Low Carbon Domestic Refurbishment in the UK Social Housing Sector: A Survey of Attitudes, Readiness and Adoption

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Declaration

The basis of this thesis is a social housing sector survey that was conducted by the author during a market research phase of a Knowledge Transfer Partnership (KTP). This work was supported by Dr Will Swan as academic supervisor to the KTP and also Bill Taylor and other housing sector professionals representing Fusion21. Since the survey, a number of press releases relating to the key findings have been issued and partial insights have formed the basis of two journal papers and a conference proceeding. Parts of this thesis therefore comprise of material the author has used elsewhere academically and commercially. This work is appropriately cited and available in the public domain.

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Luke Smith, April 2015.

Abstract

The buildings sector has been identified as being capable of delivering sizable efficiency savings from not only its current practices regarding new build but also in retrofitting the existing built stock. Indeed, there are more than 27 million homes in the UK, each contributing an average 5.1 tonnes of CO_2 emissions per annum.

The social housing sector represents 18% of the total UK housing stock, approximately 4.7 million homes and has an existing supply chain already active in maintaining and refurbishing homes in a way that is acceptable to the occupant; thus presenting an ideal starting point to build on the embryonic UK sustainable retrofit market.

To date, pilot projects have identified technical solutions, but the problem of how to deliver the required number of retrofitted properties at scale remains. This thesis investigates the sectors attitudes, readiness and adoption with regards to sustainable retrofit as well as how to address the need to deliver at scale in a way that is affordable, acceptable and assured in terms of performance.

There is an evident willingness amongst Registered Providers to take action and lead the housing sector as a whole but also some fundamental challenges, including restricted financial resources, budgetary constraints, split incentives, and under-developed retrofit supply chains. Addressing all of these facets is not insurmountable provided the sector fully embraces the challenge and begins to address the delivery process as a whole. The policy, process, people and technology issues interlink and, as such, require a coordinated response. Registered Providers must therefore realise a shared internal understanding of what the intended outcomes from sustainable retrofit are, identify how they relate to the overall business plan and then resource the development of new protocols and processes that help to guide the supply chain and enable high quality retrofit to be delivered at scale.

Chapter 1 – Research Focus

1.1. Context

This M.Phil seeks to bring together work undertaken on a 2 year Knowledge Transfer Partnership (KTP) project funded by the Technology Strategy Board (now InnovateUK), a UK non-departmental public body, from July 2010 through to July 2012. The Knowledge Transfer Partnership's academic lead, Dr. Will Swan of the University of Salford, provided academic support to the project whilst also providing mentor support to this thesis. The commercial sponsor of the KTP, Fusion21, is a social enterprise providing procurement solutions to the UK social housing sector.

The aim of the KTP project was to develop a commercially advantageous understanding of low carbon domestic refurbishment in the social housing sector and to develop an innovative tool to assess the technical and commercial viability of various energy, water and CO_2 saving interventions. As would be expected, the research conducted over the term of the KTP provided valuable insight and understanding of the emerging low carbon domestic refurbishment market and provided a considerable body of knowledge regarding the social housing sectors perception of and attitudes towards the agenda.

There is a considerable body of research that spells out the contribution that existing residential buildings make to national carbon dioxide emissions and how energy saving interventions can cost effectively help the country as a whole to meet its national emission reduction goals (Boardman, 2003; Shorrock et al., 2006; Lowe, 2007; Clarke et al., 2008; Lomas, 2010). There is also consensus with regards to what improvements to the existing housing stock can bring elsewhere in terms of our changing climate and the need for our homes to be more resilient to this change as well as the in-roads that need to be made in terms of reducing our overall reliance on fossil fuels whilst improving energy security and ensuring that warmth and energy supply to our homes is sustainable and affordable (Kelly, 2010; Mcilveen, 2010; Swan et al., 2010; Boardman, 2012). Irrefutably, our existing building stock is a major player in both the cause of and the solution to all three of these challenges (Kelly, 2009).

Low carbon domestic refurbishment includes upgrades to the fabric or systems of a property that may reduce energy use or generate renewable energy (Roberts, 2008; Swan et al., 2013). The primary issue however is that the supply chain for such activity is in its infancy (Lomas, 2010) and Government policy, regulation and guidance in this area have not yet sufficiently stimulated the market (Dowson et al., 2012; Killip, 2012; Mallaband et al., 2012; Booth and Choudhary, 2013). Moreover, the housing sector has yet to fully understand the expectations placed upon it and what delivery models, if any, it should be looking to develop.

The reason for this research thesis is that although the UK social housing sector may not represent the largest proportion of stock, it is deemed a good starting point from which to build on the embryonic UK low carbon refurbishment market for a number of reasons (Jenkins, 2010). The social housing sector differs markedly from other housing sectors in that it is regulated and heavily influenced by Government policy. This is exemplified by the works undertaken to meet the Decent Homes Standard from 2001 to 2010/11, which led to an average of £10,000 per home being invested in basic repair, weatherproofing and installation of modern kitchens and bathrooms and approximately 1.4 million homes in total benefitting from some kind of intervention (NAO, 2010). The sectors primary function is also that of providing affordable housing and therefore its tenants are some of the most vulnerable to energy and fuel price rises.

Given that a considerable amount of research has already focussed on specific pragmatic technical, policy and supply chain related issues, this thesis instead aims to capture and explore a real time snap shot of how the low carbon refurbishment agenda is truly perceived and is being acted upon at an operational level within the social housing sector.

The literature review presents a strong case to undertake such research. It is clear that there is a significant and urgent need to renovate the entirety of the UK's existing housing stock in light of the growing concern of climate change, national energy security and rapid growth of fuel poverty. The UK Government is also bound by law to meet national CO_2 emission reduction targets and has repeatedly stressed that the low carbon refurbishment of the existing housing stock is a top priority and that the social housing sector should be the market maker. What is now needed however is concerted action based on lessons to date.

1.2. Aim and objectives

This thesis aims to develop a coherent understanding of the current status of the social housing market with regards to the adoption and implementation of low carbon refurbishment of existing social housing stock and use this to identify areas of required innovation. This will specifically entail research in to the perception of retrofit as a challenge in the social housing sector, the strategic intent of the sector and interventions deployed to date as well as the sectors existing knowledge, capabilities and capacity to deliver retrofit at scale. This exploratory research draws upon existing literature, a large sample study of the social housing sector and active engagement with key stakeholders such as staff within social housing organisations, policy makers, energy companies and manufacturers, suppliers and installers of low carbon refurbishment technologies.

The specific objectives of the research are to answer the following questions:

- Why is low carbon refurbishment of the existing UK housing stock necessary and is the social housing sector best placed and sufficiently equipped to play a lead market making role?
- What are the organisational drivers and barriers to the take up of low carbon refurbishment in the social housing sector and is it a priority?
- What is the strategic intent in terms of the future adoption and implementation of low carbon domestic refurbishment and what technical and resident related interventions have social housing providers implemented to date and why?
- Based on the data and research, what innovation is required to improve the delivery of low carbon domestic refurbishment in the social housing sector?

Chapter 2 – Introduction

Globally our built environment is a massive consumer of resources and is responsible for some of the most serious global and local environmental changes. Around half of all non-renewable resources mankind consumes are in construction, making it one of the least sustainable and most polluting industries in the world (Brown and Bardi, 2001; Nässén et al., 2007; Hawken et al., 2010). More specifically, it is estimated that our global built environment is responsible for between 30-40% of global energy consumption, 30% of greenhouse gas emissions, 12% of all fresh water use and an estimated 40% of the total volume of solid waste generated by mankind (IEA, 2010; UNEP, 2011).

In November 2008 the UK Government passed the Climate Change Act, committing the nation as a whole to achieving an 80% reduction in carbon emissions by 2050 against 1990 levels (UK Parliament, 2008). As a result, the buildings sector has rightfully been focussed upon as a sector capable of delivering sizable savings from not only its current practices regarding new build but also in acting on reducing the CO_2 emissions associated with the existing built stock. Indeed, there are more than 27 million homes in the UK, each contributing an average 5.1 tonnes of CO_2 emissions per annum through a number of derived demand activities such as heating and hot water, which account for over 80% of average energy used in the home, as well as cooking, lighting and appliances (Palmer and Cooper, 2011).

The role of building related CO_2 emissions is however only one of three objectives of current UK energy policy and in parallel to the UK carbon reduction requirements runs national energy security and fuel poverty concerns (DTI, 2007; HM Government, 2011b; DECC, 2012b). With global energy use on the increase and the inevitable peak in availability of oil and natural gas, we are witnessing first-hand significant impacts on energy supply and costs. What we are therefore facing is a triple challenge that combines elements of climate change resilience, energy security and long-term sustainability and our existing building stock is a major player in both the cause of and the solution to all three of these challenges (Kelly, 2009).

Addressing the CO_2 emissions and threat of energy security, fuel poverty and climate change to our homes will require huge investment in a national low carbon refurbishment programme across all existing homes despite tenure. This will involve upgrading the fabric and heating and ventilation systems of our properties in a way that reduces energy use or generates renewable energy, through the use of microgeneration for example. A sizable problem however is that supply chains are under developed in this regard and so when the relationship between carbon emissions, fuel poverty and energy security is coupled with the enormity of the implementation challenge, a logical place to make a start with large-scale low carbon domestic refurbishment projects is with social housing (Smith and Swan, 2010). The agenda aligns well with the sectors remit to provide sustainable and affordable housing, thus any improvement works that help achieve this whilst also helping to mitigate fuel poverty amongst residents are, unquestionably, of high priority for all social housing providers. This is fitting given that the UK Government view, shared by informed commentators, is that the market for sustainable retrofit is emerging and specific targeted activity is required to effectively upscale the industry (Sandick and Oostra, 2010) to a point where it may be more accepted by the masses.

The social housing sector represents 17% of English housing stock, (3.8m homes) (DCLG, 2011) and offers an existing infrastructure of housing association and local authority bodies that are already active in maintaining and refurbishing homes in a professional manner that is acceptable to the occupant. As such, the social housing sector is well placed to provide a level of client led project management and supervision that does not naturally exist in the private sector - an important factor where the current supply chain and maturity of skills for sustainable retrofit do not yet exist in the UK (Jenkins, 2010). Procurement and rollout of retrofit goods and services are therefore likely be carried out more effectively and successfully (with projects approaching their designed performance), than with privately owned/rented accommodation (Walker, 2008).

Moreover, many of the early pilot projects of deep low carbon domestic refurbishment, such as the InnovateUK (formerly TSB) Retrofit for the Future programme in the UK (InnovateUK, 2009) were undertaken within the social housing sector. Even programmes where the demands for carbon emissions reduction were less stringent than the demonstration programmes, such as the Pay as You Save pilots (DECC and EST, 2011), Carbon Emissions Reduction Target (CERT) projects, Community Energy Saving Programme (CESP) projects and various European Regional Development Fund (ERDF) projects, are dominated by the social housing sector (Wetherill et al., 2012). Similarly, a survey of innovative retrofit projects in the UK identified that virtually all of them were enabled in some way by grant funding (Swan et al., 2012), although this might be driven by the fact that the public sector is more inclined to share knowledge and skewed the sample.

In 2010, the previous UK government acknowledged the key attributes and experience that the social housing sector possesses and identified the sector as having a market development role for low carbon refurbishment.

> *"We said last year that we intended that social housing would continue to show leadership in its environmental performance. There is a real opportunity to use social housing to stimulate the development of the industry needed to make the change described above."* (HM Government, 2010b)

This view that social housing would take a market development role was reiterated by the Business Innovation and Skills (BIS) Innovation and Growth Team: Low Carbon Construction Report (HM Government, 2010a), which was accepted by the incoming coalition government:

> *"…the use of the social housing stock to kick-start scale retrofit, utilising RMI investment and other funds."* (HM Government, 2010a)

It is clear that the perception of the government is that the social housing sector will be used as a catalyst to establish supply chains and business models to address the remainder of the domestic stock, 83% of which is in private hands, either through owner-occupiers (67%) or private landlords (16%). However, it is not entirely clear how the social housing sector views this Governmental perspective. The assumption appears to be that the sector will gladly take up the baton, that they recognise the challenges and that their residents' homes will be the test-bed where the desired market development will play out. Indeed, there are also contradictory signals, such as the launch of the Green Deal pay as you save funding mechanism in January 2013 which is geared to support the larger owner-occupied and private rented sectors rather than social housing providers (Guertler, 2011).

For many social housing providers, the implied responsibility presents a number of challenges: balancing the degree of improvement needed with the ability to fund the works; reconciling emission reduction with a desire to preserve architectural heritage; applying new and emerging technologies with minimal disruption to occupied homes; and ensuring that affordable warmth is available to residents without compromising affordable rents. All of which must be achieved despite limited financial resources, budgetary constraints, split incentives, and under-developed supply chains.

In light of the level of expectation combined with the degree of complexity, this thesis aims to identify and analyse the current attitudes and readiness of the social housing sector with regards to the low carbon refurbishment challenge. This is achieved through a large sample survey which addresses the current perspective of retrofit as an issue, strategic intent and activities that are currently being undertaken to improve both the energy efficiency and carbon emissions from the social housing stock. It is estimated that the responses cover some 20% of the English social housing stock. Using the arising data and insights as a basis the study will then go on to identify areas where further research is required whilst also evaluating where further innovation is required in the sector and how retrofit may be more successfully delivered at scale.

Chapter 3 - Literature Review

3.1 Setting the scene

In November 2008 the UK Government passed the Climate Change Act, committing the nation as a whole to achieving an 80% reduction in carbon emissions by 2050 against 1990 levels (UK Parliament, 2008). In order to achieve this, it has been accepted that emission reductions from some sectors, namely aviation and shipping, will be challenging and the strategy will not necessarily be to achieve an equal reduction from all sectors (HM Government, 2011b). The residential sector however, is an area that is considered very cost effective to treat in terms of attaining high levels of carbon abatement (Power, 2011).

Throughout much of the last decade considerable focus has been placed upon improving the performance of new build housing using regulatory approaches such as the Code for Sustainable Homes (DCLG, 2006b; Lowe and Oreszczyn, 2008) and the Building Regulations (Bell and Lowe, 2000a; Lowe and Oreszczyn, 2008; ODPM, 2010). However, the replacement rate of housing has repeatedly been less than 1% per annum and, although calculations vary, it is estimated that even at the highest rate of demolition and replacement approximately 75% to 87% of the buildings currently in the housing supply will still be in use in 2050 (Boardman, 2007; Power, 2008; Ravetz, 2008; Kelly, 2009). This statistic combined with the fact that the median UK dwelling was built between 1939 and 1959 (Lowe, 2007) and approximately 20% of all dwellings were built before 1918, places the energy efficiency of the UK's existing housing stock as vital component of the debate.

There are more than 27 million homes in the UK, each contributing an average 5.1 tonnes of CO_2 emissions per annum through a number of derived demand activities such as heating and hot water, which account for over 80% of average energy used in the home, as well as cooking, lighting and appliances (Palmer and Cooper, 2011). Between 1990 and 2011, this vast number of individual emitters has contributed an average of 78 million tonnes of CO_2 a year, 15% of the total UK CO_2 emissions (ONS, 2012a).

3.2 What is low carbon domestic refurbishment?

Modernisation, retrofit, renovation and refurbishment are all used interchangeably in literature (Bell and Lowe, 2000b; Hong et al., 2009; Kelly, 2009; Jenkins, 2010; Reeves et al., 2010) when discussing the upgrade of a property's physical characteristics to improve its environmental performance. In this thesis, the term low carbon domestic refurbishment is used throughout. Low carbon domestic refurbishment includes upgrades to the fabric or systems of a property that may reduce energy use or generate renewable energy, through the use of microgeneration for example. It may be undertaken for a number of reasons within the social housing sector, either to modernise and reduce carbon emissions or to improve the ability of occupants to heat their homes and live more comfortably.

Presently, the energy efficiency of the UK's housing stock varies enormously from solid walled properties with no central heating and little insulation through to highly efficient homes with their own energy generation. Unsurprisingly this variability is largely dictated by the age of the property, with post-1990 dwellings having half as many CO_2 emissions on average compared with pre-1919 homes (3.6 and 7.2 tonnes per dwelling) (DCLG, 2012a). Such disparity is largely down to the construction practices of different era's, where much of the UK's housing was built before the links between energy use and climate change were understood but also when there were very different expectations of thermal comfort (Palmer and Cooper, 2012). Prior to the 1970's oil crisis the building regulations made no reference to insulation or thermal comfort, thus presenting a large range of different property types with little or no insulation - traditional Georgian, Victorian, Edwardian properties (pre-1919, 20% of the English housing stock, approx. 4.6m units), inter-war housing such as Neo-Georgian council housing and experimental non-traditional construction as well as middle class Tudoresque semi's and even some Le Corbusier led Modern Movement style properties (1919-1939, 17%, approx. 3.9m units) and then post-war housing led in design by the Parker Morris housing standards report (Central Housing Advisory Committee, 1961) which resulted in a raft of different construction approaches and new designs including a wide variety of non-traditional methods as well as the construction of high rise flats (1945-1960, 19% of the English housing stock, approx. 4.5m units). In short, a very broad and diverse range of properties types spanning pre-1919 through to the 1960's which account for some 56% of the total housing stock and have little or no insulation. Whilst many such properties have received some form of upgrade over the years, with 91% of all English properties reported to have central heating, 79% having had double glazing installed, 66% of dwellings with cavity walls having been insulated and 52% of dwellings with at least 150mm of loft insulation (DCLG, 2012a), considerable opportunities to further improve energy efficiency and reduce associated CO_2 emissions remain. The very same

English Housing Survey itself stating that in 2012, 16.6 million dwellings (73% of the housing stock) could potentially have benefitted from at least one form of energy improvement measure (DCLG, 2012a). The challenge, however, is that with thousands of house types and varying site conditions such as construction techniques used, conservation status, access, and architectural detailing, there tends not to be a 'one size fits all' solution. This has driven the existing retrofitting market into adopting a fragmented approach, tackling the technical issues in an ad-hoc piecemeal manner without having clear intent with regards to the improvement potential of the house as a whole. What therefore tends to be advocated by leading retrofit practitioners is a 'whole house' approach to retrofit, either delivered as a single intervention or properly programmed and coordinated over a number of years in a way that aligns with the service life of key building components (Lowe, 2007; Lomas, 2010; Heaslip, 2012b; Baker et al., 2013; InnovateUK, 2014).

