason for any further retrofit measures would be reducing energy bills (49 of 137 responses) (see figure 5.4, full ranking in appendix 4.7). Best-worst scaling placed financial issues as the top two barriers, as shown in figure 5.5. Similarly, issues of affordability were the most common topic code to emerge from comments given in the questionnaire as the ‘one thing’ that would help implementation as shown in figure 5.6.

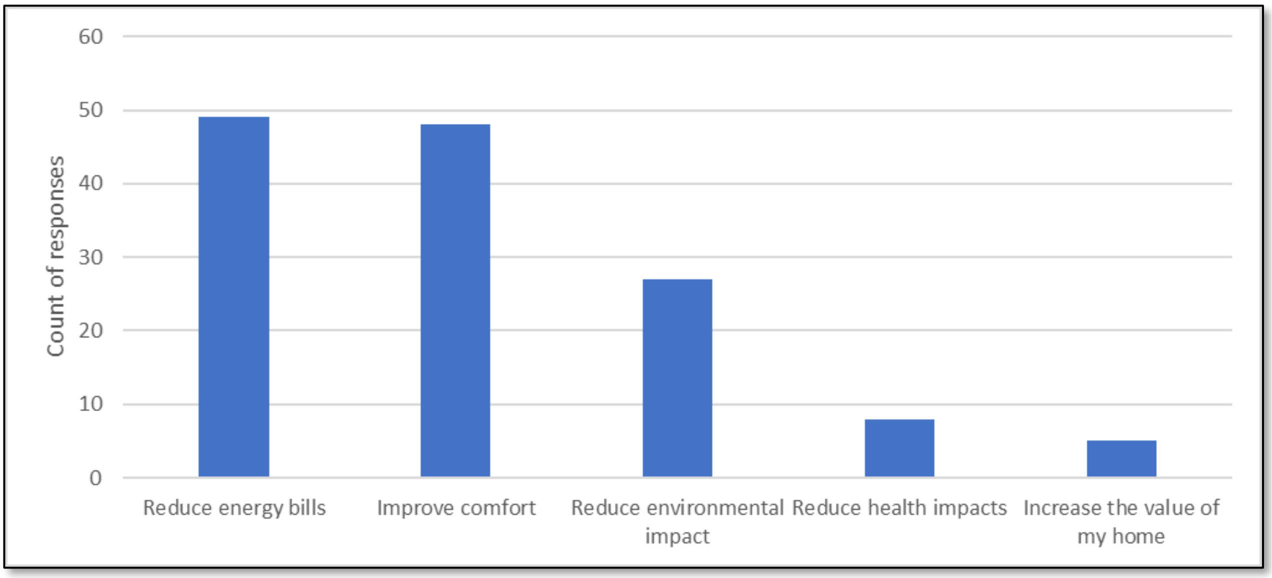

Figure 5.4: Top priorities for further efficiency measures recorded in questionnaire (N= 137).

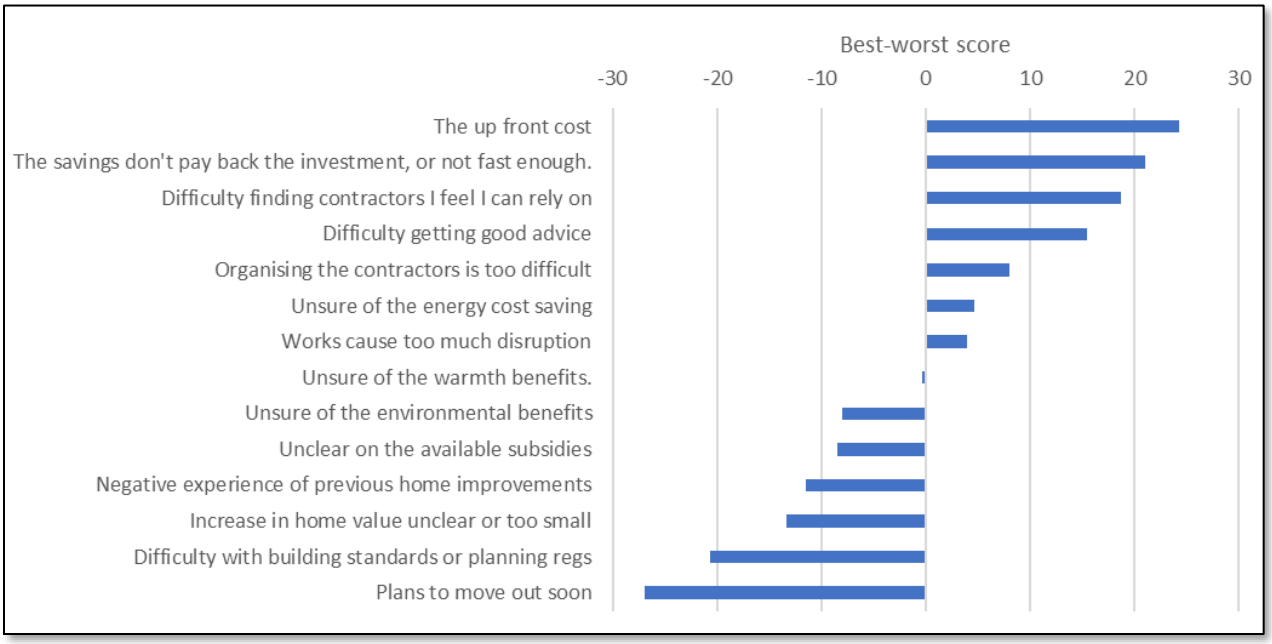

Figure 5.5: Best-worst scaling of barriers as recorded in the questionnaire shows financial considerations as the top two most important barriers. Issues with contractors and advice were the next three most important barriers (N = 111).

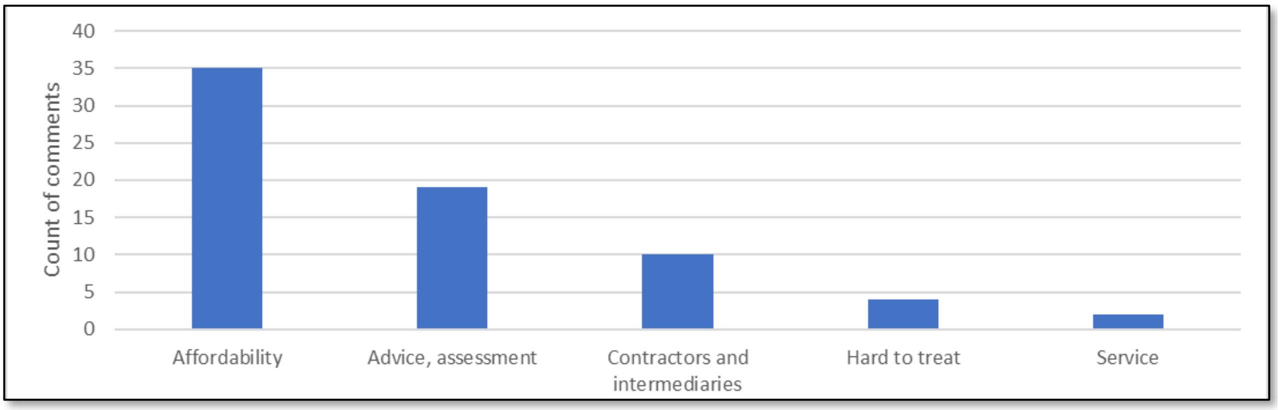

Figure 5.6: Coding of 'What one thing would make it easier...' comments made in the questionnaire shows that issues of affordability were cited most often. Advice and assessment was the second most important issue. (N=137)

However, the prioritisation of bill savings as the primary driver for retrofit is at odds with the description given by questionnaire respondents of their homes in winter. 'Too expensive to heat properly' was selected by only 16% of questionnaire respondents. As shown in figure 5.7, most respondents comments were categorised as expressing discomfort of some sort, especially in thermally inefficient solid wall and interwar cavity constructions (figure 5.8). This corresponds with the 'prebound effect': the observation that thermally inefficient homes consume less energy than technical models predict is necessary to maintain a comfortable temperature, indicating that occupants settle for uncomfortable or even unhealthy temperatures (Sunikka and Ray, 2012).

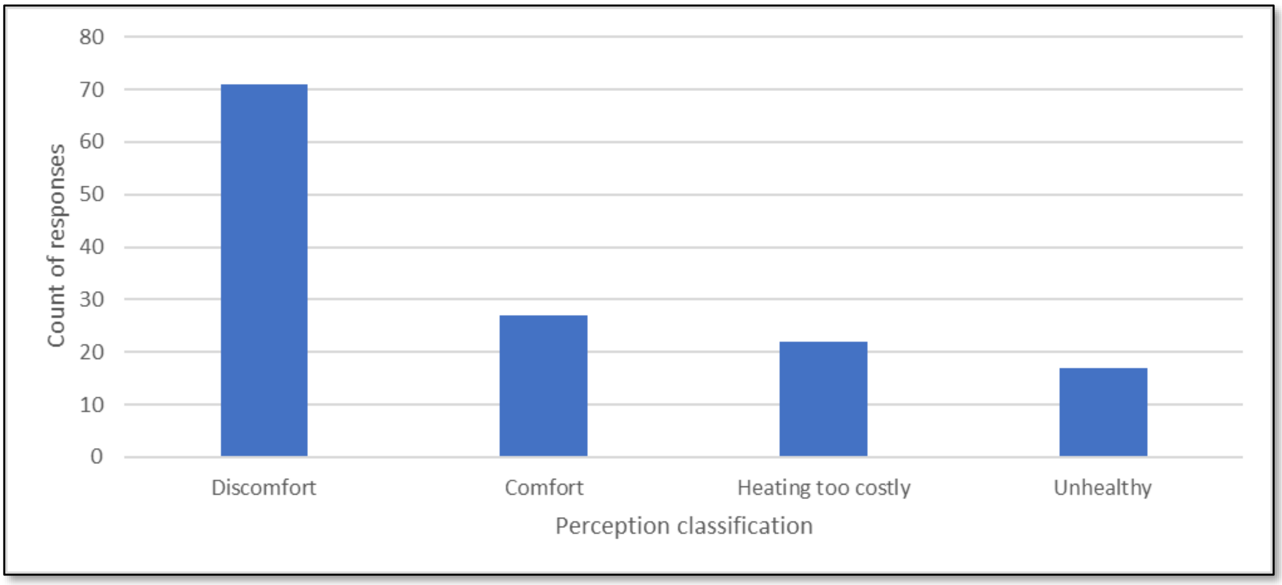

Figure 5.7: Categorisation of questionnaire respondents perceptions of their homes in winter, following the coding method detailed in appendix 1.3, shows that some level of discomfort is common.

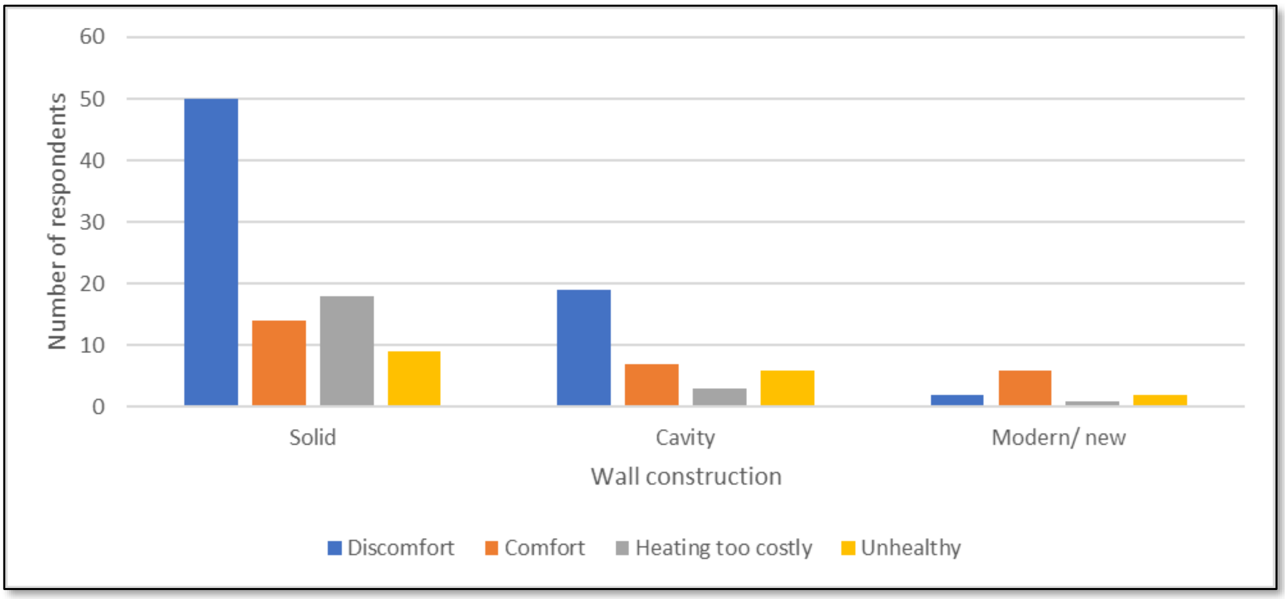

Figure 5.8: Perceptions of homes in winter, split by wall construction. Uninsulated solid wall is the least thermally efficient of the three types and this is reflect in discomfort levels and cost of heating.

One explanation for the above disconnect between experience and motivation may be that respondents currently underheat their homes and see retrofit as a way to increase indoor temperature while avoiding any increase in cost. While this has the effect of increasing comfort levels, the retrofit rationale has been expressed by the respondents in financial terms. This suggests that the concept of heat is primarily tied to cost, not comfort (nor environmental impact nor health).

Another explanation may be that homeowners are not aware of the potential scope and benefits of fabric improvements and therefore focus on the heat source. Homeowner H1, who lives in a traditional sandstone flat, had installed a new heating system:

> *"The radiators were too small in some rooms so we got bigger ones and put in a big new boiler. The difference was amazing"*

but did not see potential for insulation improvements,

> *"There's only so much you can do with these flats."*

The value of comfort was underlined by the insulation SME Director (P3):

> *"We never get positive feedback about savings, and that may be because people tend to turn up the thermostat. But feedback we get regularly is that people notice after an installation how much of a difference it has made. The comfort level has gone up."*

The case study suggests homeowners do not value comfort as a rationale for retrofit despite evidence of underheated and uncomfortable homes. Entrepreneurs and policy makers should seek to increase the appeal of retrofit by developing greater consumer appreciation of comfort as a concept independent of cost.

5.2.2. Environmental impact is rarely a primary driver

Despite the higher self-proclaimed propensity towards climate action of the sample compared to the Scottish average, environmental issues were rarely found to be a primary driver of interest in retrofit, echoing the findings of previous studies (Gram-Hansen, 2014; Haines and Mitchell, 2014) This was corroborated in interviews: "Environmental impact has always been at the back of my mind" (homeowner H1).

5.2.3. There is demand for independent customised advice

Homeowner comments, from both the questionnaire and interviews, coded to the value proposition component of the business model framework are summarised in Table 5.4. The full summary coding is provided in appendix 5. While the count is partly a function of the questions posed, it reveals several customer problems that may be addressed by innovative business models. Chief among the 'what one thing would help' responses in the questionnaire are demands for more sophisticated and independent advice.

Table 5.4: Summary coding of homeowner comments linked to the Value Proposition framework element showing interest in improved advice and assessment.

Topics coded to 'Value Proposition'	Questionnaire	Interviews	Substantive sub-topics
Advice, assessment	22	9	Independent, holistic, personalised, advanced advice.
Technology/ methods	10	6	Interest in alternative heat sources, better insulation, radiators
Policy		8	Reaction to Scottish Government policy for minimum efficiency standards for owner-occupied homes
Hard to treat	7	1	Heritage buildings, awkward cavities.
Service	2	4	Seeking improved or alternative installation services.
Environmental impact		3	As a secondary or tertiary consideration
Home value		3	Unsure of impact
DIY	1	1	Experience of 'do it yourself' insulation
Other	2		

Some questionnaire respondents prioritised impartiality and data-based justification:

> *"Easy to understand guidance that you can trust"*
>
> *"I want to see proof from engineers not suppliers"*
>
> *"To have an unbiased discussion with experts on implementation of measures."*

Others sought advice customised to their house or building archetype

> *"Personalised review to know where best to spend money to help with heat"*
>
> *"Proforma guides for different housing types of what can be done, roughly how much etc"*

> *"expert technical and cost-benefit advice suited to listed building"*

It is notable that no participants spontaneously mentioned Home Energy Scotland, the government funded advice service.

The homeowner research gave a clear indication of interest for advanced, independent energy efficiency advice. However, this was undermined by the observation by the estate agent (P5) who remarked that Energy Performance Certificates have little influence on home buyers, contradicting quantitative research (Fuerst *et al*, 2016).

5.2.4. "Someone doing all the thinking for me!"

A recurring theme was the desire for someone to take out the hassle of improvements. A 60-74 year old questionnaire respondent has a problem unmet by the trades. The one thing that would help them make their home more efficient would be a "company that could clear my loft space in a professional careful manner prior to roof insulation works.". Similarly, H5 described how she settles for a lower comfort level ('satisficing') regarding her draughty front door because of the trouble involved in replacing it.

> *"Of course, the money saving is important but it's the combination. It's not that the house is uncomfortable it just could be more comfortable. If someone came along and took away all the effort. If someone came along with a new storm door and internal door and said "we'll do it for you tomorrow and it will cost £400", that would be great. Otherwise it just never makes it up the to do list".*
> Interviewee H5

The case study data indicates that retrofit businesses can improve their value proposition by integrating services to eliminate difficulties.