The big issues that begin to arise are the complexities associated with surveying and assessing the performance of homes (Baker et al., 2013), capital costs associated with the required works (Bell and Lowe, 2000b; Shorrock et al., 2006), the disruption that is likely to be caused to tenants (i.e. is decant required?) (Reeves, 2009b; Kelly, 2011; Willey, 2012), and the whole life financial, carbon and maintenance costs associated with interventions (Swan et al., 2010; Power, 2011). Identifying and adopting a retrofit strategy and successful implementation is therefore one that requires a long lead-in time, careful planning and full appreciation of both the costs and benefits involved. Whilst identifying appropriate technologies is of significant importance, well considered management of the implementation process is central to successful low carbon retrofit.

3.3 Rationale for the low carbon refurbishment of existing dwellings

Across Europe the operation of buildings is responsible for an estimated 40% of energy consumption and 36% of total CO_2 emissions, representing Europe's largest source of greenhouse gas emissions (European Commission, 2011; Eurostat, 2011). Although the picture is similar in the UK, arguably more than 50% of all UK CO_2 emissions can be attributed to energy use of buildings if energy consumed in the extraction or manufacture of the products and materials, as well as the indirect power station emissions attributable to built environment related electricity consumption is factored in (Clarke et al., 2008; Committee on Climate Change, 2008; HM Government, 2010a).

Of the contribution that buildings make to the UK's CO_2 emissions, residential emissions account for approximately 66% and commercial and public sector building emissions account for 25% and 9% respectively (Committee on Climate Change, 2008). According to the most recent data, the UK's residential sector accounted for just over 26% of the UK's total energy use (ONS, 2012c) and 15% of the UKs total CO_2 emissions in 2011 (ONS, 2012a).

These carbon and energy use statistics alone place the built environment, and residential dwellings in particular, as a highly significant challenge if the UK is going to make a meaningful contribution to combating climate change. Nevertheless, there are at least an additional seven broader factors that further strengthen the rationale for the low carbon refurbishment of existing dwellings that can be split as being directly energy related and non-energy related:

Principle energy related arguments for retrofit

3.3.1 A changing climate and the need for adaptation

The overwhelming majority of homes were designed for the climatic conditions prevalent when they were built (Roaf et al., 2005; Arup, 2008; Roberts, 2008). However these conditions are changing and the climate change projections for the UK include hotter and drier summers, wetter winters and more extreme weather events (Murphy et al., 2009; RICS, 2009; HM Government, 2012). Ten of the warmest years on record have occurred since 1990 and August 2003 saw the hottest ever maximum temperature in the UK, 38.5 1C at Faversham, Kent (Hacker, Belcher, et al., 2005; Roberts, 2008). The average duration of summer heatwaves has increased by between 4 and 16 days in all regions of the UK since 1961 and there has been a general trend of decreasing rainfall in summer and increasing rainfall in winter, with heavier winter precipitation events (Hulme et al., 2002). It is highly likely therefore that our existing building stock will be adversely affected by overheating and flooding as well as by water stress (Arup, 2008).

Given the slow rate of housing turnover discussed above, there is an urgent need to adapt existing buildings for the future climate whilst also taking in to account the need to reduce overall energy use and carbon emissions (Hacker, Holmes, et al., 2005; Roaf et al., 2005; Murphy et al., 2009; Gething, 2010). Although beyond the scope of this thesis, there are a whole host of adaptation measures that can be integrated with the carbon reduction agenda for existing homes, spanning methods of reducing the likelihood of floods and flood water ingress, means of utilising thermal mass and passive cooling techniques to reduce overheating and water efficient technologies that can be rolled out in high water stress areas (Arup, 2008; Roberts, 2008).

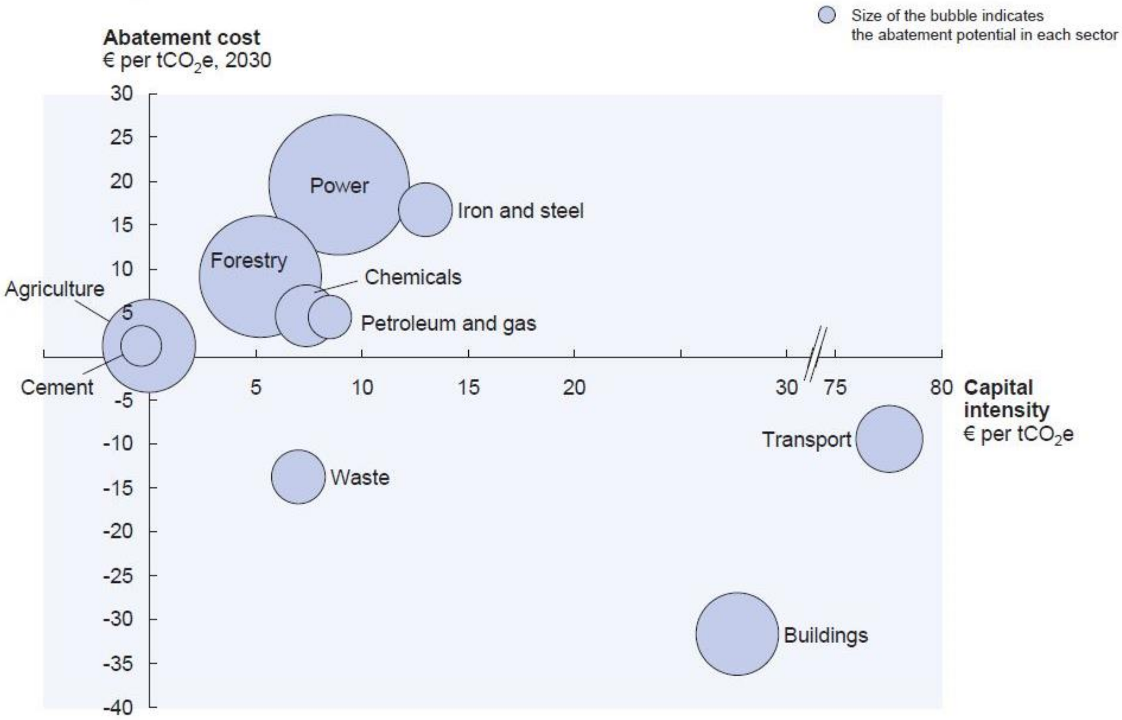
3.3.2 Low cost carbon abatement

Energy savings are among the fastest, highest impacting and most cost-effective ways of reducing greenhouse gas emissions. Whilst this applies to all sectors, low cost energy efficiency measures in buildings have long been regarded as the 'low hanging fruit' in delivering a clean energy economy (Kim et al., 2012).

Perhaps the clearest illustration of this is in the work undertaken by McKinsey and the major international Stockholm-based utilities company, Vattenfall (McKinsey, 2009). Their global greenhouse gas (GHG) abatement cost curves very clearly demonstrate that the overall economic cost of achieving reductions through energy efficiency measures in buildings is in fact negative. For example, the energy savings resulting from retrofit insulation measures have demonstrable payback times within the lifetime of the products, even without any economic subsidy (Power, 2011). It is this argument that leads to building industry experts suggesting that carbon emissions from existing buildings must be reduced to virtually nil by 2050 (Wetherell and Hawkes, 2011; Boardman, 2012), so as to balance out emissions from other more intractable sectors, such as heavy industry, agriculture and power generation.

Whilst a long term view of cost versus level of abatement is a useful metric, it is however also important to acknowledge the upfront capital and implementation challenges. For example, in transport and buildings, upfront financing is a sizeable challenge but the costs are very low once investments have been made (Hermelink and Müller, 2010; Guertler et al., 2013). In contrast, as shown in Figure 1, in the majority of industrial sectors, average abatement costs are relatively high but up front capital costs are lower and in forestry and agriculture, both abatement costs and required investments are relatively low (McKinsey, 2009).

Figure 1 - McKinsey Global Capital intensity and abatement cost analysis. Source: McKinsey, 2009.



These studies, and the Mckinsey work in particular, shows us quite clearly that no other sector comes to close to demonstrating the same level of cost effective abatement potential as available from the low carbon refurbishment of buildings. As to be discussed later however, effective implementation is no trivial task (Dowson et al., 2012).

3.3.3 Energy Security

The main source of primary energy is fossil fuels; a finite resource that will eventually peak. The IEA present two scenarios in the World Energy Outlook 2010, the first is the 'New Policies Scenario', where existing policy commitments to reduce greenhouse gas emissions are taken into account. The other is the '450 Scenario', where energy use is reduced to coincide with the capping of greenhouse gas emissions at 450 parts per million of CO_2 equivalent (ppm CO_2-eq), which is the recommended goal for keeping global temperature increases to 2^{o}C. In the New Policies Scenario global production will peak by approximately 2035 following a continuous increase in demand, cost and supply disruptions. Conversely, in the 450 Scenario global production will peak in 2020. This will be due to weaker demand rather than diminishing reserves, resulting in lower costs and less risks. However, with increasing demand from developing countries such as India and China this best case scenario is unlikely to happen (IEA, 2010). In the UK, oil and natural gas has already peaked (Stern, 2004; ONS, 2012c). Since 2004 the UK has been a net importer of these primary fuels, resulting in increasing reliance on less stable countries for supplies, which could have an impact on both energy security and costs (DTI, 2007; Bolton, 2010; ONS, 2012c).

As stated above, the UK residential sector's energy demand profile accounted for just over 26% of the UKs total energy use in 2011. Therefore, reducing energy demand from housing through reduced waste and increased efficiencies whilst integrating renewable microgeneration capacity will help significantly toward minimising the UKs overall dependence on finite energy imports as well as reducing the need for some of the UKs proposed new nuclear and large scale renewable infrastructure (Watson et al., 2006; Hinnells et al., 2007; Allen et al., 2008; Swan et al., 2010).

Principle non-energy related arguments for retrofit

3.3.4 Policy and Regulation

The main legislative instrument at EU level to improve the energy use of buildings is the EU Energy Performance of Buildings Directive (2002/91/EC) and the Energy Efficiency Directive (2012/27/EU). There are also various labelling, products and renewable energy related directives; all of which are key to achieving EU climate and energy objectives; namely the 2020 goals of achieving a 20% reduction in greenhouse gas emissions, a 20% net energy saving and 20% total energy consumption from renewable energy.

Although these EU level targets have a significant bearing on what the UK, as a member state, must do with its buildings and energy infrastructure the UK has perhaps more significantly also set its own legally binding targets. Under the Climate Change Act 2008, the UK as a whole is committed to achieving an 80% reduction in carbon emissions by 2050 against 1990 levels (UK Parliament, 2008). Moreover, the UK Climate Change Committee has introduced five-year 'carbon budgets' to monitor progress and keep developments on track. The first four of these budgets have been already set in law and are detailed in Table 1 overleaf. These include a 34% reduction from 1990 levels by 2022 and a 50% reduction on 1990 levels by 2027 (HM Government, 2011b; Committee on Climate Change, 2013c).

Table 1 - UK's legislated carbon budgets ($MtCO_2e$). Source: HM Government, 2011b; Committee on Climate Change, 2013c

	First carbon budget (2008-12)	**Second carbon budget (2013-17)**	**Third carbon budget (2018-22)**	**Fourth carbon budget (2023-27)**
Legislated budgets ($MtCO_2e$)	**3,018**	**2,782**	**2,544**	**1,950**
of which traded	1,233	1,078	985	690
of which non-traded	1,785	1,704	1,559	1,260
Average annual percentage reduction from 1990	**23%**	**29%**	**35%**	**50%**

As carbon emissions arising from energy use in existing housing represents nearly 27% of the UK's total emissions (Palmer and Cooper, 2012), these legislated goals are of huge relevance to the housing sector. Moreover, it has been accepted by Government that sufficient emission reductions from some sectors, namely heavy industry and power generation, will be challenging and the strategy will not necessarily be to achieve an equal reduction from all sectors (DECC, 2012b). Some sectors, such as housing, will therefore need to deliver more than others to make up for the sectors that are deemed to be challenging.

To help deliver upon the carbon budgets, there are a number of legislative instruments, policies and regulations which target existing homes. For example, the Energy Act 2011 paves the way for some of the key elements of the current coalition's programme for Government (DECC, 2011c). The Act seeks to tackle the barriers to investment in energy efficiency through the provision of the Green Deal and Energy Company Obligation financing frameworks and; provides powers such as an ability to regulate the energy efficiency of private rented sector housing stock and manage the introduction of Smart Meters through to 2019. The Act also improves access to Energy Performance Certificate data in a bid to better enable investment in the sector. Underpinning the Energy Act 2011 include polices such as the DECC Carbon Plan (HM Government, 2011b), the DECC The Energy Efficiency

Strategy (DECC, 2012b), Future of Heating (DECC, 2013) and the Microgeneration Strategy (DECC, 2011e).

At an implementation level the three main regulatory tools concerning the energy consumption of existing homes include; the National Planning Policy Framework (DCLG, 2012b), Part L1B of the Building Regulations (conservation of Fuel and Power) and Energy Performance Certificates derived from the reduced data Standard Assessment Procedure (RdSAP). The latter perhaps being the most widely recognised seeing as the requirement for Energy Performance Certificates in the UK stems from the European Performance of Buildings Directive (EPBD) (Directive, 2002, 2010), requiring all member states to introduce energy certification scheme for new and existing buildings so as to raise awareness of the performance of buildings and to illustrate opportunities for improvement. Unlike planning policy or the building regulations, EPCs are not used to stipulate certain actions but instead have provided the overall housing sector and social housing providers in particular, with a new insight and means of communicating building stock energy efficiency. Notable successes being that the UK is reported to have the second largest proportion of domestic EPCs in Europe (BPIE, 2011) and the social housing regulator (HCA) has, since the introduction of EPCs in 2007, required Registered Providers to report on their housing stock average rating as part of their statutory annual reporting. Whilst this study does not intend to dwell too much on the effectiveness of the policies and regulations that are present, the specific impact that they have on the social housing sector are discussed at length in a separate chapter. Nevertheless, on surveying the literature it is clear that despite the prevalence of all such policy and regulation, considerable barriers remain (Lowe and Oreszczyn, 2008; Stieß, 2008; Dowson et al., 2012) and further awareness raising and incentives for uptake of the full range of cost-effective measures in both residential and non-residential buildings is still needed (Committee on Climate Change, 2013a).

3.3.5 Economics

The notion of refurbishing existing buildings is by no means new and the domestic repair and maintenance market encompasses some 150,000 businesses and accounts for £27 billion spend per annum (TNS-BMRB, 2011; ONS, 2012d). This existing market, combined with the speculated need to refurbish around 23 million homes to better energy efficiency standards between now and 2050, equates to a programme that could be worth in the region of £280 billion to the UK economy (NRC, 2012).

In a recent evaluation of the economic stimulus that investing in energy efficiency could bring (Billington et al., 2012), it is found that directly investing in energy efficiency measures in fuel poor households has a similar or more positive macro-economic impact than an equivalent stimulus package either through increases in government current spending (e.g. NHS, education) or government capital spending (e.g. roads, building hospitals), or reductions in VAT or fuel duty. The report shows that whilst all three of these spending options causes an increase in economic output, investment in energy efficiency has the added and persisting benefit of also reducing natural gas imports. Moreover, if households spend less on energy imports, they are able to spend more on other products and services, which are in part supplied domestically.

Additionally, the Energy Saving Trust's Home Economics report (EST, 2011) estimates that more than 100,000 jobs could be created to insulate 5.7 million empty cavity walls and 12.8 million lofts that need more insulation; with boiler replacement, the total number of jobs created rises to 140,500. That includes not only installer jobs, but also manufacturing and assembly, transport and administration. For full-scale refurbishments (including solid-wall insulation, heating controls, draught-proofing, triple-glazing and renewable) a total of 4.7 million jobs could be supported.

This modelling demonstrates that whilst even the most basic level of shallow energy efficiency works brings economic benefit, demonstrable macro-economic benefits may be realised if large scale implementation complexities, as identified in market transformation (Dowson et al., 2012; Killip, 2012) or socio-technical innovation models (Geels, 2005; Swan et al., 2012), can be overcome.

3.3.6 Fuel poverty

Poor housing energy efficiency, increasing energy costs and low household income are all contributory factors to rising levels of fuel poverty (Healy, 2004; Palmer et al., 2005; Boardman, 2009). Statistically fuel poverty used to be defined as where a household needs to spend 10% of its income to heat their home to 21^{o}C in the main living areas and 18^{o}C in other parts of the home (Boardman, 1991; ONS, 2012b). However, a new more complex definition has now been adopted by Government based on the Hills review (2012) which defines fuel poverty on a 'low income/high costs' basis. This instead considers a household to be in fuel poverty if the household have fuel costs that are above the national average (national median level) and that by spending that amount the household would be left with a residual income below the official poverty line. Accompanying this definition is also a low income/high cost indicator, which aims to illustrate how far into fuel poverty households are, not simply if they are in poverty or not. This has come under considerable criticism, not least for its complexity, its accuracy in reflecting household size and composition and also in how it has changed the reporting landscape (Boardman, 2009; Moore, 2012). For example, under the old definition fuel poverty increased in the UK from a low of 2 million households in 2003 to approximately 4.75 million households or 18.6% of the UK population in 2010 (ONS, 2012b) yet under the new definition, 2.39 million households were deemed fuel poor in 2011, falling further to 2.28 million a 2012, approximately 10.4% of all English households (DECC, 2014a).