5.2.5. Coronavirus may increase the importance of retrofit for younger homeowners

A minority (36%) of questionnaire respondents indicated that their ideas about home comfort and improvement priorities had changed since the coronavirus lockdown. However, this was more important for younger homeowners with 55% of respondents aged 25-35 saying their view had changed as shown in figure 5.9. This tied with comments made by P4, the sustainability charity manager, who remarked that 'young people are usually out and about so much that they don't notice how cold their flats are' but with lockdown requirements and work from home policies this may change.

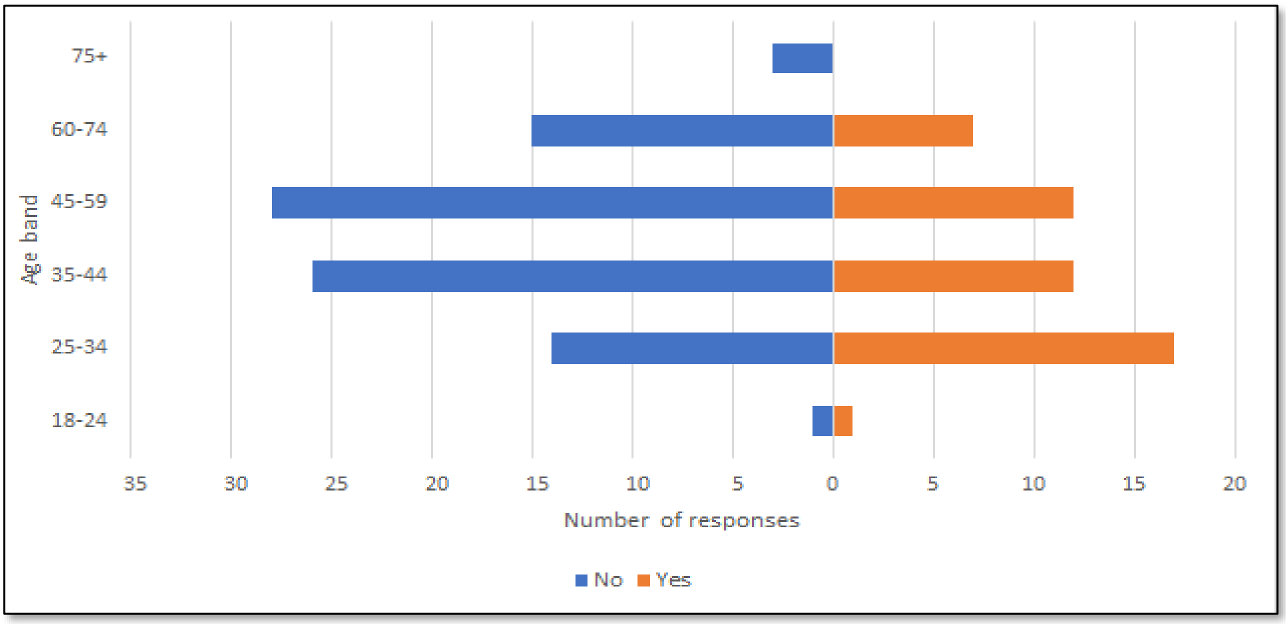

Figure 5.9: Question: 'Have your ideas about home comfort and improvement priorities changed since the coronavirus lockdown?' Breakdown by age shows greater influence of lockdown on younger homeowners.

More research is required to confirm what lockdown-related aspects of home comfort respondents were alluding to. For homeowner H4, home heat and comfort while working from home was clearly a problem: 'The weather was miserable in March - lockdown has stressed the need for insulation and better heating'. For H5 space was an issue: 'lockdown has accelerated discussion about extending'. In any case, it is reasonable to expect that if work from home policies requirements recur in winter, then erstwhile office workers may face their 'highest ever bills' (interviewee P4) and some may be drawn into fuel poverty. Just as social distancing and increased cycling during lockdown in summer (Everett, 2020) has provided a policy window for improved cycling infrastructure (Markova, 2020), so sustainable 'policy entrepreneurs' (Mintrom, 2019) should seek to exploit winter lockdown to raise government support for retrofit.

5.2.6. Value in compliance with energy efficiency regulation

All five homeowner interviewees reacted positively on hearing for the first time of the Scottish Government policy to introduce minimum energy efficiency standards for owner-occupied homes described in section 3.1, suggesting that innovative business models may directly address regulatory compliance in their value proposition. Interviewees did not find the regulation excessively intrusive in principle. H2 remarked that this seems like a natural progression on other regulations such as the requirement for new homes to be fitted with smoke detectors but that progress in this area seemed to be slow and timid. H4 remarked that it makes sense as with an EPC rating of D or less you are 'heating the universe'. This citizen perspective contrasts with behaviour of policymakers who are seen as deferring difficult decisions because of fear of public reaction (Mitchell, 2019).

A deeper discussion with H5, who had recently moved into a solid wall house, revealed the need for support for traditional constructions. She and her partner had chosen their house primarily based on location and had not considered the Energy Performance Certificate. While discussing the policy she produced her EPC and totted up the cost of upgrading from marginal D/E to C and the predicted savings:

> *"If you'd told me I had to spend £16,000 to save £300 over 3 years, it doesn't sound very motivating does it? I'm glad I moved before I heard about this.".*
> Interviewee H5

Policy makers should not fear public reaction to energy efficiency standards provided they come with social support and businesses are ready to support homeowners.

5.3. Customer Interface

Best-worst scaling in the questionnaire indicated that finding and working with reliable contractors are significant barriers to retrofit in the case study area (see Figure 5.5). Case study participants are most familiar with the atomised model in which each trade is contracted separately. Multi-trade contractors were mentioned only in relation to large building works such as extensions (interviewees H3, H4, H5). There was no evidence of homeowners having engaged a dedicated retrofit multi-trade company or intermediary such as a one-stop shop or retrofit coordinator. Questions of trust and recommendations were explored further in the interviews.

5.3.1. Interpersonal trust is the most important mode of trust in the case study area

Interpersonal trust was seen to be the main driver of contractor selection. For example, H5 expects to take advice from friends and neighbours for planned works. A neighbourhood Facebook group which has almost 10,000 members was found to be particularly influential in the case study area as it holds a list of local tradespeople that is continuously added to and amended by its members. Despite living 3.5km beyond the geographic boundary of that group, H4 joined the group to get access to the list for planned works*:*

> *"Unless my friends have some advice, I will most likely get some phone numbers from that list on Facebook".*
> Interviewee H4

The energy charity manager explained:

> *"That list is why everyone [residents] wants into that Facebook group. It's got nothing to do with community events in that neighbourhood. That list is incredibly powerful. I know several tradespeople that get a third or more of their work from it."*
> Interviewee P4

Impersonal trust was found to be of little importance because of low awareness of trade accreditations. Gassafe was the only trade accreditation that merited consideration. H4: "I will check the Gassafe register but that is it". None of the interviewees had heard of Trustmark, the governments flagship consumer protection accreditation for general trades. PAS2030 and PAS2035 were also unrecognised. H5 remarked:

> *"I would not know what was really a sign of a good tradesperson. I work in HR so I know that a double-tick symbol is a sign of a good employer from a disabilities perspective but I wouldn't know how that translates to tradespeople. So I wouldn't know if someone had a mark on their van or a flyer whether they had made it up."*
> Interviewee H5

Interpersonal recommendations may lead to less than optimal outcomes for heat efficiency. H1 described how a tradesman recommended by a friend sized a replacement gas boiler on a like-for-like basis rather than following best practice of completing a heat calculation to avoid the inefficiencies inherent in oversizing (CIBSE, 2013).

Somewhat contrary to findings by de Wilde (2019), homeowners indicated a high level of instinctive trust towards architects (professional trust) on the same level as a local community group (interpersonal trust) as shown in figure 5.10. Interviewees rated potential retrofit intermediaries on a five-point scale with 5 indicating the highest level of trustworthiness, and 1 being the lowest level of trustworthiness. It should be of concern for policy makers that interviewees placed the lowest level of trust on the local authority. The Energy Efficient Scotland foresees local authorities playing the leading intermediary role in supporting able to pay homeowners. The sample was of only five interviewees, but this is a topic worth exploring further.