Such a change to the definition is particularly contentious given that in the UK, the strategy for both England and Northern Ireland has been to end fuel poverty for vulnerable households by 2010 and eradicate fuel poverty completely by 2016 (Defra, 2004; DSDNI, 2004). In Wales the strategic ambition has been to end fuel poverty amongst the vulnerable by 2010 and to completely eradicate fuel poverty from all households by 2018 (WAG, 2010). Unfortunately, vulnerable household targets have not been met through the provision of grants, subsidies and basic energy efficiency improvements and the issue continues to grow regardless of the definition used. Therefore, as with carbon emission reduction targets, meeting future targets to eradicate fuel poverty will fundamentally require more significant reductions in domestic energy use to be made (House of Commons, 2008; Boardman, 2009). This must primarily be achieved through improving the building fabric of UK homes as heating alone accounts for over 60% of average energy used in the home (DECC, 2012a; Palmer and Cooper, 2012) and also significantly improves comfort and recues draughts. This link between building fabric, heating demand and fuel poverty is illustrated well in the fact that older and detached dwellings have a statistically higher number of households who are fuel poor (Healy, 2004; Howarth, 2010; DCLG, 2011).

3.3.7 *Attainable rate of replacement*

There are approximately 26.6 million dwellings in the UK (ONS, 2010) but fewer than 180,000 homes are built each year, and far fewer homes are demolished (Palmer and Cooper, 2012). This in turn leads informed commentators to quote that it's likely in the region of 85% of the UKs existing housing stock will still be standing in 2050, even if the UK returns to its previous highest demolition rate of 50,000 a year (Ravetz, 2008; Kelly, 2009; Power, 2010). Even if a more ambitious building rate of 200,000+ dwellings per annum were to be achieved by greenfield building and the cutting of red tape, this would only add in the region of nine million homes by 2050, meaning that 75% of the 2050 stock would still comprise what has already been built today (Power, 2010).

It is however not just the numbers that do not add up. Cheap house building on a large scale over accelerated time periods tends to produce 'lowest common denominator estates' outside existing communities which can exclude considerations of the social and economic roles of housing such as the links between housing, family, facilities, schools, transport and jobs (Communities and Local Government Committee, 2008; Power, 2010). Similarly, from a demolition perspective, whilst removing the worst properties in the worst areas may seem an obvious choice, it is slow, costly and unpopular (Power, 2008). With demolition comes political challenge, social damage, health impacts of forced re-homing, waste resources and creation of additional embodied CO_2 in the construction of replacement homes (Power and Mumford, 2003; Boardman et al., 2005; Power, 2010).

3.4 Technical retrofit options

The opportunities for reducing the energy consumption and CO_2 emissions from dwellings once they are constructed are varied. These include improvements in the building fabric and services, greater energy efficiency, and more sustainable power generation. Informing and educating the occupants also plays an important role in reducing emissions successfully and is discussed in the next section.

Whilst the approach to implementing the technical measures is largely dictated by the carbon reduction target, the house type, the region and exposure, the extent of the necessary works and disruption, the construction of the property, the historic value and the existing environmental and thermal performance, in all cases a clear hierarchy of priorities can be identified to successfully achieve emission reductions.

Firstly a full understanding of how the existing dwelling 'works' is key to a successful energy efficient refurbishment. Understanding the structural integrity of the property and how it has been constructed, how well it has stood the test of time and how it presently uses energy are the foundations to designing an effective strategy for its improvement. Such understanding must be born from a thorough survey of the dwelling in question – one that takes into account structural integrity and overall condition as well as gaining an appreciation for built characteristics and energy related matters such as existing levels of insulation, means of ventilation, property orientation and exposure, occupancy and any insights into existing performance in use. More specifically, an understanding of the following is typically needed in order to determine a robust retrofit strategy (Murphy and Patience, 2010):

- *Thermal Performance* - Understanding and quantifying energy usage, heat loss and air permeability is central in identifying performance targets and eventually measuring the degree of success realised through refurbishment. Assessing such factors requires thermal modelling, air tightness testing, thermal imaging, a review of degree day corrected meter readings and an appreciation of occupancy profiles and behaviours.

- *Damp* – The way the property deals with rising damp and water penetration will often dictate the way in which building fabric improvements are made – a dwelling may rely on an absorption and evaporation cycle where the walls become wet and then dry out, or it may be a more modern construction that forms a barrier against moisture through using impermeable materials such as damp proofing layers.

- *Defects* – a majority of stock is likely to have undergone alterations and works that have addressed particular defects e.g. damp, draughts, leaks etc. It is important to identify and understand these defects as they can be a useful guide to how the building has performed in the past and will inform the design strategy to address remedial work of the particular issues that are unique to the house as part of the refurbishment process.

- *Exposure* – The building fabric may show signs of wear if in a particularly exposed location and subject to wind and driving rain. Such exposures may be capitalised upon in the form of natural ventilation or renewables as appropriate.

- *Planning* - The refurbishment is likely to alter the appearance of the building to some degree. It is important to establish some ground rules in collaboration with Local Authority planners (and conservation officers if appropriate). The alterations that will be permitted by Planning will likely influence the degree of performance that can ultimately be achieved through the refurbishment.

With comprehensive survey data not only are you able to identify optimal environmental retrofit design strategies; home owners and housing stock managers are able to make significant time, cost and carbon savings by using existing 'trigger points' to require improvements in energy efficiency. For example when other routine/maintenance/upgrade building work is required, or when the dwellings are void or change hands (EST, 2010b; Wilson et al., 2013). This approach also helps to remove some of the disruption and hassle associated with the works. Worryingly, despite its importance, this stage of survey and assessment has become the first to suffer in the pursuit of time and resource efficiency and the sector has become almost accepting of the Energy Performance Certificate and/or Green Deal Advice Report and its somewhat basic means of inferring most likely performance (Baker et al., 2013). A good reflection of the risks this presents can be seen in the results of a recent mystery shopper exercise undertaken by the Department for Energy and Climate Change where there was a lack of consistency in the data, results and advice generated by different Green Deal Assessors for the same property with the range of EPC ratings spanning at least two EPC bands for almost two thirds of the dwellings analysed. This same research also found many differences in the values recorded for key input variables at the same property, such as total floor area, building fabric and technologies installed (DECC, 2014c). A clear disconnect between what is required and the quality of what is presently happening on the ground.

With an understanding of the stock the next step should be to begin to consider the possible environmental efficiency options. The overall guiding principle in design for energy efficient refurbishment is to first conserve energy before having to generate it. A diagram for representing the cost versus the environmental (CO_2 emissions reduction) benefits of the energy hierarchy is displayed in Figure 2 below:

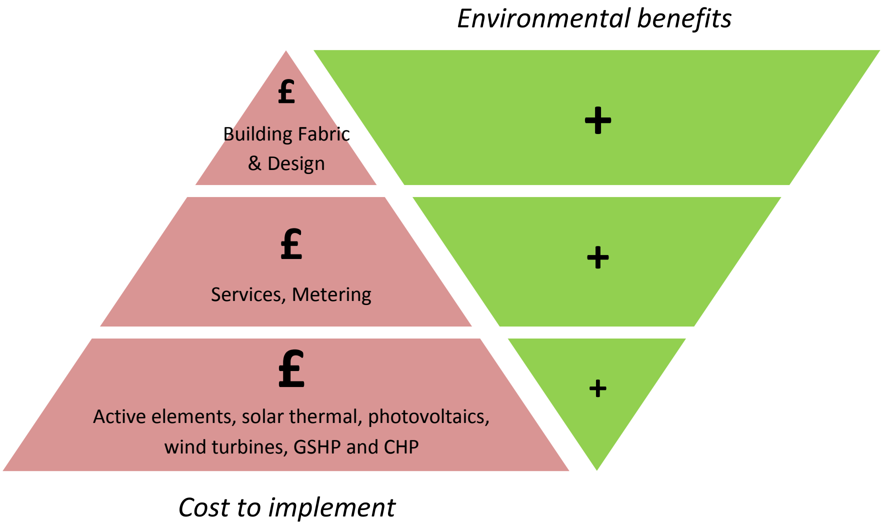


Figure 2 - The Energy Hierarchy, often referred to as the 'fabric first' approach. Source: Author interpretation of the energy hierarchy.

The main use for energy in the domestic sector is for space heating. This accounts for approximately 56% of domestic energy consumption (Xing et al., 2011), with the remainder being used for hot water, lighting, appliances and cooking. The first step therefore is to minimise heat loss through the building fabric (Roberts 2008b; Simpson and Banfill 2012). This is achieved by insulating the floors, walls and roof to the highest possible standard, installing thermal efficient windows and external doors and increasing the overall air tightness of the dwelling (InnovateUK, 2014). It is essential however that in carrying out such works a suitable and adequate ventilation strategy is also put in place and that moisture control measures are considered. Passive design measures are considered at this stage to maximise natural day lighting and natural cross and stack ventilation where at all possible (Holmes and Hacker, 2007). For example well considered placement of passive stack vents, operable windows, doors and trickle vents can provide a means of controllable natural ventilation whilst altering or adding glazing can affect how a property utilises solar heat gains as well as natural lighting. Well considered fabric improvements and passive design measures can offer significant whole life environmental performance benefits. Such measures can increase day lighting gains, reduce the buildings rate of heat transmittance and moderate internal ambient temperature fluctuations. This reduces load requirements while elevating sunlight and daylight levels internally.

An alternative but more costly approach to providing ventilation is to adopt a complete air tightness strategy and use mechanical ventilation and heat recovery (MVHR). This is a mechanical driven means of providing whole-house supply and extract ventilation that relies upon very good building fabric airtightness; without which the system would run inefficiently, drawing outside air through fabric infiltration paths. Studies to date suggest that in order to achieve the appropriate energy balance, the air permeability of the building envelope must be less than 3 m3/m2h@ 50Pa – a standard that is difficult to achieve in existing dwellings without causing significant disruption to an inhabiting resident (CPA, 2014). The other recognised draw backs of MVHR systems include challenges associated with routing of supply and extract ducts and the space that they consume (particularly in smaller properties) and also a lack of supply chain understanding with regards to commissioning and maintaining the systems as well as a lack of user understanding regarding optimal settings, control and maintenance (Banfill et al. 2011; InnovateUK 2013, 2014; ZCH 2014).

Continuing down through the hierarchy; with heat loss through the fabric minimised and passive gains maximised where possible, an efficient heating system that is sized correctly to match the anticipated space heating demands should be installed. 87% of existing properties are already fitted with gas wet central heating, 40% of which are instantaneous combination types, or ‘combi’s’, providing heating and ‘instant’ hot water from the same boiler (without a hot water storage cylinder) (DCLG, 2012a). It is therefore most common for heating system upgrades to involve renewal of existing gas boiler systems since they have relatively low carbon dioxide emissions and are relatively cheap to run. The key both in sizing the boiler to meet the heat load of the dwelling (which will have changed following installation of insulation) and also installing adequate means of control in the form of programmers, room thermostats and thermostatic radiator valves (TRVs). In addition, it is often advantageous to split the dwelling into more than one control zone so that different areas can be heated to different temperatures at different times of day (CPA, 2014). Where a gas main is unavailable or if there is ambition to reduce carbon dioxide emissions further, alternative space heating and hot water systems can include electricity driven air source and ground source heat pumps which use refrigeration technology to provide heat from a condensing unit taking heat energy from the outside air or the ground yet require well considered installation (EST, 2010a; Kelly and Cockroft, 2011). Other options include biomass heating which typically involves burning wood logs or pellets in stoves of boilers but the long term sustainability of this as a mass market solution is open to question, with replenishment trees and crops, transportation emissions and logistics all being challenging (Gustavsson and Börjesson, 1995; Nussbaumer, 2003; Verma et al., 2009). Linking properties in to larger heat networks in the form of district or communal heating is another option. Also within the building servicing tier of the hierarchy is the consideration of low energy appliances, low energy lighting.

After energy consumption and use has been minimised, dedicated renewable/low carbon electrical power systems may be considered. Renewable systems at a domestic or community scale can offer a significant contribution in both reducing the dependence on the grid and to the proportion of electricity used in the home. The choice of a reliable domestic-scale system is currently realistically limited, particularly in urban areas, to photovoltaic (PV) panels and solar hot water. Domestic wind generation has received significant inadvisable marketing to adopters living in urban areas where conditions are largely unfavourable. Small-scale generation in rural areas is still, given the correct conditions, very feasible (Drew et al., 2013). Domestic scale combined heat and power systems generating electricity as a by-product of a heat generation process (typically sterling engines but fuel cell based systems also being developed) are another option but they require large heating loads for long periods of the year to be most effective i.e. larger dwellings or multi-occupancy buildings (CPA, 2014). Generally however, specifying domestic renewable generators of most kinds involves relatively large capital costs despite Government incentives such as the Feed in Tariff and Renewable Heat Incentive which help subsidise the cost of renewable electricity and low carbon heat generation technologies. Therefore it is important to ensure the overall budget is directed primarily towards more efficient and effective energy reduction before considering renewable electricity systems.

Far more can be said about all retrofit technology options, their benefits and drawbacks and issues encountered with regards to supply chain and use (see appendix 2) but the crux of it is that there are a lot of options, all highly dependent on context and the way in which they are specified and implemented. This study will later seek to draw out what technologies the social housing sector has adopted on what grounds and how effective they deem them to be.

3.5 The role of occupants in retrofit

Regardless of the technologies deployed as part of a low carbon retrofit, the success in reducing CO2 emissions ultimately rests on its adoption and the energy consuming behaviours of the householders (J. Love 2008; Mcadie and Brown 2011). Occupants do not always behave efficiently and interact with the technologies in the way that designers of the technology expect (Stevenson and Leaman, 2010), nor is energy conservation behaviour yet the norm (Yohanis, 2012).

There are three elements to this that are pertinent to this study. The first is the existing energy consumption trends and what this may mean for the delivery of low carbon retrofit. Domestic space heating energy use has increased by two-fifths since 1970 (Palmer and Cooper, 2011) and domestic electricity use has increased by around 34% since 1990 (Phillips and Rowley, 2011). Although steps have been taken to address these issues, the increased use of energy-intensive appliances such as televisions, computers and games consoles etc.), the rise in single-occupancy households, increases in disposable income, and developments within our social lives such as increasing mobility of different household members, home-working and '24/7' living have had significant increases on energy consumption, despite progress on efficiency elsewhere (Lilley et al., 2010; Mcadie and Brown, 2011). Although generally domestic energy consumption has started to follow a downward trajectory in more recent years there are very valid concerns that regardless of how far technical innovation takes us, people will offset this is greater consumption elsewhere – be it in the home or in their wider lives in the form of more travel, more consumables etc. This phenomenon is known as the Jevons Paradox rebound effect. Vale et al (2010) have observed that whilst energy efficiency improvements do not routinely lead to increases in energy consumption, economy-wide rebound effects will be at least 10% and often higher. In no circumstances are they likely to be zero. This suggests that focussing too much on energy efficiency as opposed to energy consumption can lead to a reduction in actual consumption being overlooked (Diamond, 2011; Chahal et al., 2012).

The second facet concerns the matter of engaging with householders or tenants on the subject of energy demand reduction, gaining their buy-in, trust and a willingness to act and then transposing this to on the ground action. A socio-technical approach is needed (Hinton, 2010) and for technologies to be even adopted the right messages, support mechanisms and supply chains are needed. In the social housing sector, residents must be made aware of the benefits early on in a retrofit programme, engaged fully in decision making and given chance to fully understand the implications of the upgrades and the upgrade process. Not doing so can make it extremely difficult to even gain access and to physically install upgrades let alone start to make in-roads in to altering energy use behaviours. Take the delivery of the Decent Homes Standard, where even the prospect of simply bringing a property up to a recognised standard of decency through the provision of measures such as new kitchens, bathrooms and heating systems (DCLG, 2006a) bore the issue of refusals and inability to gain access. According to the sectors statistical data return to the regulator, there were 54,813 properties that did not meet the Decent Homes Standard in 2011, with 31,487 (57 per cent) reportedly due to tenant refusal (HCA, 2013b). These numbers excluded Local Authority owned stock, where an additional 217,000 units were reported as non-decent however the proportion caused by tenant refusals is not known. Whilst the reasons for refusals can be complex and often linked to a residents specific personal circumstance, retrofit technologies may be considered just as difficult to deploy at scale, if not more so given that many interventions are equally as disruptive as the fitting of a new kitchen or bathroom (Egbu, 1997; Bell and Lowe, 2000b; Dowson et al., 2012; Sunikka-Blank et al., 2012; CPA, 2014) but also often less appealing from an aesthetic and functionality perspective.

The third facet is one of technology awareness and usability. Not even the most advanced and efficient building fabric and technologies will perform to their optimum if unaware occupants undermine their intended use (Love, 2008; Galvin, 2014). With the technologies installed and occupant aware of their role, efforts can be completely undone through poor commissioning, hand-over, follow-up support or indeed product design (InnovateUK, 2013, 2014). This issue can commonly be seen in the effectiveness of building services and their control systems where occupants are either left dissatisfied with a system that doesn’t work as intended due to inappropriate specification and/or poor commissioning or are left unaware of how best to operate the technologies for optimal performance or simply struggle to learn complex controls and programmers. All such matters can only be overcome through close engagement with the end users from the very early stages of a project so as to understand their specific lifestyles, energy use behaviour patterns and needs and requirements.

3.6 Low carbon domestic refurbishment in the UK social housing sector

3.6.1 Social housing sector overview

The UK housing stock is made up of approximately 27.3 million homes (DCLG, 2011; Welsh Assembly Government, 2012; Northern Ireland Housing Executive, 2013; Scottish Government, 2013) as shown in Table 2. Across the UK, the majority of dwellings (22.4 million, 82%) are privately owned, with 17.8 million (65% of the total) owner occupied and 4.6 million (17% of the total) private rented. The remaining 4.6 million dwellings (18% of the stock) makes up the social housing sector, with approximately 2.5 million owned by housing associations and 2.4 million owned by local authorities. Social housing is defined as, housing that is affordable, provided on a needs driven basis where housing provision is not met by the market and includes households renting from Local Authority, including Arm's Length Management Organisations (ALMOs) and Housing Action Trusts; Housing Associations, Local Housing Companies, co-operatives and charitable trusts (DCLG, 2011). The umbrella term for these organisations registered to provide and manage social housing is Registered Providers. This term was first introduced by the Housing and Regeneration Act 2008 which allowed for-profit companies to have a stake in social housing for the first time (HM Government, 2008). This in turn led to the scrapping the concept of a 'registered social landlord', as used previously under the Housing and Regeneration Act 1996, and replacing it with 'Registered Providers'.

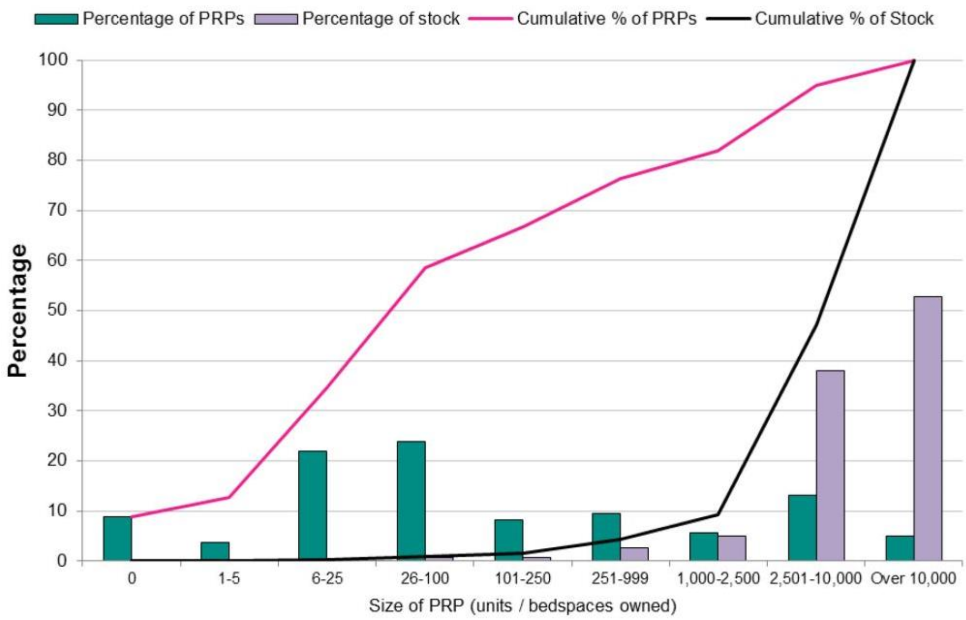
Table 2 - UK all tenures and breakdown of stock by country (millions). Source: DCLG, 2011; Welsh Assembly Government, 2012; Northern Ireland Housing Executive, 2013; Scottish Government, 2013

	England	**Scotland**	**Wales**	**Northern Ireland**	**UK**
All tenures stock (millions)	**22.8 (83%)**	**2.5 (9%)**	**1.4 (5%)**	**0.76 (3%)**	**27.46**
Owner occupied (millions)	14.8 (83%)	1.5 (8%)	1.0 (6%)	0.5 (3%)	17.8
Privately rented (millions)	4 (87%)	0.3 (7%)	0.2 (4%)	0.1 (2%)	4.6
Social stock (millions)	**4.0 (82%)**	**0.6 (12%)**	**0.22 (4%)**	**0.12 (2%)**	**4.9**
of which owned by housing associations	2.1 (84%)	0.27 (11%)	0.13 (5%)	n/a	2.5
of which owned by local authorities	1.9 (79%)	0.32 (13%)	0.09 (4%)	0.12 (5%)	2.4

The Homes and Communities Agency is responsible for registering and regulating all providers of social housing in the UK. They maintain a Statutory Register of Providers of Social Housing, which lists private (both not for profit and for profit) as well as local authority providers. The register fluctuates monthly with a handful of new registrations and de-registrations but the most recent update of the register, dated February 2015, lists a total of 1,798 registered providers in the UK made up of 1,573 (87%) non-profit registered providers, 195 (11%) local authorities and 30 (2%) profit making registered providers (HCA, 2015b).

The HCA also publishes the Statistical Data Return (SDR), an annual online survey completed by all English Private Registered Providers of social housing (but not local authorities who own and manage social housing stock because economic standards, including the Governance and Financial Viability standard, do not apply to LA providers) (HCA, 2013b). The most recent return shows registered providers in England reported a total of 2,753,701 managed units/bedspaces (including management of properties owned by themselves or other Registered Providers). In terms of size and spread, the majority of Registered Providers are small, owning under 1000 units/bedspaces, but there are a small number of very large Registered Providers who own the majority of the social housing stock. This is illustrated in Figure 3 which shows that 4.2% of the social housing stock is owned by 91% of Registered Providers, whereas Registered Providers with over 10,000 units represent just 4.9% of the Registered Provider population but own 52.8% of total stock within the sector.

Figure 3 - Percentage of social housing stock owned vs. Registered Provider size. Source: HCA, 2013b



In terms of geographical spread of the stock Figure 4, extracted from the 2012/13 statistal data return, shows the social housing owned by private registered providers, social housing stock owned by local authorities as well the spread of private sector stock (private rented and owner occupied combined). The English region with the highest volume of Social Housing stock is the North West (19.6% of total), with East Midlands having the least (5.6%).

Figure 4 - English housing stock by region. Source: HCA, 2013b

Additional detailed information on the social housing sector in the rest of the UK is available from the respective devolved administrations. However, due to differences in collecting period, methodology and terminology, comparisons beyond that of just total stock numbers is challenging. For example, there are no statistics concerning the size of Registered Providers in Northern Ireland, Scotland or Wales housing statics. Despite this shortcoming in the data, as illustrated in table 2, 82% of the total UK social housing stock is in England (12% Scotland, 4% Wales and 2% NI) thus making many of the trends evident in the English data reasonably representative.

3.6.2 Low carbon domestic refurbishment of the social housing stock

Whilst the UK social housing sector may not represent the largest proportion of stock, it is deemed a good starting point from which to build on the embryonic UK low carbon refurbishment market for a number of reasons.

The social housing sector differs markedly from other housing sectors in that it is regulated and heavily influenced by Government policy. This is exemplified by the works undertaken to meet the Decent Homes Standard from 2001 to 2010/11, which led to an average of £10,000 per home being invested in basic repair, weatherproofing and installation of modern kitchens and bathrooms and some 1.4 million homes in total benefitting from some kind of intervention (NAO, 2010). More specifically; the Decent Homes Programme included a range of fabric and heating improvements that improved the energy performance of the stock (Power, 2008; Reeves, 2009a) which, according to DCLG estimates, led to an 8% reduction in social housing sector emissions from 2006 levels and a 36% reduction in the number of social sector homes failing on the thermal comfort criterion (DCLG, 2010b).

Robust evidence of the progress made by the Decent Homes programme is perhaps best illustrated in the English Housing survey which reports on stock energy efficiency ratings determined by the Government's Standard Assessment Procedure (SAP). The SAP methodology is used to measure energy efficiency on a like-for-like comparable basis on a scale from 1-100, with a higher score indicating higher energy efficiency (Roberts, 2008; Guertler and Preston, 2009). The most recent English Housing Survey (DCLG, 2011) identifies the average SAP rating for the housing stock as 56.7 in all tenures, broken down as an average rating of 55.4 in the private sector and 62.9 in the social housing stock, indicating a marginally better performance. In a similar vein, the 2011 survey highlights that local authority (3%) and housing association (2%) dwellings had the lowest percentage of dwellings in the least efficient Energy Efficiency Rating (EER) Bands F and G, compared to 8% of owner occupied and 11% of private rented dwellings . This performance is illustrated in Figure 5.

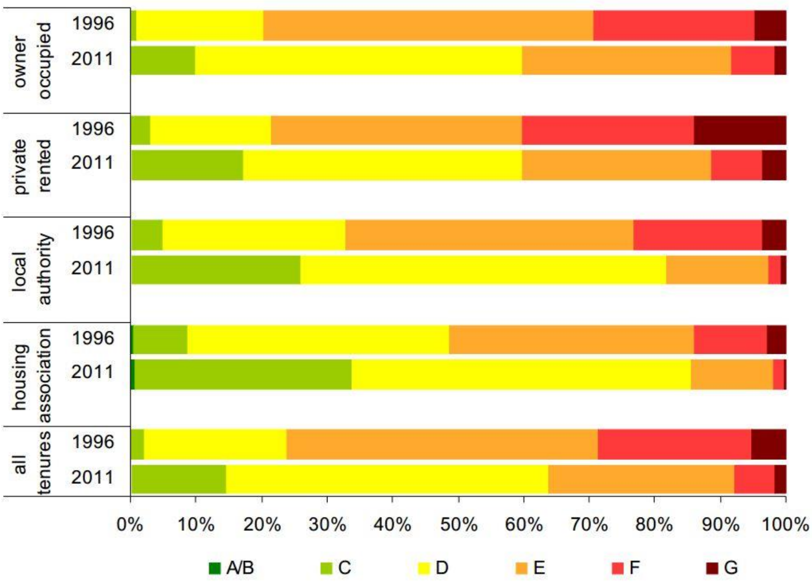


Figure 5 - EER Bands, 1996 and 2010, performance by tenure. Source: DCLG, 2011

Other programmes that have driven progress toward improving the energy efficiency of the stock in the sector include the Carbon Emissions Reduction Tariff (CERT) and the Communities Energy Saving Programme (CESP); both of which were UK Government programmes delivered by energy companies. CERT was a programme focused on the reduction of carbon emissions deploying measures such as loft and cavity wall insulation (Jenkins, 2010). It had a requirement to address vulnerable households; older people, families with children under five, and those on some types of benefit (Druckman and Jackson, 2008), many of whom live in social housing. CESP addressed community-wide projects, taking a whole-house approach to sustainable retrofit (Reeves, 2009a) in areas of deprivation. The Energy Company Obligation (ECO) replaced the CERT and CESP programmes in 2012/2013 (Department for Energy Climate Change (DECC, 2011d). ECO instead has three main components; affordable warmth and carbon saving, which replicate the CERT elements, and the Carbon Saving Communities Obligation (DCLG, 2011), replacing the CESP area-based approach. Warm Front, which ended in 2013, was a programme targeted at fuel poverty and health (Gilbertson et al., 2006; Critchley et al., 2007). This scheme delivered over 2.3 million upgrades over its course (DECC, 2011a) but was also replaced by ECO. Running in parallel to the ECO scheme since January 2013 has been the Government's flagship 'pay and you save' policy, the Green Deal. However, this has had a far lesser impact to the social housing sector given that the most cost effective measures that the policy targets have largely already been dealt with (DCLG, 2012a) and the interest rates available on the Green Deal loans are far in excess of what the Registered Providers themselves can obtain in the market place (Affinity Sutton, 2011; Guertler, 2011). At time of writing the Department of Energy and Climate Change quarterly statistics indicated that only 37,828 Green Deal Assessments (11%) had been lodged in the social housing sector (DECC, 2014b), less than 1% of all social housing units.

While thanks to many of these programmes social housing appears to perform better than the general stock, it might be considered that older houses in the private rented sector and owner-occupier sector present better opportunities for the reduction of carbon emissions through low carbon sustainable refurbishment. It should be noted that the owner-occupier sector contains many larger properties and individuals on higher incomes, both factors that drive higher energy consumption (DECC, 2011f). It should also be noted that despite the positive progress that these programmes have driven in in the sector, Government policies to drive stronger action to reduce emissions in social housing, for example, by mandating interventions to insulate solid-walled homes or to achieve minimum energy efficiency standards, have to date not been forthcoming (Reeves et al., 2010). As a consequence, the extent of carbon reduction refurbishments to date has largely been restricted to low to 'shallow' refurbishments comprising medium cost measures (loft insulation, cavity wall insulation, central heating installations, improved heating controls, etc.) (Boardman, 2012). Yet if we are to achieve the substantial emission cuts required to meet both the national and EU targets, much more substantive action is required. For example, analysis of technical interventions coupled with financial and political viability highlight that such greater emissions cuts from the domestic sector (Hermelink and Müller, 2010) and, more specifically, the UK social housing sector are possible (Reeves, 2011; Crilly et al., 2012).

Leadership from the social housing sector must therefore continue but this must be recognised and supported by measures in the form of public policies and coherent, robust financial and regulatory encouragement. This way, the presence of professional asset managers, building surveyors and project managers within social housing who are well experienced in investment decision-making and large scale refurbishment programmes, may be exploited and their valuable insight from programmes such as Decent Homes, CESP, CERT and Warm Front may be built upon. For instance, many of the challenges of delivering at a worthy scale, such as the need for high levels of private borrowing repaid via rental streams, volume procurement, large scale delivery of improvement measures, gaining access to people's homes and engaging extensively with residents all remain regardless of programme complexity (Smith and Swan, 2010).

3.6.3 Known challenges in the UK social housing sector

One of the biggest challenges facing Registered Providers over the next decades will be to retrofit its existing stock to meet the joint challenges of carbon reduction requirements and also to mitigate fuel poverty amongst residents. The previous government's Household Energy Management Strategy, Warm Homes, Greener Homes (HM Government, 2010b) identified the UK social housing sector as the best suited catalyst for the development of the low carbon domestic retrofit market. However, although social housing is generally at the forefront of the low carbon domestic retrofit implementation, there is considerably less literature published in this specific area, especially where perceptions around commercial and technical drivers and barriers are concerned.

The most commonly cited limitation within the literature is a lack of funds to finance the required high cost interventions (Existing Homes Alliance, 2009; Reeves et al., 2010) and the issue of split incentives. Other key issues identified include the lack of a strong drive to act from government, a need for increased internal capacity to enable Registered Providers to deliver and manage carbon reduction interventions (SHAP, 2009) and a low level of interest from residents in achieving emission cuts (Chahal et al., 2012).

Unlike in the commercial sector where there are large companies that are easy to influence and potentially regulate; much of the carbon abatement potential in the UK social housing sector will come from the ability for social housing organisations to effectively manage millions of small emitter's i.e. individual households. This fragmentation also contributes to significant barriers in planning for ambitious low carbon investment programmes. The challenge therefore is for the social housing sector to capture the benefits to individual tenants, the wider community, and the local economy in order to make a clear case to funders and lenders for the impact of the investment now and into the future. Table 3 below provides a summary of the commercial and technical barriers identified in this literature review.

Table 3 - Key low carbon domestic refurbishment barriers facing UK social housing providers. Source: Author's own summary

High capital costs / limited technical understanding	Registered Providers & tenants **ill-informed** and lack awareness of energy efficiency and its whole-life benefits (Aspden et al., 2012; Mallaband et al., 2012)
	Registered Providers & tenants sensitive to the level of **disruption** as well as the **time and money** needed to improve energy efficiency of homes (Reeves, 2011)
	Low levels of Government intervention and policy. Retrofit works perceived **high risk** and by some as a **low priority** (Dowson et al., 2012)
Split incentives	Little **incentive** to invest in energy efficient measures when the benefits are paid for by the Registered Provider but directly enjoyed only by the tenant (Guertler et al., 2013)
Technological immaturity / barriers to mass roll-out	Lack of technical knowledge and inadequate supply chains. Many low carbon technologies are still **low volume** and **expensive** (Smith and Swan, 2010)

This research seeks to build on the understanding of how the UK Social Housing Sector perceives the low carbon domestic refurbishment challenge. Undertaken in July 2010, the

Retrofit State of the Nation Survey was designed to provide a perspective of current attitudes to retrofit amongst UK social housing providers, covering issues of strategy, drivers and barriers, technological adoption and perceptions of resident attitudes. It addressed the perspective of social housing providers regarding sustainable retrofit as an issue and strategic intent and activities that are currently being undertaken to improve both the energy efficiency and carbon emissions from the social housing stock. This is considerably different to previous studies which have typically focussed on the potential technical options and the factors that may influence adoption.

Chapter 4 - Methodology

4.1 Introduction to research approach

Research into construction is considered a relatively recent academic discipline (Barlow, 2012) and needs to develop similar rigour and objectivity to other, more established fields, by applying sound methodologies and systematic, thorough execution (Fellows and Liu, 2009).

To date, the academic community has produced various general and subject-specific texts (e.g. Denscombe and Martyn 2010; Fellows and Liu 2009; Knight and Ruddock 2009; Robson 2002) and devised models such as the “research onion” (Saunders and Tosey, 2012) in order to provide guidance to researchers formulating research methodologies. Industries and government sectors also publish their own guidelines and requirements for research, all of which aim to capture appropriate philosophical concepts and link them to tried and tested research approaches and techniques. This presents researchers an extensive range of information, advice and examples from which to select and justify a specific approach.