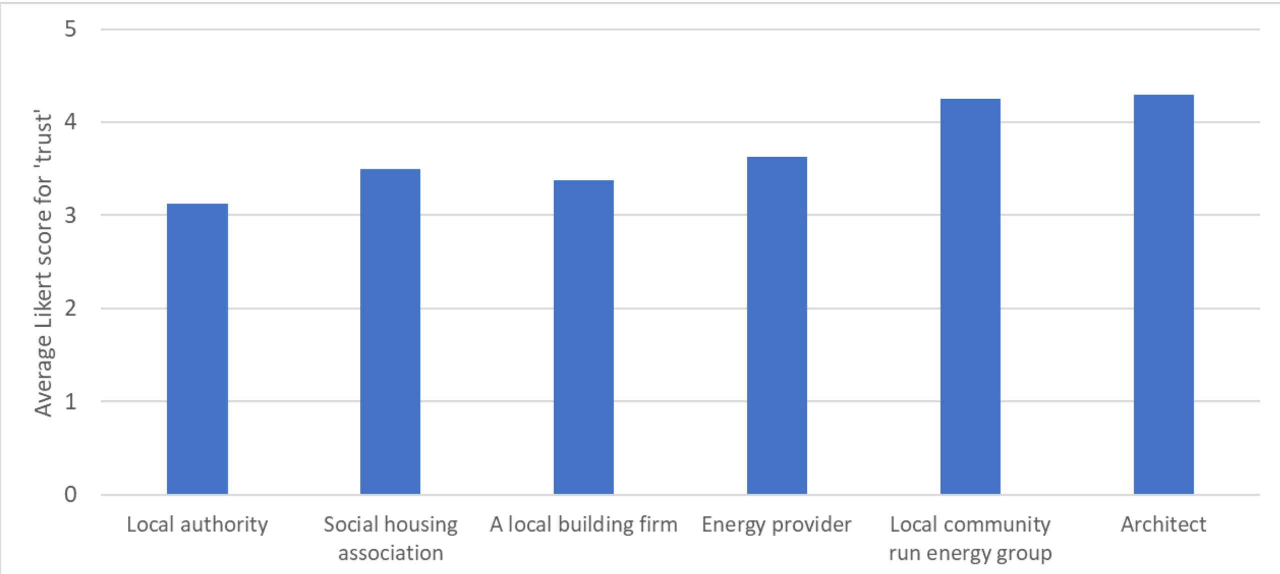

Figure 5.10: Interviewees indicated a high level of trust towards both community group and architects. Question: "Based on your past experience to what degree would you instinctively trust the following organisations if they were acting as an intermediary organising the package of work to be done on your home. Rate on scale from 1 to 5, where 5 is most trustworthy"

5.3.2. Approaches to customer segmentation

Other than the relationship between age and impact of coronavirus, attempts to cluster homeowners on a demographic basis did not identify further patterns in attitudes towards retrofit, corroborating findings by Kastern and Stern (2015). Discussion of issues was most often contextualised in terms of position in the life course. For example, H4 had recently purchased the property and was concerned about the impact of her planned improvements on property value. H5 had also recently moved in but home improvement decisions were influenced by the degree of hassle involved while attempting to work from home and look after young children. H2 had retired and was looking for the most effective ways to improve environmental impact with low capital outlay. This reinforces the value of the persona-based approach put forward by Haines and Mitchell (2014) especially in view of the opportunities provided by life transitions as observed by Burningham and Venn (2017).

Datazone was found not to be a useful basis for analysis. Although the Scottish datazones were designed to contain people with similar social characteristics, this was found not to be the case more often than had been expected. For example, one datazone contained affluent households in large semi-detached houses as well as a large block of social-rented housing.

5.4. Financial Model

Retrofit business models may find an additional revenue stream to fund retrofit from employees or employers with work from home policies or if lockdown restrictions recur. The sustainability charity manager (P4) mentioned that one employer in the area is paying its employees a weekly allowance to compensate for the cost of working from home. One questionnaire respondent suggested such payments should be standard practice. Another seeks help with claiming tax relief on working from home. Retrofit businesses should consider the potential for employers to invest in retrofit to reduce the long-term cost of compensating workers to work from home. This requires further research and is dependent on the outlook for pandemics and work from home policies.

5.5. Supply Chain and Business Model Governance

This section address both the supply chain and governance components of Brown’s business model framework.

5.5.1. Strategies to address quality

Homeowner concerns about identifying reliable contractors identified through the best-worst scaling question (see section 5.2.1) appear to be well founded. Insulation SME contractor (P3) remarked: 'We're PAS2030 qualified but you'd be shocked at the rogue traders in this industry'.

There were mixed views among professionals in relation to the value of PAS2035 and its role in assuring the quality of retrofit. The retrofit architect (P1) remarked 'PAS2035 is good because it provides a structure with roles and will manage quality and risk'. However, the insulation SME contractor (P3) believes PAS2035 will not address the rogue operators that give their industry a bad name:

> *"I think PAS2035/PAS2030:2019 is a bit of a joke. Bureaucracy is not the solution. The rogues can do the paperwork. You can ask them to do more paperwork, but it won't improve the quality of the work. I'm a firm believer in enforcement – you need more people checking the standard of work completed."*
> Interviewee P3

P2 observed that PAS2030 and PAS2035 may be more important within the supply chain than in the customer interface.

> *"It's certainly the way things are going. PAS2035 is going to become a prerequisite for funding and policy".*
> Interviewee P2.

This observation is backed up by the announcement made during the research phase that government funding in England through the Green Homes Grant scheme is to be conditioned on contractors being PAS2030 registered (BEIS, 2020b).

A further challenge to the potential for PAS2035 to address consumer protection issues raised in the 'Each Home Counts' review (BEIS, 2016) is the negligible level of awareness for even general trade accreditations as shown in section 5.3.1. Scottish Government retrofit policy should include efforts to both raise awareness of PAS2035/2030 and provide funding for enforcement checks on work.

5.5.2. Leveraging scale

Following the suggestion made in the questionnaire that "Local projects being done together would probably incentivise me", interview questions considered the possibility of transferring into the private sector the scaled approaches to retrofit currently common in social housing. Case study participants demonstrated interest in intermediary support for collective action. This ranged from cooperation with immediate neighbours to arrange cavity wall insulation in a 'four in a block' multi-family building to community level collective action. Homeowner interviewees expressed a higher level of trust in a community-based organisation (see section 5.3.1). P1, who lives in a tenement saw this as little different to self-factoring and organising repairs to common areas with neighbours.

Professionals indicated that cooperation in the private sector is feasible and could yield economies of scale. The consulting engineer (P2) agreed that 'the building physics are the same' and that little innovation is needed:

> *'it's boring stuff but it just needs doing. We won't make progress until companies start going street-by-street'.*
> Interviewee P2

The architect (P1) revealed that economies of scale had already been yielded from a programme of advanced assessment of common archetypes in the private sector under the aegis of a Scottish local authority.

The community charity manager (P4) agreed that group purchase may be a way to cut the contractors costs and get better prices. In the example of expensive sash and case double-glazing required in conservation areas, this would mean having a specialist in the area for an extended period to do several properties consecutively, keeping his employees fully productive and reducing customer acquisition costs. However, the insulation specialist (P3) advised caution against community-led programmes because in his experience they often did not appreciate the technical aspects and had wasted his time on inappropriate sales leads.

5.5.3. Opportunity for system building

P4 remarked that bottom-up retrofit communities have not developed in Scotland to the same extent as elsewhere. While Retrofitworks in south east England (Retrofitworks, 2020) and Carbon Coop in Greater Manchester (Carbon Coop, 2020) are building the supply chain of, and demand for, competent deep retrofit trades and 'do-it-yourself' homeowners there are no equivalent examples in Scotland. This may be explained by different approaches from government. Retrofitworks and Carbon Coop have both benefited from government support for intermediary development while the Energy Efficient Scotland strategy (Scottish Government, 2018b) is for local authority led approaches.

5.6.Methodological Considerations

The questionnaire method appeared to be largely effective with a low drop-out rate of 14% despite the complex best-worst scaling question. The best-worst scaling method was effective in forcing a discriminatory prioritisation of a long list of barriers.

The recruitment approach resulted in 2% of respondents over 75 despite that demographic making up 6% of the local population (GCC, 2020). The use of email recruitment targeted at older residents only partially balanced the age distribution. Further research may be able to improve on sampling if unencumbered with lockdown restrictions.

There was little evidence of questions being misunderstood. A potential weakness related to perceptions of comfort where it was not clear whether homeowner responses were predicated on an intention to reduce cost, or to reduce cost as a means to then improve comfort, as discussed in section 5.2.1. Further research should more carefully delineate perceptions of value to reveal deeper insights. Furthermore, primary research should be carried out during cold winter weather when thoughts of comfort are fresh in the mind.

As an exploratory case study focused on revealing key themes the methodology provided robust internal validity. The retrofit barriers and drivers most important to the case study area were revealed and triangulated using the multi-methods approach. The semi-structured interview method adapted well to homeowners in different life situations which is relevant to triggers to retrofit. Sufficient depth of meaning was revealed to permit connection of the emergent themes to the research framework of Brown's (2018) business model elements. One dimension that was left out of the questionnaire for reasons of brevity was gender. The different experiences of comfort of men and women, and their differing roles in retrofit decision-making (Galvin and Sunikka-Blank, 2017), may mean that some significance in participants contributions has been lost.

The robustness of the case study findings could be increased by applying statistical analysis to the best-worst scaling data set of retrofit barriers. A Bayesian probability distribution could be determined by following the method described by Balcombe *et al* (2014) which used an identically structured BWS method.