Research into construction is often considered “at the intersection of natural science and social science” (Love et al., 2002), so research approaches adopted for construction related studies are commonly viewed on a sliding scale or continuum (Crotty, 1998; Sexton, 2004). To illustrate the applicability of different approaches, Table 4 (adapted by Barlow 2012 from Pathirage et al, 2008; Sexton 2004) notes five common research methods along the continuum whilst also highlighting the extent to which the researcher is immersed in the process (Barlow, 2012).

It is this recognised research paradigm that epitomises the challenge faced for my own research. In wishing to both gain an understanding of the current attitudes to and extent of sustainable retrofit in the social housing sector, both ideographic and nomothetic elements must be balanced. To make a judgement on this, the five different research methods must be explored in more detail.

Table 4 - Range and characteristics of research approaches. Source: adapted by Barlow 2012 from Pathirage et al, 2008; Sexton 2004

<table>
<tr><td colspan="3">Research into natural phenomena</td><td colspan="4">Research into construction</td><td colspan="3">Research into social phenomena</td></tr>
<tr><td>Experiment</td><td colspan="3">Survey</td><td colspan="2">Case study</td><td colspan="3">Action research</td><td>Ethnography</td></tr>
<tr><td colspan="5">Nomothetic research approaches</td><td colspan="5">Ideographic research approaches</td></tr>
<tr><td colspan="5">Deduction from theory</td><td colspan="5">Induction from data</td></tr>
<tr><td colspan="5">Explanation via analysis of causal relationship</td><td colspan="5">Explanation of subjective meaning systems</td></tr>
<tr><td colspan="5">Generation and use of quantitative data</td><td colspan="5">Generation and use of qualitative data</td></tr>
<tr><td colspan="5">Testing of hypothesis</td><td colspan="5">Research in everyday settings</td></tr>
<tr><td colspan="5">Highly structured</td><td colspan="5">Minimum structure</td></tr>
<tr><td colspan="2">Experimental</td><td colspan="3">Evaluative</td><td colspan="3">Engaged</td><td colspan="2">Embedded</td></tr>
<tr><td colspan="10">Researcher involvement</td></tr>
</table>

4.1.1 Ethnography

Ethnography is a qualitative research method aimed at exploring social and cultural phenomena. It typically requires the researcher to become involved and immersed in a group of people over a duration of time; observing the interdependencies of culture and social structure from the point of view of the subject. The researcher must impose a minimal amount of their own bias on the subject and data gathered and must also study matters holistically (Brewer and John, 2000; Denscombe and Martyn, 2010).

Whilst social and cultural views are being sought from the UK Social Housing sector, low carbon retrofit is widely recognised as a socio-technical matter (Lomas, 2010) which cannot be adequately appreciated through ethnography alone. Also, from a practical perspective, an ethnographic study into a small team within an active social housing provider organisation would likely fail to adequately capture the full extent of the challenges facing the sector as a whole, focussing too much on the circumstances of that one organisation, it's culture and it's staff.

4.1.2 Action research

This approach is often initiated to solve immediate issues and involves researchers carrying out systematic enquiries to improve the understanding and practice of processes (Robson, 2002; Denscombe and Martyn, 2010). It is a democratic problem solving approach achieved through a cyclical process that moves between initial problem identification and reflection to planning, taking action, evaluation then further reflection and planning. Action research is not deemed an appropriate approach for this research because of the non-intervention of the researcher.

4.1.3 Case study

Case study research excels at bringing us to an understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research. As shown in Table 4, case study falls centrally between ideographic and nomothetic research, and they may be prospective (in which criteria are established and cases fitting the criteria are included as they become available) or retrospective (in which criteria are established for selecting cases from historical records for inclusion in the study) (Stake and Savolainen, 1995; Yin, 2013). However, similar to an ethnographic study, the sheer diversity in the sector in terms of organisational size, governance and operating structures and assets and liabilities, as found in the literature review, would mean that a disproportionate number of case studies would need to be produced to adequately reflect the sectors attitudes and perceptions toward retrofit as a whole. Instead, for a case study approach to be more effective, the research question would need to be focussed more directly on social housing providers of a certain size and operating structure in order to provide at least one constant in the analysis of different attitudes and approaches taken toward retrofit.

4.1.4 Survey

A survey is designed to generate information from a sample, usually by questionnaire or interview, which can be generalised to a population with the objective of statistical validity (Fellows and Liu, 2009). Since survey research is almost always based on a sample of the population, the success of the research is dependent on the response rate and the resultant representativeness of the sample with respect to a target population of interest to the researcher. It is also essential that the design of the method of data collection is such that the returns can be analysed statistically. Poorly designed and distributed surveys can raise issues of non-response rates and potential respondent bias.

Whilst deemed an impersonal research approach that lacks the opportunity for interaction and observation of the research subject (Barlow, 2012), well designed surveys enable large target populations to be reached and valuable insight to be gained. This latter point is particular important given the challenges associated with the other research methods and their tendency to require a greater focus than looking at something as large and diverse as the entire UK social housing sector - though it is important to note that this very same advantage can be readily lost if representation of a certain segment of the sector within the survey response is low.

4.1.5 Experiment

Conventionally, an experiment takes place in an isolated, controlled laboratory environment, where the effects of changing variables are controlled and measured to verify or refute hypotheses on research subjects (Grix, 2010). Although this definition remains applicable to the work of physical sciences, a wider definition of an experiment is simply where the researcher actively influences something to observe consequences. Whilst an experiment may be appropriate for the testing of building components or for challenging or predicting phenomenon’s, it is not a practical approach for construction management research or, specifically, as an approach for understanding the UK social housing sector attitudes toward sustainable retrofit.

4.2 Justification of survey method for this research

Having assessed these five primary research approaches, the survey method is the most appropriate option for the research being undertaken. The principle justification for this lies in the characteristics of the research problem.

As previously noted, the aim of this research thesis is to identify and evaluate the current attitudes to and extent of low carbon domestic retrofit in the social housing sector. This is not an isolated phenomena that can be directly observed and it requires a sizable sample from a population represented by 1,788 registered providers of social housing (HCA, 2015b). A survey research method targeting a representative cross-section of the whole UK social housing sector will allow both qualitative and quantitative information to be gathered at a single point in time (Babbie, 1990). A survey is also efficient and versatile in that many variables can be measured without substantially increasing the time or cost, whilst in addition, it offers one of very few means of developing a representative picture of the attitudes and characteristics of a large population.

Despite there being design and implementation risks associated with a survey, a comparative look at the other research approaches that sit either side of the survey method on the continuum (Table 5) confirms that a survey is most appropriate for the nature of the research problem. The most significant attributes being the number of cases that can reached and the ability to gather both qualitative and quantitative insights in a relatively light touch and non-disruptive manner.

Another benefit of using a survey to serve as the basis of the research is that if for any reason further investigation is required following analysis of the survey findings further fieldwork, structured interviews or investigative case studies may be considered to supplement unclear conclusions. This is made particularly plausible given my position as a KTP associate already working closely with a number of registered providers.

Table 5 - Comparison of survey with experimental and case study approaches. Source: Barlow, 2012

	Experiment	**Survey**	**Case study**
Number of cases	Small number	Large number	Small number, sometimes just one
Information gathered & analysed	Very small number of features of each case	Small number of features of each case	Large number of features of each case
Control of variables	Controlled as a primary concern	Naturally occurring, but selected to represent a larger population	Naturally occurring
Quantification of data	A priority	A priority	Not a priority
Aim	To test / develop theory or evaluate intervention	An empirical understanding of the perceptions, attitudes and behaviours of a population derived from a sample	To understand a specific case. The wider relevance of findings is often conceptualised

4.3 Research design

Having identified and justified a cross-sectional survey as an appropriate research approach, this section discusses decisions on specific aspects of survey method design. Of paramount importance to the survey design is to acknowledge that in order for a survey to succeed, it must minimize the risk of two types of error: poor measurement of cases that are surveyed (*errors of observation*) and omission of cases that should be surveyed (*errors of non-observation*) (Groves, 2004). The Research Methods Knowledge Base (Trochim, 2006) also cites a number of essential considerations, the most applicable of which are summarised in Table 6 below.

Table 6 - Summary of key considerations when selecting and designing and survey method. Source: Author's own summary

Population and accessibility issues	Can the population be enumerated? Will the population cooperate? What are the geographic restrictions?
Sampling Issues	What data about the sample is available? Who is the respondent? Can all members of population be sampled? Are response rates likely to be a problem?
Question issues	What types of questions can be asked? How complex will the questions be? Will screening questions be needed? Will lengthy questions be asked?
Context issues	Can the respondents be expected to know about the issue? Will respondent need to consult records?
Bias and accuracy issues	Can respondent distortion and subversion be controlled? Can false respondents be avoided?
Administrative Issues	costs Resources and facilities Time

The following sub-sections discuss defining the sample, the questions and their format as well as the chosen method of analysis.

4.3.1 Sample selection

A survey sample most typically refers to the number of units that were chosen from which data were gathered. How well a sample represents a population depends on the sample frame, the sample size, and the specific design of selection procedures (Babbie, 1990).

Sample size can be defined in various ways. There is the designated sample size, which is the number of sample units selected for contact or data collection and there is also the final sample size, which is the number of completed surveys from which data are actually collected. Although the final sample size may be much smaller than the designated sample size if there is considerable nonresponse, ineligibility, or both, it does not necessarily discredit the research. Providing that the sampling procedures and framing are robust, the size of the population from which a sample of a particular size is drawn has virtually no impact on how well that sample is likely to describe the population. For example, a sample of 150 people will describe a population of 15,000 or 15 million with virtually the same degree of accuracy (Floyd J, 2009).

The sample frame is the set of people that has a chance to be selected, given the sampling approach that is chosen. Statistically speaking, a sample only can be representative of the population included in the sample frame. One design issue therefore is how well the sample frame corresponds to the population a researcher wants to describe (Floyd J, 2009).
The sample framing and designation approach adopted for this survey was facilitated by two commercial organisations involved in the KTP project. Fusion21, the lead sponsor and Procurement for Housing, are both providers of procurement services to the social housing sector. Together they provided a register containing direct email contact details for senior individuals within 704 different registered provider organisations. The list was derived from a larger mailing list and contained only details of individuals with an active email account and those with a role in managing existing social housing assets (as opposed to those in new build, HR or administrative roles). This therefore served to be the sample frame and in terms of comprehensiveness, represented approximately 39% of the total sector population. Also, of this sample, all 64 of the English registered providers that manage over 10,000 units and collectively own 52.8% of the total sector stock are represented.

Although not the complete population, the presence of the robust framed sample meant that no further sample designation was needed and a survey approach with accompanying questions could be developed which serve to help assess suitability to respond and allow for detailed analysis.

4.3.2 Research format and questions

Given the size of the sample, an interview approach to administering the survey has been ruled out. This leaves the option of a questionnaire format that may be either group administered, paper-based and posted or web-based and emailed. Although a group administered approach, where a sample of respondents is brought together and asked to respond to a structured sequence of questions, achieves a high response rate this is also deemed impractical given the size of the already designated sample. Both paper-based and web-based options do however allow large samples to be reached. They also offer an ability to ask a range of different questions in different formats. Crucially however, both methods have been shown to achieve similar response rates, whilst web-based surveys offer both financial cost and administrative advantages (Dillman et al., 2008). A web-based survey has therefore been selected. This approach allows the collection of data through a self-administered electronic set of questions on the web, removing printing, postage and data collation costs. In addition, better quality control is made possible through the use of regulated structured response formats such as multi and single-option variable questions, drop-down lists, radio buttons and text boxes that can limit the number of characters.

With the survey objectives, sample and format set, a draft set of questions were developed based on specific issues identified in the literature. These were built up around the primary research objectives reprised here as;

1. Perception of retrofit as a challenge in the social housing sector
2. Strategic intent in terms of the adoption and implementation of the low carbon domestic refurbishment agenda in social housing
3. Knowledge and capabilities of the social housing sector in terms of the adoption of low carbon domestic refurbishment
4. Perceived drivers and barriers for the adoption of retrofit
5. Adoption of specific low carbon domestic refurbishment technologies in the social housing sector
6. Adoption of resident interventions with regards to low carbon domestic refurbishment within the social housing sector

So as not to dissuade respondents, a finite number of simple questions with a familiar mixture of structured and free text response formats (Dillman et al., 2008) were used. The draft questions were then consulted upon with three housing sector professionals each with specific expertise in low carbon domestic retrofit in the social housing sector. This included one supply-chain consultant and two social housing provider asset managers who reinforced the direction of the questions and ensured the critical areas of concern within the sector were being adequately challenged by the questions.

The final web-based survey form comprised of a total of 27 questions, inclusive of the initial respondent details questions such as name, title, job title, organisation, address and postcode. A mixture of multiple-option variable, single-option variable, Likert Scale, numerical input and free text response formats were used and a breakdown can be seen in Table 7 overleaf. For ease of recipient response and to improve the quality of response evaluation, by far the most predominant question format used was single-option variable questions. Ten of the questions were designed in this way, having only a single selectable response option. Multiple-option variables were applied to eight questions, again due to the perceived ease of interpretation. Two of the remaining question formats were then Likert Scale questions to allow respondents to rank the effectiveness of technologies and resident engagement approaches adopted and the remaining questions were a numerical input field for the responding organisations average SAP rating and six intentionally placed free text fields to allow respondents to freely state other opinions against questions where the multiple options didn't allow. Although a relatively simple structure, the survey design team felt that consistency and simplicity in what was being asked of the respondent was key to minimising the time the survey would take to complete and also in ensuring that the clearest possible interpretations could be made in the response analysis phase. The full set of survey questions can be found in appendix 1.

A brief introductory text setting out the context and purpose for the survey was compiled and this, alongside a direct link to the web-based questionnaire, was sent via email directly to each of the 704 individuals within the designated sample in July 2010. To provide an incentive to respond, five copies of a book relating to the subject matter of domestic retrofit were offered. This book reward was offered to all respondents on a random basis so as not to only incentivise those that respond quickly. The online survey was closed to responses one month after issue on the 2nd August 2010 as set out in the invitation to participate in the survey.

Table 7 - Summary of question formats. Source: Author

Question format	Total number of questions
Single option (drop-down lists, radio buttons)	10
Multiple option (check box lists)	8
Likert Scale (rate on a scale)	2
Numerical input only	1
Free text input	6

4.3.3 Research analysis

An ill-thought-out analysis process can produce incompatible outputs and many results that never get discussed or used. It can also lead to key findings being overlooked and failure to pull out the subsets of the sample where clear findings are evident (UoRSSC, 2001). Early conception of an analysis process is therefore paramount and this in turn can lead to the development of features which are embedded during the design and administration of the survey to help facilitate latter stage analysis. For example, a significant advantage of using a web-based platform to administer this research survey is in the ability to add validation rules to individual fields and quality control features which help to avoid the presence of incomplete, invalid or inconsistent response submissions. This functionality, combined with intelligent consideration of the question and instruction wording meant that only basic policies for handling incomplete questionnaires were needed.

Before undertaking any detailed analysis, responses were vetted for consistency, completeness and duplication. As a result of the above described protocols, there were very few issues except for the presence of cases where more than one individual from the same registered provider organisation responded. There were nineteen of these types of organisational duplicates within the total data set and in each case the response deemed most representative was retained i.e. first, the job title was looked at the assess how close they were likely to be to internal asset management functions, then the completeness of their responses to matters such as baseline asset performance, technology deployment and resident engagement were compared. With the response data checked and cleansed of duplicates, response partitioning (determination of homogenous sub-groups where considered appropriate) and detailed analysis could take place.

By definition, the survey is limited to capturing broad attitudes in the social housing sector at a specific point in time. The research analysis must therefore consider both the findings arising from the individual questions and the interrelationship of the responses, as well as the wider social, economic and political context identified in the literature review. A follow up study in 12 or 24 months' time may also provide an interesting perspective of the trajectory of these attitudes. An overview of the primary themes being analysed are identified in Table 8 below.

Table 8 - Overview of the question issues. Source: Author

Topic area	**Question**
Organisational information	Provider type Provider size Region
Strategic perspective	Main sectoral challenges Decent homes progress Strategic plan Adoption timescale Barriers
Assets	Average SAP rating Confidence in asset data
Knowledge	Externally sourced? Sources of information
Technology	Technologies adopted Effectiveness of technology
Resident engagement	Approaches adopted Effectiveness of approaches Drivers for residents to adopt Barriers for residents to adopt

The proceeding section describes the population and provides in-depth analysis into the said research themes. The discussion considers the social housing sectors current perspective of retrofit as an issue, strategic intent and activities that are currently being undertaken to improve both the energy efficiency and carbon emissions from the stock and which technologies and approaches to resident engagement have been adopted and why.

4.4 Respondents

As discussed within the methodology chapter, a direct link to the web-based questionnaire was sent via email directly to each of the 704 individuals within the designated sample in July 2010. The online survey was closed to responses one month after issue on the 2nd August 2010 as set out in the invitation to participate in the survey. There were 148 responses in total but 19 were rejected for being organisational duplicates. The total number of valid responses that remained after the vetting process was 129, a response rate of 18 percent. This means that, in light of findings from the literature review which revealed that there are approximately 1,788 registered providers registered in England (HCA, 2015b), the total sample covers approximately 7percent of the total UK social housing sector.