The findings have some external validity beyond the case study boundary. The building archetypes of the research participants are common throughout Scotland. For example, the traditional solid wall archetypes (88 of 137 questionnaire respondents) represent 17% of Scotland's housing stock (Scottish Government, 2020a)

Brown's five-element framework for retrofit business models was a useful construct within which to analyse the case study. It had the advantage of having been designed specifically for retrofit and was simpler than alternatives such as the nine-element business model canvas (Osterwalder and Pigneur, 2010). However, it has a firm-centric approach and the more recent innovation intermediaries perspective (Brown *et al*, 2019) would be more useful for further research into the intermediary approaches raised in this dissertation as discussed in section 5.5.

5.7.A Retrofit Business Model for Langside

Returning to the original motivation for this research, what do the above findings tell us may be an effective approach to accelerating residential heat efficiency and decarbonisation retrofit in south Glasgow? While homeowner thinking is currently dominated by cost and payback, an integrated approach that follows the life and development of households and homes would make a substantial improvement on existing value propositions. Homeowners place value on advanced, holistic and personalised advice and would do more energy efficient retrofit if someone was on hand to do the thinking for them. This would help ensure that opportunities for retrofit, like moving in, renovation improvements and life transitions are not missed. Simple unmet problems may provide openings with potential customers, like advising on boiler sizing and loft clearance prior to insulation.

The customer interface of a Langside business model should recognise the value placed on interpersonal recommendations. A community-based organisation seen as serving the local community would engender homeowner engagement. Communication with households should tap established social networks including through online social media. Customer segmentation should be made on a persona basis considering age and life transitions, motivations and plans for other improvements such as amenity or aesthetic changes.

A pragmatic approach to supply chain management and quality assurance would focus on applying the principles of PAS2035 and PAS2030, even if suppliers are not registered and producing all the paperwork. The dominance of a relatively small number of building archetypes in Langside provides the opportunity for cost innovation through economies of scale.

6. Conclusions

This dissertation successfully applied case study methodology to examine the potential for business model innovation to accelerate the implementation of heat efficiency and decarbonisation retrofit. Interviews with professionals provided a reality check on findings arising from homeowner input. A synthesis of findings provided a vision for community based approach to retrofit sector development in the case study area.

Homeowner decision making criteria are dominated by considerations of cost and expectations of short financial payback periods. The potential for improving the comfort of older buildings is likely not fully appreciated by homeowners and this causes some conflation between energy bills and comfort as drivers of retrofit. However, indications of demand for advanced building energy assessments may provide an opportunity to change perspectives. The prospect of coronavirus lockdown restrictions and continued work from home policies may increase the value proposition of retrofit, especially for younger people, and employers may be tapped as an additional source of revenue to pay for comfortable home working environments.

Interpersonal trust was found to be the dominant mode of trust and one neighbourhood Facebook group in particular was found to have an outsized impact on tradesperson selection in the case study area. Echoing findings in the literature, demographics were found to have weak correlation with attitudes relevant to retrofit. An approach to customer segmentation based on personas and windows of opportunity would be more effective, especially when considering life stage transitions, and plans for other renovation improvements.

Interviews with professionals gave force to the external validity of the findings beyond the case study area. The commonality of the case study building archetypes throughout Scotland mean that scaled approaches may meet with success if supported by a trusted intermediary organisation and building on experience in social housing.

Implications for policy include the finding that the Scottish Government's preferred local authority-led intermediary approach for able to pay homeowners may not immediately engender the same level of trust as could be expected through the use of community-based intermediaries. Further research in this area is merited.

Homeowners indicated a positive reception to the principle of minimum efficiency standards for owner-occupied homes but expect further financial support to be forthcoming for hard to treat properties. Homeowner implementations may be encouraged by shifting the focus of dialogue on energy efficiency away

from saving money and towards the value of fabric improvements to create more comfortable homes. Furthermore, more should be done to raise awareness of the environmental impact of gas boilers.
Another finding for policy is that while trade accreditations including Trustmark and PAS2035/2030 are valued in principle by professionals, low homeowner awareness and lack of regulatory enforcement means that their impact may not be as great as expected. Government should invest in standards enforcement.

Quantitative approaches could build on the best-worst scaling dataset created in this project. Without the restrictions of coronavirus social distancing, future research may be able to follow a probabilistic sampling method.

The influence of gender in experiencing and managing home heating is an under-examined aspect of retrofit research (Galvin and Sunikka-Blank, 2017) and further case study work examining this topic in the Langside area would be a valuable complement to this project.

Brown's (2018) five characteristics of retrofit business models was found to provide an effective conceptual framework for this research. The emerging importance of intermediaries, highlighted in this project, means a more recent framework provided by Brown *et al* (2019) may become more useful. Future research should refine its examination of perceptions of retrofit value, especially in terms of comfort levels. Ideally, this research should be carried out in winter.

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Appendix 1 – Case study questionnaire design

Appendix 1.1 – Case study questionnaire

Page 1

What is your age?

- ◯ 18-24
- ◯ 25-34
- ◯ 35-44
- ◯ 45-59
- ◯ 60-74
- ◯ 75+

What is your postcode?

What kind of building is your home?

- ◯ Flat - traditional sandstone tenement
- ◯ Flat - other
- ◯ House - solid wall (for example, traditional sandstone)
- ◯ House - other / don't know.

Is your home rented or owned?

- ◯ Rented
- ◯ Owned (with or without mortgage)

Page 2

How is your home heated?

- ◯ Gas boiler
- ◯ Electric heating (for example storage heaters)
- ◯ Heat pump
- ◯ Other or don't know

Thinking about your home in the middle of winter, which phrases apply?
(select all that apply)

- ☐ Issues with damp or mould.
- ☐ Comfortable
- ☐ Temperature is just right
- ☐ Air is too dry/ I get a cough
- ☐ Cosy
- ☐ Draughty
- ☐ Too warm
- ☐ Cold floors/ I get cold feet
- ☐ Too cold
- ☐ There are cold spots
- ☐ Too expensive to heat properly
- ☐ Some rooms too cold, others too warm

If you were to make additional improvements to your home insulation, draught-proofing, or heating, what would be your reasons?

Drag the items to put them in priority order. (1 = most important)

- Reduce energy bills
- Increase the value of my home
- Reduce health impacts
- Reduce environmental impact
- Improve comfort

Have your ideas about home comfort and improvement priorities changed since the coronavirus lockdown ?

- ○ Yes
- ○ No

Page 3

Has your household implemented, or considered implementing, any of the following heat efficiency measures for your current home?

- Extra loft insulation
- Cavity wall insulation
- Internal or external wall insulation
- Upgraded external doors or double-/triple-glazed windows
- Underfloor insulation
- Heat pump
- Efficient gas boiler

- ○ Yes
- ○ No, my household has never considered any of these measures for my/our current home.

Page 4

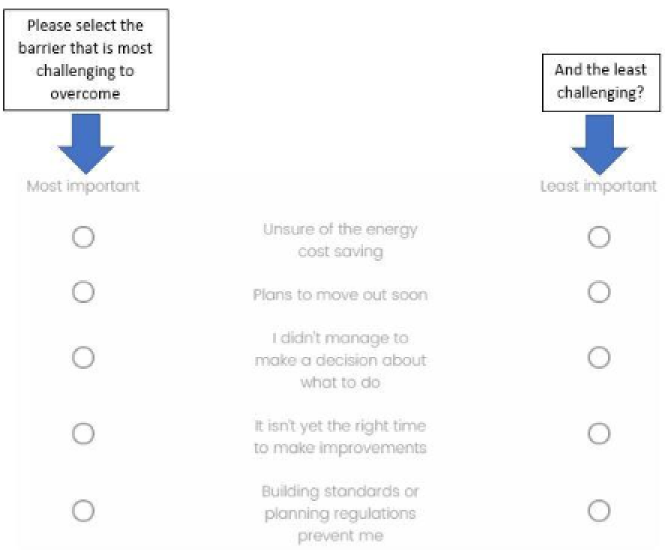
In the following pages you will see seven lists, each with five possible BARRIERS to implementing heat efficiency measures (for example, insulation, new windows, new boiler, ...).
Thinking about your own experience of considering or implementing measures, please select:

- on the left the one item that is or was the MOST important barrier for your implementation. In other words, the item most difficult for you to overcome

AND

- on the right the item that is or was the LEAST important barrier.

EXAMPLE BELOW - CLICK TO NEXT PAGE



Page 5

(1 of 7)

Out of the 5 options below, based on your experience, please indicate

- on the left - which is the most challenging barrier to implementation of heat efficiency measures

and

- on the right - which is the least important barrier.

Most important		Least important
○	Unsure of the energy cost saving	○
○	Plans to move out soon	○
○	Unsure of the environmental benefits	○
○	The savings don't pay back the investment, or not fast enough.	○
○	Difficulty with building standards or planning regulations	○

Page 6

(2 of 7)

Out of the 5 options below, based on your experience, please indicate

- on the left - which is the most challenging barrier to implementation of heat efficiency measures

and

- on the right - which is the least important barrier.

Most important		Least important
○	Plans to move out soon	○
○	Difficulty with building standards or planning regs	○
○	The up front cost	○
○	Difficulty finding contractors I feel I can rely on	○
○	Increase in home value unclear or too small	○

Page 7

(3 of 7)

Out of the 5 options below, based on your experience, please indicate

- on the left - which is the most challenging barrier to implementation of heat efficiency measures

and

- on the right - which is the least important barrier.

Most important		Least important
○	Difficulty finding contractors I feel I can rely on	○
○	Unsure of the energy cost saving	○
○	Increase in home value unclear or too small	○
○	Unsure of the warmth benefits.	○
○	Works cause too much disruption	○

Page 8

(4 of 7)

Out of the 5 options below, based on your experience, please indicate

- on the left - which is the most challenging barrier to implementation of heat efficiency measures

and

- on the right - which is the least important barrier.

Most important		Least important
○	Difficulty with building standards or planning regs	○
○	Works cause too much disruption	○
○	Unsure of the warmth benefits.	○
○	Difficulty getting good advice	○
○	Organising the contractors is too difficult	○

Page 9

(5 of 7)

Out of the 5 options below, based on your experience, please indicate

- on the left - which is the most challenging barrier to implementation of heat efficiency measures

and

- on the right - which is the least important barrier.

Most important		Least important
○	The up front cost	○
○	Unsure of the warmth benefits.	○
○	Difficulty getting good advice	○
○	Negative experience of previous home improvements	○
○	Unclear on the available subsidies	○

Page 10

(6 of 7)

Out of the 5 options below, based on your experience, please indicate

- on the left - which is the most challenging barrier to implementation of heat efficiency measures

and

- on the right - which is the least important barrier.

Most important		Least important
○	Increase in home value unclear or too small	○
○	Organising the contractors is too difficult	○
○	Plans to move out soon	○
○	Negative experience of previous home improvements	○
○	The savings don't pay back the investment, or not fast enough.	○

Page 11

(7 of 7)

Out of the 5 options below, based on your experience, please indicate

- on the left - which is the most challenging barrier to implementation of heat efficiency measures

and

- on the right - which is the least important barrier.

Most important		Least important
○	Unsure of the environmental benefits	○
○	The up front cost	○
○	Unsure of the energy cost saving	○
○	Unclear on the available subsidies	○
○	Difficulty finding contractors I feel I can rely on	○

Page 12

Which of the following statements comes closest to your view of climate change?

- ◯ Climate change is an immediate and urgent problem
- ◯ Climate change is more of a problem for the future
- ◯ Climate change is not really a problem
- ◯ I'm still not convinced that climate change is happening
- ◯ Don't know

To what extent do you agree with the following statement:

"It's not worth me doing things to help the environment if others don't do the same."

- ◯ Strongly agree
- ◯ Somewhat agree
- ◯ Neither agree nor disagree
- ◯ Somewhat disagree
- ◯ Strongly disagree
- ◯ Don't' know

What one thing would make it easier for you to implement heat efficiency or decarbonisation measures? (optional)

If you would like to share further reflections on home insulation, decarbonisation or the impact of lockdown, please comment below. (optional)

Page 13

Are you willing to be interviewed to explore the topic in more detail (about 30 minutes by phone or zoom)? If yes, please provide your email address.

If you would like to receive a copy of the project findings, please enter your email address.

Appendix 1.2 – Best-worst scaling method to prioritise barriers

Question 10 in this questionnaire used the case 1 (object) form of best-worst scaling (BWS) to estimate the ranked importance of 14 barriers to retrofit. BWS, sometimes called Max-Diff, involves repeatedly asking respondents to identify the best and worst, or most and least important, objects in varying subsets of a longer list of objects in order to estimate the rank order of all items in the list (Louviere *et al*, 2013).

BWS carries advantages over other methods. Respondents may score disparate objects in different ways on ranking scales, such as Likert scales. Also, respondents often show a tendency to report that all the presented objects are similarly important. Alternatively, orthogonal arrays of paired comparisons – where respondents are asked to compare A with B, B with C, then A with C and so on – place a large cognitive load on the respondent and the time required can cause high drop-out rates (Louviere *et al*, 2015).

The barriers considered in this research, given in Table 1, were identified with reference to the literature with particular reference to a study on retrofit decision-making by Klöckner and Nayum (2016). The question design was based closely on a BWS questionnaire that considered barriers to uptake of microgeneration (Balcombe *et al*, 2014).

Table 1: 14 barriers to retrofit considered using best-worst scaling in the questionnaire.

Barriers to heat efficiency and decarbonisation retrofit
Unsure of the energy cost saving
Plans to move out soon
Unsure of the environmental benefits
The savings don't pay back the investment, or not fast enough.
Difficulty with building standards or planning regs
The up-front cost
Difficulty finding contractors I feel I can rely on
Increase in home value unclear or too small
Unsure of the warmth benefits.
Works cause too much disruption
Difficulty getting good advice
Organising the contractors is too difficult
Negative experience of previous home improvements
Unclear on the available subsidies

For a given number of objects to be compared, J, BWS questions present the respondent with b subsets each containing a subset of k objects. Designs of b and k and the position of each object in each subset have been developed in the field of combinatorial mathematics. These designs, called balanced incomplete block designs (BIBD) are available from dedicated libraries. In this research, the BIBD used by Balscombe (2014) was replicated: 14 objects studied in seven varying subsets of five objects.

Statistical analysis using random utility theory is often used to analyse BWS experiments, often using dedicated proprietary software such as the Sawtooth platform (Balscombe, 2014). However empirical evidence shows that a simple arithmetical scoring, shown in Figure 6, correlates strongly with the outcomes of statistical approaches (Louviere et al, 2015). This arithmetic approach is increasingly used by practitioners, especially in market research (CenSoc, 2020; Louviere *et al*, 2013) and is applied in this dissertation project.

$$\text{Score} = \frac{\text{Number of times object chosen as most important} \\ \text{minus} \\ \text{Number of times object chosen as least important}}{\text{Number of times object appears in the survey}}$$

Figure 6: Calculation of best-worst scaling score used to analyse question 10 in the case study questionnaire.

Appendix 1.3 – Method of coding perceptions of home in winter

Question 6 asked the respondent to select descriptors that best fitted their view of their home in winter: "Thinking about your home in winter, which of the following phrases apply?". The descriptors were a simplified list of the perceptions of comfort and factors relevant to health identified in the literature (Morgan, 2018) as well as a descriptor relevant to fuel poverty. The full list of descriptors is listed in Table 2.

Table 2: List of perceptions of home in winter descriptors presented in question 6 in the questionnaire.

Home comfort descriptors
Cosy
Comfortable
Too warm
Temperature is just right
Too expensive to heat properly
Too cold
Draughty
Cold floors/ I get cold feet
There are cold spots
Some rooms too cold, others too warm
Issues with damp or mould.

As respondents could select any number of descriptors, including contradictory descriptors, a coding logic was designed to support analysis. Four categories were identified for coding responses. These categories were set in an order of precedence driven by the policy context that prioritises fuel poverty and its associated health issues above issues of comfort. This coding logic is laid out in Table 3. For example, if a respondent included ‘too expensive to heat properly’ in their response then their perception was categorised as ‘too costly to heat’, regardless of what other descriptors they had selected.

Table 3: Coding and precedence logic for perceptions of home in winter, question 6 in the questionnaire.

Precedence	Category	Definition
1	Too costly to heat	Contains ‘too expensive to heat properly’
2	Unhealthy	Contains any health indicators: • Issues with damp or mould • Too warm • Air is too dry/ I get a cough
3	Discomfort	Contains any discomfort indicators: • Too cold • Draughty • Cold floors/ I get cold feet • There are cold spots • Some rooms too cold, others too warm.
4	Comfort	Contains only comfort indicators • Cosy • Comfortable • Temperature is just right

Appendix 1.4 – Example recruitment advertisement


Chris Carus ▶ Shawlands, Strathbungo & Battlefield Community Group - No Business Posts

18 July at 13:56 ·

Home improvement, energy efficiency and climate change.

Hi everyone. I'm a local resident and MSc student at Strathclyde Uni looking into home heat efficiency with a focus on the southside. If you are a homeowner in Shawlands/ Strathbungo/ Langside sort of area I'd be very grateful if you would take 10 minutes to complete my survey.

Many thanks!

https://stratheng.eu.qualtrics.com/jfe/form/SV_9HVaPu4I36KIRNP

3 2 comments

Like Comment Share

Appendix 2 – Interview guide - Homeowner

This research is about heating efficiency and decarbonisation, That includes insulation, air tightness, and improving the efficiency of or replacing heat sources (boiler, alternatives, radiator).

Please remember you can choose not to answer questions or end the interview when you like. You won't be identifiable. I'll refer to you as something like "solid wall house owner".

[If consented] I'm going to start recording now.

HOME

1. How long have you lived in this home?
    - Live with others?
    - Decisions about home energy, renovations, maintenance made jointly?
    - Who makes decisions about decoration, furnishing?
    - Plans to move out soon?