4.4.1 Responses by type of registered provider

The responses from the sample by type of registered provider are shown in Table 9. Here, traditional, large stock voluntary transfer and co-operative/community based housing associations cumulatively account for 81 percent of the sample and may be deemed to represent the 88% of the non-profit registered providers in the UK. Local authorities and Arm's Length Management Organisations jointly account for 16% of the sample and represent the 11 percent of registered provider local authorities in the UK and the remaining 3 percent of the sample disclosed their organisation type as other. Whilst this 3 percent could be deemed to solely represent profit making registered providers (which make up 1 percent of all registered providers in the UK) it is a less reliable category as other unique or hybrid arrangements may also be lodged here. Nevertheless, in terms of overall representation in terms of organisational type the sample is sound and all key tiers of the registered provider market including Local Authorities, including Arm's Length Management Organisations (ALMOs) and Housing Action Trusts; Housing Associations, Local Housing Companies, co-operatives and charitable trusts (DCLG, 2011), are represented to a proportionate degree.

Table 9 - Response by type of registered provider. Source: Author analysis of survey results

Type of Registered Provider	% of respondents
Housing Association (traditional)	43
Housing Association (LSVT)	36
Housing Co-operative / Community based HA	1
Local Authority	4
Arm’s Length Management Organisation (ALMO)	13
Other (e.g. for profit)	3

4.4.2 Responses by size of registered provider

As an estimate, in total over 1.3 million homes are represented by this survey. Table 10 compares the responses from the sample by registered provider size (total number of units managed) and type. A red colour gradient has also been applied to this table, where the more pronounced colour is used to highlight higher concentrations of responses. Overall this correlates well with the national picture where it is known that 91 percent or the Registered Providers manage just 4.2 percent of the stock, while the largest 4.9 percent of Registered Providers manage 52.8 percent of the total (HCA, 2013b). Upon review it is evident that the most prominent proportion of the sample representing traditional housing associations were those managing 1001-5000 units, LSVTs responding mostly managed between 5001-10,000 units and ALMOs mostly 10,001–50,000. Also of particular significance is that all five of the Registered Providers managing more than 50,000 units in the UK were captured within the sample, each defining themselves as traditional housing associations. Local authorities represented an even spread from 1001 units through to 50,000, whilst the other category was split evenly with 1.5 percent managing 10,001-50,000 units and 1.5 percent managing less than 250.

Although the link between organisation type, size and retrofit activity will be discussed in a latter section, another reason for mostly medium to large Registered Providers responding to this survey beyond simple correlation with the national picture may be that those with greater numbers of units are more likely to have already understood and engaged in the low carbon domestic refurbishment agenda. This is quite likely due to fact that they will have larger budgets, more significant internal resource and better progressed asset management programmes.

Table 10 - Cross tabulation of response by size and type of registered provider. Colour gradient illustrates concentration of responses. Source: Author analysis of survey results

	< 250	251 - 1000	1001 - 5000	5001 - 10,000	10,001 - 50,000	> 50,000	Total %
Housing Association	2%	3%	16%	9%	9%	4%	43%
Housing Association (LSVT)	0%	1%	9%	18%	7%	0%	36%
Co-op / Community HA	1%	0%	1%	0%	0%	0%	1%
Local Authority	0%	0%	1%	1%	1%	0%	4%
ALMO	0%	0%	1%	5%	6%	0%	13%
Other	1%	0%	0%	0%	1%	0%	3%

4.4.3 Responses by region

Nine of the registered providers in the sample identified themselves as national (7 percent), 48 as regional (36 percent) and 77 as local (57 percent). Respondents were then invited to state which specific regions they operated within. In comparing these responses by region with the English registered provider Statistical Data Return (SDR) (HCA, 2013b), it becomes evident that three regions were considerably over-represented when compared to the national distributions of social housing providers: East Midlands, South West and North East (Table 11). The best represented areas were London, the North West and East of England. In total 111 respondents stated that they operated in only one region, whilst 12 operated in between 2 and 3 regions - identifying connected regions such as London, East of England and the South East, the South East and South West and East Midlands and East of England. Only 2 respondents operated in between 6 and 7 regions and 4 registered providers operated in all 9 of the English regions.

Table 11 - Percentage of respondents operating within region. Source: Author survey analysis

Region	% of respondents	SDR %
East Midlands	12	6
East of England	15	10
London	17	17
North East	11	6
North West	25	20
South East	22	14
South West	18	9
West Midlands	17	10
Yorkshire and Humberside	12	8

4.4.4 Responses by job role

The designated target sample sought to yield responses from those with a senior role in asset management or technical and/or environmental related managerial positions. Table 12 illustrates that this was largely achieved, with 62 percent of the respondent sample with asset, technical and environment related roles and 28 percent in a higher level managerial, director or CEO function. The remaining 10 percent of respondents were in procurement and finance related roles, which are without doubt also likely to be highly involved in making decisions regarding investment in low carbon domestic refurbishment related goods and services. Although difficult to conclude the exact role of 'Other Directors' and Other Managers' who jointly made up for 23 percent of respondents, it is most likely that they oversee multiple activities such as both asset management as well as procurement, technical or environment matters. In obtaining responses from such a broad range of roles the perspectives of senior managerial/strategic level staff, less involved finance and procurement staff and lower level practical asset management and technical staff are all well represented.

Table 12 - Percentage of responses by job role. Source: Author analysis

Job role	% of respondents
Asset/property management	42%
Technical function	6%
Procurement	7%
Environment	14%
CEO	5%
Finance	3%
Other Directors	9%
Other Managers	15%

In summary, the survey population provides a robust sample that may be deemed largely representative of the sector when captured in July 2010. Throughout the proceeding discussion and detailed analysis, all of the above described population stratification approaches i.e. population by Registered Provider type, size, operational geography and respondent role will be considered in order to draw conclusions. This will ensure all segments of the target population are given due consideration and represented as best as possible.

Specifically, proceeding chapters will investigate the perception of retrofit as a challenge in the social housing sector, the strategic intent of the sector and interventions deployed to date as well as the sectors existing knowledge, capabilities and capacity to deliver retrofit at scale. This research will principally draw upon the survey sample data but will also acknowledge existing literature and well as past and present engagement with key stakeholders such as staff within social housing organisations, policy makers, energy companies and manufacturers and suppliers and installers of low carbon refurbishment technologies. The study will go on to use the arising data and insights to identify areas where further research is required whilst also discussing where further innovation is required in the sector and how retrofit may be more successfully delivered at scale.

Chapter 5 - Results and Discussion

The survey results are analysed and discussed in four primary categories of response:

- Perception of low carbon domestic refurbishment in the social housing sector
- Sector baseline and its knowledge and capability to deliver
- Technology adoption and perceived effectiveness
- Adoption of resident engagement related interventions

5.1 Perception of low carbon domestic refurbishment in the social housing sector

5.1.1 Low carbon domestic refurbishment as a challenge

In line with a key objective of the research, a series of questions within the survey sought to identify how low carbon domestic refurbishment is perceived within the context of other identified challenges in the social housing sector and also to gauge the strategic intent of the population. Table 13 illustrates that sustainable retrofit was identified as the second biggest challenge faced by the Registered Providers overall, with 35 responses (27 percent) of the sample identifying it as the main challenge. The biggest challenge was the general economic downturn (52 responses, 40 percent), although this is not surprising given the status of the UK economy at the time, the impending government spending review (HM Treasury, 2010) and the general bearing that financial stability has on all wider activities. The other large concerns, housing benefit cuts (15 responses, 12 percent) and reduced new build development programme (15 responses, 12 percent), are also closely connected with the economic climate. Those responding under the heading of 'other', predominantly cited that all challenges had an equal weighting, whilst general uncertainty was also a concern.

Table 13 - Main challenges facing the social housing sector. Source: Author survey analysis.

Major Challenge Type	Responses (%)
General economic downturn	52 (40%)
Reduced development programme	15 (12%)
Housing benefit cuts	15 (12%)
Sustainable retrofit	35 (27%)
Social instability / ASB	1 (1%)
Threat of restriction of role to 'welfare housing'	6 (5%)
Other	5 (4%)

In isolation, the response to this question indicates that while low carbon domestic refurbishment is considered important, wider economic, social and political issues influence the sector strongly. However, considering such challenges in a black and white manner is perhaps not very helpful given that the remit of all Registered Providers is to sustainably provide a range of services, spanning both building new stock and supporting new tenants through to maintaining existing stock and meeting the needs of existing tenants (Hills, 2007; Malpass and Victory, 2010). The weighting placed on each of the main areas – economic, social, development, sustainable retrofit – will undoubtedly be strongly influenced by the role of the individual responding as well as the priority of the organisation at the time. For example, in jointly considering the ranking of challenges and the progress made toward fully achieving the Decent Homes Standard across all existing stock (Table 14), it is evident that almost twice as many respondents that have completed the programme consider the economic situation a bigger concern than sustainable retrofit (red colour gradient applied with the more pronounced colour highlighting higher concentrations of responses). However, those with more of the Decent Homes programme to deliver rank sustainable retrofit more highly than anything else. Similarly, when looking at the respondent's average Energy Performance Certificate score of the stock, those with the highest average SAP scores appear more concerned about the economic situation, whilst concern of the sustainable retrofit challenge is high amongst those with medium to high performing portfolios (average SAP of 61-70) as they perhaps recognise the level of intervention required to further improve their stock. Drawing conclusions from average SAP scores can however be unreliable as they can be largely skewed by the type and diversity of the Registered Providers inherent stock and also by how active a Registered Provider is in new build development and the ratio of higher performing new properties that it manages.

Table 14 - Cross tabulation of perception of major challenge and Decent Homes progress. Colour gradient illustrates concentration of responses. Source: Author survey analysis.

	Progress made on the Decent Homes Programme			
	95% complete now	Complete 95% by Dec 2010	Complete 95% by Dec 2011	Complete 95% later than Dec 2011
General economic downturn	32%	4%	2%	3%
Reduced development programme	9%	2%	1%	1%
Housing benefit cuts	9%	2%	1%	0%
Sustainable retrofit	17%	6%	2%	2%
Social instability / ASB	1%	0%	0%	0%
Threat to 'welfare housing'	2%	1%	2%	1%
Other (please state)	2%	1%	1%	0%

5.1.2 Strategic intent with regard to low carbon domestic refurbishment

A further two questions sought to identify the strategic position, as well as strategic intent into the future. Table 15 identifies the number of Registered Providers who are at different stages of strategic development of a retrofit strategy. This shows a fairly even split of those organisations that have a strategic position (51 percent) and those that do not (49 percent).

Table 15 – Strategic intent with regard to sustainable retrofit. Source: Author analysis.

Current organisational engagement with retrofit	**Responses (%)**
Strategic plan in place and delivering	14%
Developing a strategic plan	37%
No plan as such but a number of projects undertaken	23%
A few pilot projects only	22%
None	4%

Cross tabulation of the data to assess whether those individuals that identified sustainable retrofit as an issue of strategic importance were in organisations that have developed a strategic position yields no clear patterns. This indicates that the fact that an organisation was developing a strategy did not necessarily influence the perception of retrofit as the main challenge. It also suggests that the perception of retrofit as a challenge is potentially influenced by the role of the individual responding as well as by the scale and nature of other challenges facing the organisation at the time.

Table 16 below illustrates the survey population's response with regards to when they anticipate adopting an organisational low carbon domestic refurbishment strategy. This shows that despite strong views toward sustainable retrofit as a challenge, only a minority (14 percent) have a clear strategy in place. Of the remaining population, 60 percent intend to have a strategic plan in place by 2012, whilst alarmingly 26 percent think it likely that they won't adopt a focussed retrofit strategy for approximately 3 to 5+ years.

Table 16 – Strategy adoption time frame with regard to sustainable retrofit. Source: Author analysis.

Adoption of Retrofit Strategy	Number of Responses (%)
Have already	18 (14%)
2010/2011	29 (22%)
2011/2012	49 (38%)
2012/2014	15 (12%)
In 5+ years' time	14 (11%)
Do not anticipate adopting a retrofit strategy	4 (3%)

As defining a strategic direction and a strategy document is resource intensive, the relationship between the size of the organisation and strategic intent was compared (Figure 6). The results illustrate that much higher proportions of larger Register Provider organisations have a plan in place or are currently developing a plan. Although organisations managing less than 1,000 properties are slightly underrepresented in the survey, the pattern suggests that it is larger Registered Providers with in excess of 10,000 properties that are more actively gearing up to deliver low carbon domestic refurbishment. This seems a reasonable conclusion given that the larger organisations tend to have more resource and internal capacity and that they have also been much better placed in recent years to work on large scale deployment programmes with obligated energy companies under the CESP and CERT programmes.

Investigation of strategic intent by organisation type illustrates that it is large-scale voluntary transfer housing associations (LSVTs) (63 percent) and traditional housing associations (50 percent) with the most intent whilst Local Authorities and ALMO's show the least intent with 40 percent and 41 percent respectively.

Figure 6 - Cross tabulation of strategic intent toward retrofit and size of organisation. Source: Author survey results analysis.

5.1.3 Perceived drivers and barriers for the adoption of low carbon domestic refurbishment

The final questions concerning the perception of low carbon domestic refurbishment in the social housing sector sought to consider the primary drivers and barriers that are likely to affect the decision of whether to fundamentally deliver retrofit or not. In the field of sustainable construction, drivers and barriers typically focus on policy, financial, knowledge and client demand factors (Pitt and Tucker, 2009), although these vary depending on the position within the supply chain (Häkkinen and Belloni, 2011). Drivers and barriers presented to the designated survey population were therefore designed to be specific to social housing providers, but still followed the broad pattern of policy, regulation, clients, knowledge and finance highlighted in wider studies.

Drivers for Retrofit

Respondents were asked to identify up to 3 driving factors that encourage their organisation to install sustainable retrofit measures in their stock (Table 17). The biggest drivers for registered providers by quite a margin are the impacts retrofit has on individual tenants in terms of their financial position i.e. reduced full bills and running costs (88 responses, 68 percent) and the related issue of fuel poverty (63 responses, 49 percent). This is most likely considered in terms of the direct and immediate benefit that retrofit can being to residents but the policy goals for the Registered Provider and the long-term sustainability of their rental income may also be a factor.

When compared against the issue of climate change (16 responses, 12 percent), fuel poverty and reduced energy bills for residents were seen as substantially stronger drivers. This aligns well with a survey of 250 social housing residents undertaken by Chahal et al (2011) where tenant's reasons for adopting energy efficiency were identified. Climate change accounted for only 3.6 percent of the responses, with immediate benefits of reduced energy costs (17 percent), improved comfort (9 percent) and improved health (5 percent). Combined, these studies begin to suggest that the immediate benefits of sustainable retrofit are the major driver, when compared with more remote issues such as climate change. However, what is also evident in the Table 17 results is that the overall demand for retrofit from the residents themselves is low. This therefore highlights the need to increase tenant awareness of the tangible benefits, which could in turn create a more effective level of demand.

Policy was identified as a driver by 56 respondents (43 percent). This is by no means insignificant, but the role of central Government in shaping the agenda is not considered as strong as it once was with previously highly regulated large-scale programmes such as Decent Homes. It should however be reiterated that at the time of the survey, the Green Deal and Energy Company Obligation (ECO) were in development whilst the predominant retrofit delivery mechanism at the time was CESP which was a 'trial'. A repeat of the survey, in light of today's policy options, would be revealing.

Table 17 - Drivers for retrofit adoption. Source: Author survey results analysis.

Drivers for retrofit	**Number of Responses (%)**
Reduced fuel bills and running costs for tenants	88 (68%)
Fuel poverty	63 (49%)
Government policy and targets	56 (43%)
Available finance	54 (42%)
Organisational commitment	52 (40%)
Maintaining asset value / stock condition	30 (23%)
Climate change	16 (12%)
Resident demand	11 (9%)
Maintaining lettability of property	8 (6%)

Organisational factors such as organisational commitment and financial position (maintaining asset value/stock condition, maintaining lettability and sustaining resident demand) were also identified as significant drivers for the adoption of retrofit within the social housing sector. Taken together, the willingness and financial capacity of social housing providers to respond can be considered a strong driver and further reinforces the views of policy makers and other professionals that the UK social housing sector is well placed to serve as a catalyst for the development and growth of the low carbon domestic retrofit market (HM Government, 2010b).

Both the policy drivers combined with the demands of residents and overall organisational commitment in the sector should be viewed as interlinked. Policy and demands of residents shape organisational response. Issues such as finance, driven by factors as varied as the benefits regime and the ability of providers to access capital markets, all influence the position that social housing providers can take when delivering retrofit programmes. These interrelationships mean that policy demands for social housing providers to participate in this market-making role must recognise the broader context in which they operate. With policy requirements and sector commitments better dovetailed, a far more effective response to the retrofit challenge may be achieved.

Barriers for Retrofit

Following the identification of drivers, the sample was asked to identify up to a maximum of 4 barriers to the take up of low carbon domestic refurbishment (Table 18). The biggest barrier identified by nearly all of the respondents is that of effective funding streams (111 responses, 86 percent). Although at the time of the survey finance related policy instruments such as Green Deal and ECO were still under development, there were still some funding channels such as CESP, CERT, FiT and Renewable Heat Premium Payments (RHPP) and yet respondents still identified it as a core issue. Since the survey many have indeed argued that the situation has worsened, with the Green Deal pay as you save mechanism failing to serve social rent models and volatility in the support coming from obligations placed on the energy companies (Willey, 2012; ACE, 2013; Mason, 2014). Indeed, the lack of policy and Government intervention was identified as another key barrier with 47 responses (36 percent) and a study undertaken by a large national registered provider since this survey has investigated the situation in detail to conclude, as per previous discussion, that the policy and support required needs to be much more tailored toward the wider context in which Registered Providers operate, rather than a one size fits all approach (Affinity Sutton, 2011). The owner occupied sector is larger and the private rented sector is worse performing but neither are as well placed to develop the embryonic supply chains and deliver at scale to high standards (Smith and Swan, 2010).