2. Let's talk about your home – it is a house/flat…
    - Flat – ground/ mid/ top floor?
    - Construction. Type of wall. When built?
    - What kind of heating? Condensing boiler? When installed?

3. Thinking about your home in winter – is it comfortable, or cold or draughty? Priorities for improvement?
    - What would you like to improve about it? Why?
    - How do you value on comfort? E.g. Compare comfort with the value of a new kitchen?

4. Have your views changed since lockdown?
    - Been working from home?

IMPROVEMENTS

5. For your home, recommended efficiency improvements would include the following.... (based on above description of home and prior document study)
    - double/secondary/triple glazing, -
    - Loft, floor, wall upgraded windows/ doors;
    - air tightness and ventilation
    - Integrated package
    - New boiler or heat pump.
    - Optimised boiler + radiators, controls

6. Have you made any home improvements?
    - Insulation, draught-proofing, new heating system
    - Or improvements including amenity new kitchen or bathroom?

7. What was your experience of finding contractors?
    - Getting advice
    - Finding contractors

- Finding funding
- In the survey you said barriers were XXXX.
- You commented XXXX.

BUSINESS MODEL

8. What is needed to get you to commit to further work?
   - Measures of whether something is worth doing – payback, % reduction kWh, reduction in bills, CO2, days of work/disruption. (CMD)

9. Who would you trust to advise on work to be done?
   - personal recommendations, (neighbours say or do?, advocates – MSP, councillor, church, community group). Social media recommendations.
   - trust marks,
   - professional standards (de Wilde)

10. Let's say you have decided to make a big improvement – perhaps even a package of various improvements. Insulation, air tightness, new heating system…What would attract you, or put you off, the following approaches to the work? Who would you trust most?
    - Co-ordinate all the contractors myself
    - Independent advisor recommends a shortlist of contractors but you select.
    - Pay a one stop shop to project manage contractors

11. Based on your past experience to what degree would you instinctively trust the following organisations if they were acting as an intermediary organising the package of work to be done on your home. Please score each one a scale from 1, least trustworthy, to 5, most trustworthy. (review one by one)
    - GCC,
    - Social housing association,
    - Current building factor (if applicable).
    - Local building firm
    - Energy provider
    - Local community-run energy group;
    - Architect

12. To reduce cost or better manage quality would you consider clubbing together with neighbours?

13. Would you pay extra for a guarantee of performance?
    - Sensors etc. Contractor will come back to fix, or pay for the difference in energy bill?

POLICY

14. The Scottish Government proposes to make it mandatory, that owner-occupied properties be at least an EPC 'C' rating when they are sold or have major renovation, where cost-feasible. Current policy is to enforce from 2030 or possible from 2024.
    - Did you know? What is your reaction?
    - Do you feel you understand what is needed, if anything, to bring your home to that standard?
15. Anything else that would help you engage with heat efficiency and home improvement?

Thank you for your time.

I'll stop the recording now.

Appendix 3 – Interview Guides - Professionals

[Confirm written consent received]

Thank you for agreeing to take part in my research. I am a postgraduate engineering student at Strathclyde University.
In this interview I would like to ask you about your work relating to home heat efficiency and approaches that may be taken to accelerate implementation in the so called 'able to pay', owner-occupier sector.

Please remember you can choose not to answer questions or end the interview when you like. You will be anonymous in the report – e.g. 'local estate agent'.

Any questions before we start?
[If consented] I'm going to start recording now.

Appendix 3.1 Energy Assessors / PAS2035 accredited/ Architectural technologists.

1. Please help me understand your business – nature of work and clients.

2. EPCs are simplified assessments. Their estimates of energy consumption and improvement recommendations can be unreliable. Do you see any emerging demand from owner-occupiers for more advanced energy surveys – for example a full SAP assessment, or a Passivhaus-type assessment?

3. What scope is there to adapt your model for detailed assessment / deep retrofit for mass housing? E.g. large areas of similar interwar or sandstone housing?

4. What is your opinion of the risks and opportunities associated with group procurement of assessment or retrofit design services for similar homes?

5. The Scottish Government proposes to make it mandatory that owner-occupied properties be at least an EPC 'C' rating when they are sold or have major renovation, where cost-feasible. Current policy is to enforce this from 2030 or possibly from 2024. It is proposed that obligation can transfer to the buyer to complete the work within a set period of taking possession of the property with the cost of works taken out of the sale value.
   - Did you already know about this policy?
   - What is your reaction? Should government be regulating private housing in this way?
   - What are the pros and cons of such a policy?

6. Anything else to help accelerate retrofit?

Appendix 3.2 Community energy charity, advocate or organiser

1. Understand your business

2. Do you do energy assessments?

3. Who are the clients?

4. What measures do you recommend or support? Deep or individual?

5. Do you direct people to government funding?

6. How to deal with restrictions on windows in conservation areas? Are these restrictions appropriate?

7. What scope is there for collective purchase of advice, of measures?

8. How do people find tradespeople?

9. Do you see potential for supporting people to do deep retrofit, for example IWI, if they had help with materials and training?

10. The Scottish Government proposes to make it mandatory that owner-occupied properties be at least an EPC 'C' rating when they are sold or have major renovation, where cost-feasible. Current policy is to enforce this from 2030 or possibly from 2024. It is proposed that obligation can transfer to the buyer to complete the work within a set period of taking possession of the property with the cost of works taken out of the sale value.
    - Did you already know about this policy?
    - What is your reaction? Should government be regulating private housing in this way?
    - What are the pros and cons of such a policy?

Appendix 3.3 Insulation installers.

1. Please help me understand your business – nature of work and clients.

2. How do you get work? What are your main sources of leads? Work with retrofit coordinators?

3. Do you have any formal or informal collaboration with other providers for joined up or 'whole house' retrofit'? Architect, PAS2035 retrofit co-ordinator?

4. What is your opinion of the risks and opportunities associated with the following approaches?
    - Group procurement of design and retrofit for similar homes

5. The Scottish Government proposes to make it mandatory that owner-occupied properties be at least an EPC 'C' rating when they are sold or have major renovation, where cost-feasible. Current policy is to enforce this from 2030 or possibly from 2024. It is proposed that obligation can transfer to the buyer to complete the work within a set period of taking possession of the property with the cost of works taken out of the sale value.
    - Did you already know about this policy?
    - What is your reaction? Should government be regulating private housing in this way?
    - What are the pros and cons of such a policy?

6. Anything else to help accelerate retrofit?

Appendix 3.4 Estate agents

1. How important are EPC ratings to house values and buyer decisions? Any emerging trend in buyers priorities?

2. Based on your experience or expectations, how would advanced or novel energy efficiency and low carbon measures affect the resale value of properties in the southside of Glasgow? Would you recommend to sellers or advise against? For example a heat pump (like an air conditioner running in reverse with hot water tank inside)

3. A heat pump would be a low carbon heating option. Do you see any questions or interest from buyers looking for that kind of feature?

4. The Scottish Government proposes to make it mandatory that owner-occupied properties be at least an EPC ‘C’ rating when they are sold or have major renovation, where cost-feasible. Current policy is to enforce this from 2030 or possibly from 2024. It is proposed that obligation can transfer to the buyer to complete the work within a set period of taking possession of the property with the cost of works taken out of the sale value.
   - Did you already know about this policy?
   - What is your reaction? Should government be regulating private housing in this way?
   - What are the pros and cons of such a policy?

5. When people buy a property that is a chance to do a lot of work. Do buyers ever seek your help – for example doing a deeper survey before they get possession.

6. Some lenders are starting to provide ‘green mortgages’ where borrowing can be extended or interest rates reduced if energy efficiency measures are implemented. What is your experience, if any, of such mortgages?

Thank you for your time.

Appendix 4 - Questionnaire data

Appendix 4.1 Profile of respondents by building archetype and deprivation ranking (SIMD)

Profile of respondents by building type and SIMD – (5 is most affluent). Respondents mostly in solid wall constructions and more affluent areas, consistent with the demographics and built environment of the case study area.

Wall	Verified house type	SIMD quintile (5 most affluent)					Number of responses
		1	2	3	4	5	
Solid	Flat - traditional sandstone tenement	3	10	11	18	4	46
	House - semi/terrace - solid wall		7	2	20	13	42
	Flat - conversion		1			2	3
Cavity	House - semi/terrace - cavity wall		2		12	6	20
	Cottage flat - cavity wall			8			8
	Bungalow - cavity wall				6		6
	Flat - cavity		1				1
New	Flat - modern/new	1	2	2	4	2	11
Total		4	23	23	60	27	137

Appendix 4.2 Profile of respondents by age (question 1) and flat/house (question 3)

Most age groups and both main types of home are well represented.

Age	Flat	House
No answer	0	1
18-24	1	1
25-34	24	7
35-44	19	19
45-59	14	26
60-74	10	12
75+	1	2

Appendix 4.3 Perceptions of own home comfort (question 6) versus wall construction (from document study)

Categorisation of respondent comments was based on the method outlined in appendix 1.3.

Modern constructions generally more comfortable.

Wall	Discomfort	Comfort	Too costly to heat	Unhealthy	Total
Solid	55%	15%	20%	10%	91
Cavity	54%	20%	9%	17%	35
Modern/ new	18%	55%	9%	18%	11
Total	52%	20%	16%	12%	137

Appendix 4.4 Perceptions of own home comfort (question 6) versus deprivation ranking (SIMD) (from document study)

No pattern could be established by deprivation (SIMD) ranking.

SIMD 2020 Quintile (5 most affluent)	Discomfort	Comfort	Too costly to heat	Unhealthy	Grand Total
1	50%	25%	25%	0%	4
2	48%	17%	17%	17%	23
3	43%	17%	30%	9%	23
4	58%	17%	10%	15%	60
5	48%	30%	15%	7%	27
Total	52%	20%	16%	12%	137

Appendix 4.5 Reasons for potential future efficiency measures (question 7) by heating type (question 5)

Top priority by heating type – bills and comfort most important.

Heating type	Reduce energy bills	Improve comfort	Reduce environmental impact	Reduce health impacts	Increase the value of my home	Number of responses
Gas boiler	47	44	27	8	5	131
Electric heating (for example storage heaters)	1	3				4
Other or don't know	1	1				2
Total	49	48	27	8	5	137

Appendix 4.6 Reasons for potential future efficiency measures (question 7) by wall construction (from document study)

Top priority by construction type. Modern home occupants less concerned with comfort but there were only 11 responses from these occupants.

Wall	Reduce energy bills	Improve comfort	Reduce environment al impact	Reduce health impacts	Increase the value of my home	Number of responses
Solid	35%	37%	23%	4%	0%	91
Cavity	34%	31%	17%	6%	11%	35
New	45%	27%	0%	18%	9%	11
Total	36%	35%	20%	6%	4%	137

Appendix 4.7 Reasons for potential future efficiency measures (question 6)

The table below details the ranking of reasons for further efficiency improvements, question 6 in the questionnaire. It shows that reducing environmental impact was most commonly placed as the third priority.

	Number of times at this rank				
Rank	**Reduce energy bills**	**Improve comfort**	**Reduce environmental impact**	**Reduce health impacts**	**Increase the value of my home**
1	49	48	27	8	5
2	44	32	35	11	15
3	29	31	41	18	18
4	11	18	24	42	42
5	4	8	10	58	57
Sum of ranks	288	317	366	542	542
Overall rank	1	2	3	4	5

Appendix 4.8 Reasons for potential future efficiency measures (question 7) by deprivation ranking (from document study) – percentages

Most deprived were more motivated by bills (weak correlation). No pattern on environmental impact.

SIMD 2020 Quintile (5 most affluent)	Reduce energy bills	Improve comfort	Reduce environmental impact	Reduce health impacts	Increase the value of my home	Number of responses
1	50%	25%	0%	0%	25%	4
2	30%	26%	26%	13%	4%	23
3	39%	35%	9%	13%	4%	23
4	38%	35%	20%	3%	3%	60
5	30%	44%	26%	0%	0%	27
Total	36%	35%	20%	6%	4%	137

Appendix 4.9 Views of home changed since lockdown (question 8) by age band (question 1).

Age	No	Yes
18-24	1	1
25-34	14	17
35-44	26	12
45-59	28	12
60-74	15	7
75+	3	

Appendix 4.10 Views of home changed since lockdown (question 8) by deprivation ranking (SIMD) (from document study).

No pattern identified.

SIMD 2020 Quintile	No	Yes	Total
1	3	1	4
2	16	7	23
3	8	15	23
4	41	19	60
5	20	7	27
Total	88	49	137

Appendix 4.11 Views of home changed since lockdown (question 8) by wall construction (from document study).

Views of those in modern homes less likely to have been impacted by lockdown, however small sample of 11.

Wall	No	Yes	Total
Solid	65%	35%	91
Cavity	54%	46%	35
Modern/ new	91%	9%	11
Total	64%	36%	137

Appendix 4.12 Best worst scaling of potential retrofit barriers (question 10)

The best worst scaling scores place cost and finding contractors as the most important barriers.

	Most important (number of responses)	Least important (number of responses)	# times presented in questionnaire	BWS score
The up-front cost	98	25	3	**90**
Difficulty finding contractors I feel I can rely on	83	27	3	**74**
The savings don't pay back the investment, or not fast enough.	61	19	2	**52**
Difficulty getting good advice	41	10	2	**36**
Unsure of the energy cost saving	42	28	3	**33**
Organising the contractors is too difficult	36	20	2	**26**
Works cause too much disruption	42	34	2	**25**
Unsure of the warmth benefits.	29	30	3	**19**
Unclear on the available subsidies	19	36	2	**1**
Increase in home value unclear or too small	21	61	3	**1**
Negative experience of previous home improvements	21	44	2	**-1**
Unsure of the environmental benefits	5	21	2	**-6**
Difficulty with building standards or planning regs	11	73	3	**-13**
Plans to move out soon	11	92	3	**-20**

Appendix 4.13 Respondents attitudes to climate change (question 11) compared to Scottish polling

Question: 'Which of the following statements comes closest to your view of climate change?'

Case study respondents in 2020 were more likely to think climate change is a problem than the 2018 Scottish polling average.

Age band	Climate change is an immediate and urgent problem	Climate change is more of a problem for the future	Climate change is not really a problem	I'm still not convinced that climate change is happening	No answer	Don't know
25-34	100%	0%	0%	0%	0%	0%
35-44	88%	3%	0%	3%	6%	0%
45-59	84%	3%	3%	3%	3%	3%
60-74	84%	11%	5%	0%	0%	0%
- 75+	100%	0%	0%	0%	0%	0%
Questionnaire	**89%**	**4%**	**2%**	**2%**	**3%**	**1%**
	+24% vs Scotland	-12%	-2%	-5%	2%	-6%
Scotland 2018	**65%**	**16%**	**4%**	**7%**	**1%**	**7%**

Appendix 4.14 Respondents attitudes to climate action (question 12) compared to Scottish polling

Question: 'To what extent do you agree with the following statement: "It's not worth me doing things to help the environment if others don't do the same".'

Case study respondents in 2020 were more likely to independent climate action than the 2018 Scottish average.

Age band	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	No answer/ don't know
25-34	0%	16%	12%	28%	44%	0%
35-44	0%	16%	6%	16%	56%	6%
45-59	0%	16%	0%	19%	63%	3%
60-74	5%	26%	11%	11%	47%	0%
- 75+	0%	0%	0%	33%	67%	0%
Questionnaire	1%	17%	6%	19%	54%	3%
	18% (+3% vs Scotland)		**(-4%)**	**73% (+7%)**		**(-5%)**
Scotland 2018	5%	10%	10%	21%	46%	8%
	15%			**67%**		

Appendix 5 – Summary of homeowner comment coding

Comments were coded into substantive topics and sub-topics and then grouped by their relevance to Brown's retrofit business model framework.

Business model characteristics	Substantive topic	Sub topic	Total	Questi-onnaire	Interview
Value proposition	Advice, assessment	Advice	23	22	1
		Assessment	8		8
	Technology/ methods	Energy sources	7	4	3
		Insulation	3	3	
		Gas	3	3	
		Heat or energy source	1		1
		Emitters	1		1
		Insulation	1		1
	Policy	EPC minimum	8		8
	Hard to treat	Conservation	6	6	
		Hard to treat	1		1
		Building design	1	1	
	Service	Performance guarantee	4		4
		Help to clear loft	1	1	
		Help with disruption	1	1	
	Environmental impact	Environmental impact	3		3
	Home value	Prioritisation	2		2
		Valuation	1		1
	DIY	Experience of DIY insulation	2	1	1
	Other	New builds	2	2	
	Comfort	Ideas of comfort	1		1
		Influence of clothing on heat demand	3	2	1
	Triggers/ opportunities	Replacing radiators for aesthetics	1		1
	Contractors and intermediaries	Quality	1		1
	Hassle	Prioritisation	1		1
Supply Chain	Contractors and intermediaries	Quality	1		1
Customer interface	Contractors and intermediaries	Recommendations - 1 interpersonal	10		10
		Contractors	9	7	2
		Recommendations - 2 impersonal	5		5
		Recommendations - 3 professional	4		4
		Selling/ prices	2		2
		Not for profit	1		1
		Contractor	1		1
		Quality	1		1
	Triggers/ opportunities	When purchasing home/ moving in	4	2	2
		Amenity improvements	2		2
	Technology/ methods	Smart tech	1		1
		Insulation	1		1
Financial model	Affordability	Funding	31	29	2
		Cost	6	6	
		Prioritisation	1		1
		Advice	1		1
		Finance	1	1	
	COVID	Paying for working from home	3	3	
	Hard to treat	Conservation	2	2	
Governance	Contractors and intermediaries	Intermediaries	5	4	1
		One stop shop	3		3
		Neighbours club	3		3
		Government	1		1
		Factor	1		1
Other	Behaviour	Influence of clothing on heat demand	3	2	1