Table 18 - Barriers to retrofit adoption. Source: Author survey results analysis.

Barriers for retrofit	**Number of Responses (%)**
Lack of funding support	111 (86%)
Commercial difficulties such as failure to establish business case	55 (41%)
Lack of policy and Government intervention	47 (36%)
Lack of technical knowledge	43 (33%)
Too much long term risk - e.g. defects or non-performance	43 (33%)
Other organisational priorities - e.g. development	43 (33%)
Lack of installation skills supply chain	26 (20%)
Lack of equipment supply chain	23 (18%)
Lack of repairs and maintenance supply chain	21 (16%)
Resident resistance	17 (13%)

Organisational commitment and difficulties relating to forming of a business case for sustainable retrofit were also identified as a barrier, with 55 respondents (41 percent) identifying organisational commitment as a challenge. Whilst this conflicts with it also being a driver for many, the presence of other high scoring barriers such as lack of technical knowledge, a perception of long term risk relating to defects and non-performance and also supply chain risks relating to skills, equipment/products and repair and maintenance capabilities suggests that this issue is more one of wanting to minimise investment risk rather than an outright lack of interest or commitment to the cause. Also, when compared with their own organisational position with regards to strategic response to retrofit, the respondents that identified organisational commitment as a barrier did not display any significant difference in distribution of strategic position as compared to the whole sample.

This potentially means that this response was a perception of the sector as a whole, rather than respondents drawing on their own organisational experience.

The high scoring barriers relating to internal and external risks, such as capability to deliver, knowledge and supply chain readiness draw out the traditional traits of the UK social housing sector – well known for being seen as socially responsible, well-regulated and risk averse (Jones et al., 2011).

When combined, 88 percent overall identified a skills and knowledge issue, either internally or within the wider supply chain. Whilst these issues are largely perceived to be external, such as lack of installation skills, lack of an equipment/products supply chain and lack of repairs and maintenance the responses also offer insights into how registered providers perceive their own internal technical knowledge. Table 19 below identifies the breakdown by size of Registered Provider.

Table 19 - Lack of Technical Knowledge by Size of Organisation. Source: Author analysis.

Size of Provider	% Lack of Internal Knowledge as a Barrier to Sustainable Retrofit
50,000+	20%
10,001 – 50,000	35%
5,001 – 10,000	32%
1,001 – 5,000	41%
251 – 1,000	0%
Less than 250	33%

Concentrating on the bulk of the organizations (i.e. the 91 percent between 1,000 and 50,000 units), there appears to be little difference in terms of how they viewed their own technical knowledge. Results perhaps indicating that larger organisations are marginally more comfortable with their own internal know how.

Similarly there are no clear signs that organisations of different size perceive a lack of external supply chain skills and knowledge any differently to one another. When combined, organisations did however identify skills and knowledge within the supply chains as the next biggest issue after lack of funding with installation (26 responses or 20 percent), repairs and maintenance (21 responses or 16 percent) and equipment (23 responses or 18 percent) aspects of the supply chains all causing concern for some of the respondents. When combined, a total of 54 percent identifying some form of supply chain readiness issue. This should be considered alongside the potential for long-term technical risk, such as defects or non-performance of sustainable retrofit, which was seen as a barrier to take up by 43 respondents (33 percent) – a risk that may perhaps also be deemed a partial consequence of not having adequate supply chain capability or knowledge. As has been uncovered in the Retrofit for the Future pilot study analysis (InnovateUK, 2014), this latter issue of non-performance can however also be affected by factors beyond the immediate control of the supply chain, such as the accuracy of modelling tools, the inter-play between multiple products and the behaviour of occupants.

The view of supply chain capability from housing professionals reinforces the need for supply chain development and also indicates that, during the development phase, there are risks associated with engaging with an immature supply chain. The barriers cannot be considered in isolation from one another. Organisational intent, financing and the capacity to deliver are all interrelated factors. What this identification of the barriers does indicate is that supply chain development is required for the retrofit sector along with an accompanying policy and financial support framework.

5.2 Sector baseline and its knowledge and capability to deliver

The third objective set was to identify the knowledge and capabilities of the social housing sector with regards to the adoption of low carbon domestic refurbishment. In order to do this, the basis from which the sector must build upon must be considered and then the sectors inherent skills, knowledge and capabilities may be reviewed. Already we have seen that the sector as a whole sees supply chain readiness and the prevalence of in-house technical expertise as a barrier to large scale deployment of retrofit but there are also insights here in to why the sector may be deemed better placed than others to build national capability.

Sector baseline

With the sector already having embarked on delivering to the Decent Homes standard - a large scale coordinated investment programme backed by the regulator from 2001 to 2010/11 – the survey first sought to judge the progress that responding organisations have made toward fully achieving Decent Homes, how this effects the average SAP rating of their stock and also their intentions to deliver more advanced low energy retrofit measures. Measures which by their very nature, are likely to be more costly and challenging to deliver and integrate with existing cyclical plans.

As expected the majority of respondents stated that they have already achieved 95 percent Decent Homes across their stock (71 percent), with 15 percent stating that they would reach 95 percent completion by Dec 2010 and 14 percent stating that they will complete by Dec 2011 or later.

Table 20 - Lack of Technical Knowledge by Size of Organisation. Source: Author analysis.

Progress towards Decent Homes	**% Proportion with average SAP score of 61 or more**	**% Proportion with no strategic retrofit delivery plan in place**
95% complete now	87%	48%
Will complete 95% by Dec 2010	63%	47%
Will complete 95% by Dec 2011	44%	78%
Will complete 95% later than Dec 2011	78%	33%

Although one would assume that those who have delivered on their Decent Homes obligation would have a higher performing stock in terms of SAP score and also be ahead in putting in place a strategic retrofit delivery plan, the results shown in Table 20 above do not draw such a straightforward conclusion. The results show that whilst those who have either already delivered on their Decent Homes programme or were close to doing so at the time have a slightly better overall SAP average and less cases of having no strategic plan in place, those who anticipate delivering their programme later than December 2011 also fare quite well. This suggests that many Registered Providers are successfully managing to marry both ‘traditional’ stock investment with new programmes such as sustainable retrofit. For example, delivering new kitchens, bathrooms and basic energy efficiency works such as cavity wall and loft insulation, boilers and windows and doors whilst also pursuing greater energy efficiency standards through a strategic retrofit delivery plan that recognises the need for more advanced interventions such as solid wall insulation, floor insulation and low and zero carbon heating systems and renewables.

Although further research into identifying the effectiveness and extent of this concurrent joined up activity is needed, asset management guidance from the National Housing Federation (Jones et al., 2011) and literature (Smith and Swan, 2010; Crilly et al., 2012) indeed already advocate such an approach on the grounds of improved resource efficiency, reduced resident disruption and improved performance and durability from the resultant works. This is ultimately a great example of how a sector with past and current experience of managing large scale asset management programmes can take-on a challenge such as sustainable retrofit by further developing and refining models first geared toward delivery of Decent Homes such as methods of volume procurement, large scale delivery of complimentary measures and gaining access to people's homes and engaging extensively with residents.

Whilst progression toward Decent Homes is as advanced as would be expected and respondents reported average SAP scores reflective of the better than national average performance also reported to the regulator (HCA, 2013b) and identified by the most recent English Housing Survey (DCLG, 2012a), a third question regarding readiness was asked in relation to confidence in housing stock data. Table 21 overleaf gives an overview of the response given.

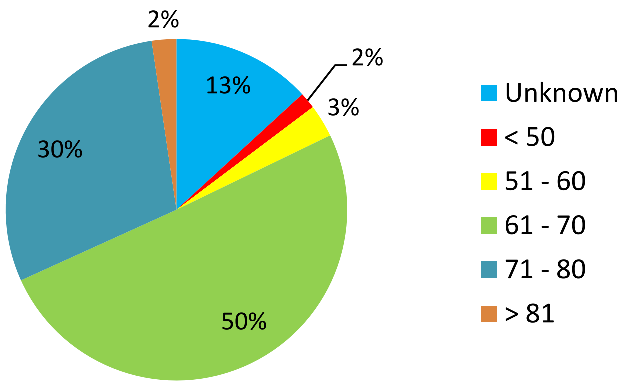


Figure 7 - Reported average SAP bands. Source: Author analysis

Table 21 - Level of confidence in housing stock data. Source: Author survey results analysis.

Level of confidence in stock data	Number of Responses (%)
Very High	19 (15%)
High	76 (59%)
Medium	33 (26%)
Low	1 (1%)
Very Low	0 (0%)

Whilst at first glance this shows a positive picture, with 74 percent of the sample reporting high to very high confidence in their housing stock data, there are additional factors to consider. One is that this is a qualitative question where respondents will undoubtedly be biased in their perception of the quality of their own housing stock data. But more importantly still is that housing stock data represents everything a Registered Provider knows about its assets, which sector wide have a total book value exceeding £100 billion (Jones et al., 2011; HCA, 2013a). Anything less than complete and robust information on assets may therefore be deemed irresponsible since managing assets effectively is crucial to both the operation of a landlords business as well as its ability to achieve its aims and maintain its values.

Indeed 27 percent of respondents directly report a less assured stance, declaring in the survey response to having only medium to low confidence in their housing stock data. This is telling of the transition that the sector is enduring and even more central to the sectors capacity to deliver retrofit than its past experience in delivering Decent Homes or its average SAP ratings. In the past there was little incentive to maintain detailed records of the legal title and basic features of each property. However, with increased trading activity, more demanding due diligence on loan security and the need to understand market values, it has become essential that Registered Providers maintain records to an ever higher standard (Jones et al., 2011). Up-to-date and robust information about the condition of property is needed to inform decision making and to plan investment in stock over time – both traditional day-to-day cyclical spend but also longer term investments in energy efficiency and microgeneration technologies.

It is well documented that in order to deliver retrofit successfully, detailed records of the properties dimensions, built characteristics, condition (at a component level), occupancy and baseline energy performance are all needed before an effective strategy for its improvement can be established (Smith and Swan, 2010; Baker et al., 2013). With comprehensive stock condition and asset management data not only are you able to identify optimal environmental retrofit design strategies; Registered Providers are able to make significant time, cost and carbon savings by using existing ‘trigger points’ to require improvements in energy efficiency. For example when other routine/maintenance/upgrade building work is required, or when the dwellings are void or change hands. This approach also helps to remove some of the disruption and hassle associated with the works. To further improve the appraisal process it can also prove enormously beneficial for providers to overlay physical stock data with tenant demographic data and wider tenure patterns to help maximise outcomes, smooth logistics and better correlate the relationships between energy, people and technology (Baker et al., 2013).

Finally, what is also interesting to note with regards to the confidence held by the sector in their housing stock data is that it comes at a time where the introduction of electronic data collection and storage has made information more prevalent than ever. For example, many Registered Providers adopted new and advanced asset management database systems in order to introduce component level accounting practices to the way in which they were delivering Decent Homes and by far the most comprehensive, property specific, data gathering undertaken in recent history has been for the purpose of producing Energy Performance Certificates (EPCs) – a mandatory requirement for all properties on the open market since August 2007 and for all rented properties since October 2008. It could in fact be that this wave of new data itself has caused confidence to waiver; an interesting conundrum given that such information is pivotal in ensuring that the right retrofit options are selected and implemented.

Knowledge and capability to deliver

In light of the progress made by the sector to date - its current baseline with regards to progress toward Decent Homes, its average SAP and overall confidence in housing stock data – respondents were asked to identify the main sources of information used when they were planning and making decisions about investing in the delivery of sustainable retrofit. The first question was designed to identify perceived organisational capability to make decisions, considering the adoption issues identified by (Egmond et al., 2006), to indicate the role internal knowledge played in adoption of retrofit.

Of the 129 respondents, 66 (51 per cent) stated that they relied on internal sources, while 63 (49 per cent) relied on external sources. Once the categories with low respondent numbers have been discounted, there appears to be a slight increase of reliance on internal advice as the size of the organisation increases (Table 22). This indicates that larger organisations have the potential to better support the retrofit decision-making process internally when compared to smaller organisations. An unsurprising finding given that larger Registered Providers typically employ more staff and are better placed to resource research and innovation, whereas smaller organisations may outsource (Walker, 2000).

Table 22 - Reliance on internal or external knowledge by Registered Provider size. Source: Author survey results analysis.

Size of Registered Provider	Internal (%)	External (%)
50,000+	4 (6%)	1 (2%)
10,001 – 50,000	20 (30%)	14 (22%)
5,001 – 10,000	25 (38%)	19 (30%)
1,001 – 5,000	14 (21%)	20 (32%)
251 – 1,000	1 (2%)	5 (8%)
Less than 250	2 (3%)	4 (6%)
Total	66	63

Table 23 overleaf identifies the external sources of information that the 129 Registered Providers relied on to make decisions with regards to investment in sustainable retrofit. For this question, respondents were allowed to select a maximum of three responses, ranking them in no particular order.

The largest source of information is professional networks, particularly other social housing providers (80 responses – 62 per cent). This is potentially driven by two factors; first, the social housing sector is willing to share and publicise new knowledge, and second, the sector has had a number of demonstration projects in the retrofit area (Bell and Lowe, 2000b; Roberts, 2008; Aspden et al., 2012; Wetherill et al., 2012). Both factors a good reflection of how the social housing sector traditionally operates – a not for profit, social, economic and environmental value driven approach overseen by a regulatory regime based on the principle of co-regulation (Jones et al., 2011). For example, a central Government review of social housing regulation (DCLG, 2010a) encourages landlords to make robust and honest self-assessments of their own performance, drawing on external validation (such as peer review) as needed. Whilst the regulator should set clear out-come focussed standards, the fundamental responsibility for effective service delivery lies with landlords and not the regulatory system. It is perhaps this core attitude and approach that puts the sector in a position where it is willing and able to share best practice and lessons learnt through a well-established network of channels such as those facilitated by the representative bodies, the National Housing Federation, Chartered Institute of Housing and the Housing Forum. Registered Providers continue to adopt a commercial approach to day to day operations, but it is largely residents and the regulator that they respond to rather than seeking competitive advantage over one another. This reiterates the role of communities of practice (Davenport and Prusak, 2000; Wenger et al., 2002; Henderson et al., 2013; Karvonen, 2013) in generating and sharing trusted knowledge between organisations.

Table 23- External sources of information for retrofit decision making. Source: Author survey results analysis.

Information source	**Number of Responses (%)**
Networks (e.g. other RPs, NHF)	80 (62%)
Government advisory services	62 (48%)
Consultants	51 (40%)
Manufacturers	46 (36%)
Industry reports	37 (29%)
Internet	30 (23%)
Installers	23 (18%)
Professional procurement organisations	23 (18%)
Universities	7 (5%)

The next largest number was government advisory services (62 responses – 48 percent), which at the time of the survey included bodies such as the Energy Saving Trust, Energy Efficiency Partnership for Buildings and Carbon Trust. Since the survey, this particular type of service provision has seen significant funding cuts which judging by its perceived value will have had a sizable impact on the sectors access to affordable, valued knowledge. Prior to their privatisation, for example, the Energy Saving Trust and Carbon Trust both actively published free to access publications and guidance documents which has now slowed to a private commission or ad-hoc public funding contract basis only. This may indeed be an opportunity area for Universities who at point of survey were considered a source of information for 7 respondents (5 per cent) but this is again dependant on wider research council and public sector recognition of the need for stimulus in this field.

The next interesting group of responses is around manufacturers (36 per cent), installers (18 per cent) and consultants (40 per cent) as sources of information. This does not chime with construction innovation generally where product manufacturers and installers were seen as major sources of innovation (CIOB, 2007). However, the study is less specific than this questionnaire, relating to construction innovation generally, which can potentially explain the differences (Swan et al., 2013).

Overall, the response to what sources of information Registered Providers use when engaging with the challenge of sustainable retrofit reinforces the research community’s view that the supply chain is under developed and fragmented (Karvonen, 2013). Expertise is largely preferred to be internal where it can be afforded and then if looking external, professional networks and fellow Registered Providers are most highly regarded. This is followed by a preference to draw upon advice and guidance from a trusted central body such as local and national government advisory services and/or consultants who are typically impartial and could be considered the most experienced of all with regards to the practicalities of retrofit specification and delivery. Tellingly manufacturers and particularly installers and procurement bodies come across as less valued, perhaps illustrative of the fact that the sector has yet to realise large-scale delivery of deep retrofit over a time frame that adequately demonstrates competence and assured performance (Smith and Swan, 2010). No finding here is necessarily a bad reflection on the social housing sectors preparedness or capacity to deliver, it is instead a sign that despite having shown willingness and initiative, Registered Providers only really have themselves and peers to learn from and stimulate the market.

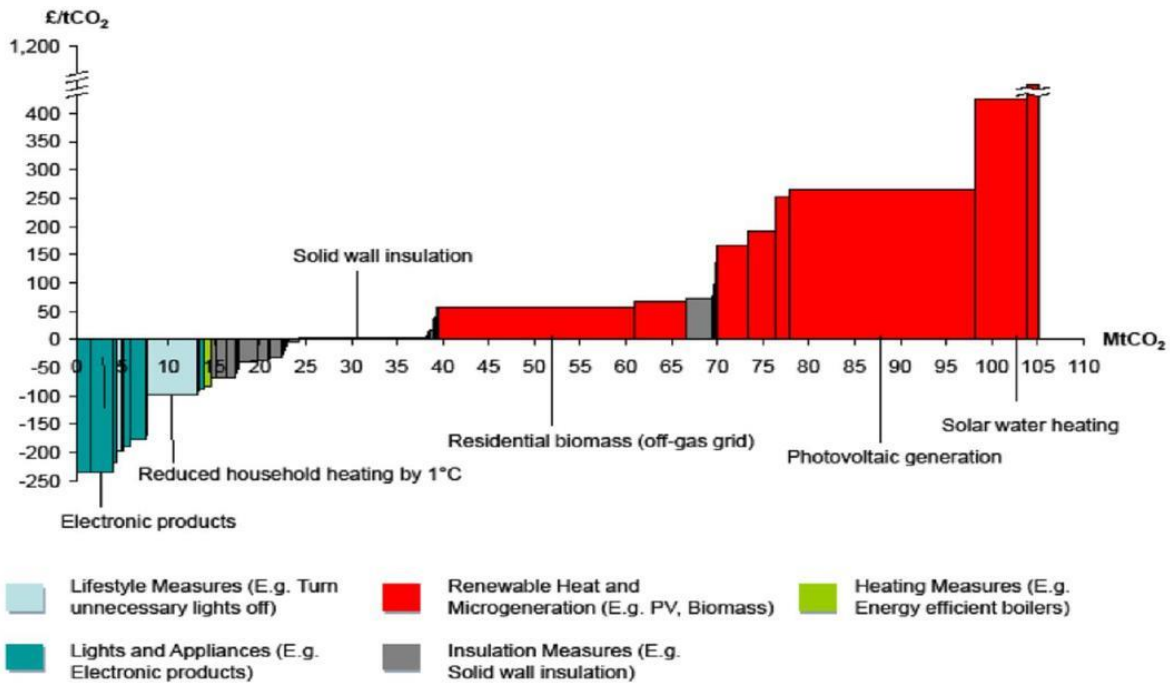
5.3 Technology adoption and perceived effectiveness

Whilst it is clear that the delivery rate of whole house deep retrofit is far from the required levels to make meaningful reductions in national energy consumption and carbon emissions, Registered Providers have delivered many 'shallow' retrofits through the deployment of low to medium cost measures (Hermelink and Müller, 2010; Reeves et al., 2010; Boardman, 2012). They have also delivered numerous pilot schemes and demonstrator projects through government backed programmes such as Retrofit for the Future (InnovateUK, 2014) as well as via their own balance sheets and other collaborative R&D projects (Wetherill et al., 2012). In this respect, Registered Providers can be regarded as the largest and most experienced group of housing owners when it comes to physically deploying and maintaining retrofit technologies, as reflected in their average SAP ratings discussed previously. There have of course been many low to medium cost measures deployed in the owner occupied and private rented sectors but neither have the feedback loops, vested interest nor the degree of stability in installer base to truly shed light on technology related issues and although there are early adopter networks such as SuperHomes, their experiences are many and varied with little consistency in circumstance for clear conclusions to be drawn (Fawcett and Killip, 2014).

With 42 percent of respondents in an asset management function and a further 6 percent declaring themselves to have a technical, 7 percent procurement and 14 percent environment related job role, a number of questions were asked with regards to retrofit technologies with a view to obtaining an informed indication of how different retrofit technologies are perceived. Table 24 compares the level of take-up of a specific technology as compared to the average perceived effectiveness for the specific technology. The question did not address the numbers of installations, rather it identified whether or not a Registered Provider had installed a particular technology. The respondent was then asked to rate the technology in terms of effectiveness on a Likert Scale of 1-5, with 1 being not effective and 5 being highly effective.

The high level perspective of what effectiveness is and how it is evaluated used in the survey does however raise a number of issues. What criteria are the respondents using to assess effectiveness? A number of authors have identified the kinds of carbon savings that might be achieved through the application of different technologies (Bell and Lowe, 2000b; Jenkins, 2010; Reeves et al., 2010), but given the context of issues such as fuel poverty and resident relationships that are part of the social housing landlords agenda, is this carbon saving perspective view of effectiveness too narrow? The most common means of assessing technologies is to identify the highest savings of running costs for each invested pound over the life time of a dwelling, i.e. low investments with high effects. For example, the Committee of Climate Change: Energy Use in Buildings and Industry report (Committee on Climate Change, 2013b) demonstrates a marginal abatement cost curve (MACC) for the domestic sector (Figure 8) which identifies a technical emissions reduction potential worth as much as 105 $MtCO_2$. Of this, just under 40 $MtCO_2$ could be achieved at less than £40/tCO_2 – measures to the left hand side of the chart, dominated by fabric insulation measures and improved space heating and hot water, lighting and appliance efficiencies. Lifestyle measures are also identified at this end of the spectrum but were not evaluated in the sector survey due to the difficulties associated with reliably assessing costs, benefits and wider impacts of such measures.

Figure 8 - Carbon abatement potential in the UK domestic sector. Source: Committee on Climate Change, 2013b



Others, including the Building Research Establishment (Shorrock et al., 2006) have conducted similar evaluations but rarely do they simultaneously consider other factors beyond capital cost and lifetime impact in terms of CO_2 and/or energy reduction. Installation challenges such as disruption caused to residents occupying the property during works, lifetime maintenance implications, in-use usability and control of systems and end of life impacts of technologies are all additional factors that need to be evaluated and which could well play in to respondents thought process when rating overall effectiveness of a measure (Baker et al., 2013). The Construction Products Association (CPA, 2014) have perhaps pioneered this thinking in their study of potential retrofit solutions having identified three factors that typically colour specifier, homeowner and landlords views of effectiveness; cost, carbon savings and the level of disruption caused by installation. Still, there are other dynamics such as how residents engage with technologies, maintenance and wider whole life impacts but there is only so far a single assessment methodology can go before secondary tools and rating techniques need to play a role – for example Which and Energy Saving Trust type consumer ratings with regards to usability and BBA certificates and the BRE Green Guide to Specification (Anderson and Shiers, 2009) for assessment of performance, whole life impact and embodied energy.

The survey was designed to gain a higher level insight into the attitudes of the sector concerning a range of issues surrounding sustainable retrofit and in terms of considering effectiveness; it does not investigate the context in which measures are implemented and the precise definitions that may be used by different respondents. This view may be driven by organisational context (Reeves, 2011), as well the complex inter-relationship between project definition, delivery and in-use factors, all of which have a capacity to influence the potential performance of retrofit solutions. The complexity surrounding the notion of effectiveness is considered below on a technology-by-technology basis but is also worthy of further consideration in wider the wider research community.

Table 24 - Technology take-up and perceived effectiveness. Source: Author survey results analysis.

Technology adopted	**Number of providers adopting (%)**	**Mean perceived effectiveness of technology**	**SD**
Loft insulation	127 (98%)	4.42	1.03
Cavity wall insulation	124 (96%)	4.26	1.12
Thermally efficient doors and windows	98 (76%)	3.99	0.95
Draughtstripping	84 (65%)	3.45	1.16
Solid wall insulation solutions	73 (57%)	3.96	1.10
Solar thermal	71 (55%)	3.61	1.04
Air source heat pumps	64 (50%)	3.30	1.01
Mechanical ventilation / Heat recovery	62 (48%)	3.09	0.95
Grade 'A' space heating and DHW appliances	57 (44%)	4.00	1.21
Photovoltaics	56 (43%)	3.53	0.80
Ground source heat pumps	36 (28%)	3.65	1.04
CHP boilers	31 (24%)	3.34	1.20
Supply of high-efficiency white goods to residents	21 (16%)	3.21	1.15
Biomass boilers	20 (16%)	2.11	0.99
Wind Turbines	1 (1%)	1.00	0

The four most widely adopted technologies are what may be deemed 'basic' cost effective fabric improvement solutions: loft insulation, cavity wall insulation, doors and windows and draught stripping. Cavity wall and loft insulation also ranked highest in terms of overall perceived effectiveness. This is largely what one would expect to see given the overall cost-benefit of such measures (Clinch and Healy, 2000; DECC, 2012b) and other research into national deployment rates of energy efficiency technologies such as the GB Energy Fact File (Palmer and Cooper, 2012). With space heating accounting for approximately 56 percent of the domestic energy consumption (Xing et al., 2011), this finding illustrates a sector wide appreciation that energy conservation through minimising heat loss though the building fabric is the optimal first step to be taken in any energy efficient refurbishment. For a similar reason such measures have perhaps also been rated highly because they have been driven at a national level by programmes such as Warm Front, CESP, CERT, ECO and as a thermal comfort criterion within the Decent Homes Standard. Respondents are therefore more likely to have had experience with these interventions that any other whilst simultaneously recognising that they are being driven for good reason. What is also interesting here however is that all four of these measures require little in the way of user interaction. Loft and cavity wall insulation as well as draught stripping are what may be termed static fit-and-forget measures – they cause minor disruption to residents when being installed and then perform for their designed lifespan without residents or the landlord having to engage. Upgraded windows and doors are similar in character but have added advantages in that they are not solely an energy efficiency upgrade. Modern windows and doors also deliver added security, improved solar and light control and better acoustics (Strong, 2012) thus further skewing what respondents may be communicating in their rating of overall perceived effectiveness.

Although these basic fabric measures alone are not able to deliver the required level of energy efficiency, it is argued that such technologies, which come at a modest cost and have been well proven since the early 1980's, can deliver improvements in the region of 50 percent (Bell and Lowe, 2000b). And it is the fact that these very measures have been deployed at such scale in the social housing sector that reflects the sectors higher than national average SAP ratings. The challenge now however is that as a result of already addressing the lower hanging fruit, the cost per unit of energy/tonne of carbon saved in the social sector will be higher than addressing poorer performing tenures where adoption of even the most basic measures is low e.g. 52 percent of the cavity walls insulated in the private rented sector compared to 74 percent in social housing (DCLG, 2012a).

The next range of technologies includes solid wall insulation, solar thermal, air source heat pumps and mechanical ventilation and heat recovery (MVHR), which can all be viewed as more technically complex. Similar to the top four, solid wall insulation is both a static fit-and-forget fabric improvement measure from a resident interaction perspective but also a measure than has been incentivised at a national level, particularly through energy company obligation initiatives such as CESP, CERT and most recently, ECO. As with the other fabric improvement measures, solid wall insulation also ranked highly in terms of overall mean perceived effectiveness. The term solid wall insulation solutions in this question refers to both systems that may be applied internally or externally which, although not exclusively, are most commonly applied to solid masonry walls. Solid masonry wall construction was the dominant construction type for load bearing walls up to 1945. Owing to the higher proportion of older homes, it is important to therefore note that a greater proportion of homes of solid wall construction are found in the private rented and owner occupied sector (29 per cent) compared with social homes (13 percent) (DCLG, 2012a). Nevertheless, the English Housing Survey Energy Efficiency report (ref: 2012), found that of the 7.1 million homes with solid walls in England, 350,000 (5 per cent) have solid walls insulation applied, the social housing sector had insulated 16 percent of its solid walls with the private (rented and owner occupied) having only insulated 3 percent. This picture will of course continue to evolve but it is another good illustration of how the social housing sector is well place to lead an emerging market (Sandick and Oostra, 2010; Boardman, 2012) and transfer best practice to the larger housing sectors.

It is interesting that solar thermal, air source heat pumps and mechanical ventilation systems with heat recovery are identified as the next most commonly adopted measure. Although they have been incentivised through subsidy programmes such as the Renewable Heat Premium Payment (PHPP) and more recently the Domestic Renewable Heat Incentive (RHI), as well as heavily trialled in programmes such as Retrofit for the Future (InnovateUK, 2014), they certainly have not been rolled out as prolifically as 'grade A' space heating and DHW appliances such as gas fired boilers. Changes to Building Regulations in 2005 led to a large increase in the proportion of dwellings with an energy efficient condensing or condensing-combination boiler from 2 percent in all sectors in 2001 to 44 percent in 2012 (DCLG, 2012a) and high efficiency heating systems were also driven hard as a requirement within the Decent Homes Standard. Although highly ranked in terms of perceived effectiveness, the boilers item also received the highest standard deviation with regards to sample agreement, thus perhaps indicating a degree of misunderstanding amongst respondents as to what was meant by this option in the survey. The other measures in this grouping – solar thermal, air source heat pumps and MVHR - all rank in the lower half of the table in terms of their perceived effectiveness with scores of 3.61, 3.30 and 3.09 respectively, with their standard deviations in the lower end of the range, suggesting marginally more agreement among the respondents with regards to their effectiveness when compared to other technologies. When compared with the perceived effectiveness of the more heavily adopted fabric improvement measures, it becomes evident that there is a degree of recognition of the challenges and pitfalls associated with the specification and deployment of space heating, hot water and ventilation systems. With heat loss through the fabric minimised thanks to the installation of insulation measures, a robust ventilation strategy is required and heating and hot water systems, as well as emitters an ancillaries, all need to be sized correctly to match the anticipated heating and cooling demands and also occupancy profiles. Air source heat pumps, for example, have a number of recognised issues around appropriate specification, sizing and siting that can significantly affect their performance (EST, 2010a; Kelly and Cockroft, 2011), solar thermal systems are sensitive to the cylinders, timers and back-up heating systems that they are married to (Flaherty et al., 2012) and whilst MVHR systems present a wide range of specification, installation and commissioning challenges (Banfill et al., 2011; InnovateUK, 2013; ZCH, 2014) as well as issues around usability (Heaslip, 2012b).

Solar photovoltaics were next after grade 'A' space heating and DHW appliances in terms of number of Registered Providers who had adopted them. This position in the list is itself interesting given that solar PV has been subsidised far longer than measures above it in the list such as air source heat pumps and solar thermal, which are both equally as sensitive to siting constraints. The English Housing Survey (DCLG, 2012a) makes this same observation, noting that of the 71,000 social housing properties in England with some form of solar panel installed, 23 percent were solar thermal installations whereas 77 percent were photovoltaic panels, a disparity caused largely by the presence of the Feed-in tariffs (FITs) scheme introduced in 2010. Solar PV is also perceived to be marginally less effective than solar thermal but suitability and performance is highly context specific, a matter evaluated later in this chapter.

Ground source heat pumps, combined heat and power, biomass boilers, the provision of high efficiency white goods and wind turbines all had significantly lower levels of adoption. This is largely due to the physical and technical limitations of such technologies, with many of the technologies only truly suitable for high-density accommodation such as block of flats and/or the presence of an on-site facilities manager. The lack of adoption of wind turbines is probably due to the view that wind is generally ineffective at a small scale and in urban and suburban environments limiting its applicability to housing (Drew et al., 2013) and the provision of high efficiency white goods often not considered as part of the remit of housing providers given that such items are often already owned by tenants. In terms of low effectiveness, two technologies stand out, biomass and wind turbines. Twenty Registered Providers adopted biomass with an average effectiveness rating of 2.11, slightly ineffective.

Wind turbines were only adopted by four Registered Providers and given a rating of 1.0 thus deemed as not at all effective.

There were four responses in the other category. Two of these responses were concerned with improved overall airtightness and two relating to the provision of low energy lighting. Whilst improved airtightness is a criterion that needs to be pursued as part of any deep whole house retrofit (Banfill et al., 2011), it was excluded as an option in the survey with the view that it is rarely adopted as a measure in itself and is instead typically achieved as part of an enhanced approach to insulating the overall fabric (Xing et al., 2011). For example, those that have achieved a marked improvement in airtightness will have done so through a package of measures such as solid wall insulation, upgraded glazing as well as active sealing up of service penetrations and unintended leakage paths. The mean effectiveness rating given for the two mentions of airtightness was 4.5 but this is an unreliably small sample. Low energy lighting was also deliberately excluded from the study as the resident, without landlord intervention, could directly adopt them. Low energy lighting was given a mean effectiveness rating of 4.

The mid to lower table heating, hot water and ventilation technologies raise another important consideration when it comes to perceived effectiveness. Where the higher ranking fabric improvement measures can typically be installed in isolation with little dependency on other interventions, the way in which many other retrofit technologies work together as a package of measures can have a significant influence on their performance (Simpson and Banfill, 2008). For example, heating systems provided without additional fabric improvements can lead to underperformance and resident dissatisfaction or MVHR without adequate airtightness can lead to a net increase in energy consumption. This is perhaps the single biggest difference between what is termed 'shallow' refurbishments comprising the implementation of medium cost measures (loft insulation, cavity wall insulation, central heating installations, improved heating controls, etc.) (Boardman, 2012) which have dominated the delivery landscape in recent history and whole house deep retrofits which involve a far greater number of interventions working in unison to deliver more significant cuts in energy consumption and carbon emissions (Hermelink and Müller, 2010; Reeves et al., 2010; GBPN, 2013). Although the survey question regarding technologies does not investigate the context in which measures are implemented or how respondents felt technologies worked as part of a package of measures, it is clear from the literature review that mainstream practices appear to remain rooted in the ad-hoc deployment of measures in isolation, with deep retrofits only being delivered at a pilot/demonstrator scale. Nevertheless, it can only be assumed that the technologies ranked here are predominantly judged on their generalised individual merits, with lesser consideration toward how they may perform in conjunction with other technologies or in certain contexts. There is perhaps also a degree of publicity bias toward some technologies, for example heat pumps, mechanical ventilation heat recovery and solar thermal all being the subject of high profile field trials in recent years (EST, 2010a; Flaherty et al., 2012; InnovateUK, 2014) and many insulation measures heavily promoted through central government backed initiatives.

In summary, loft and cavity wall insulation are the most heavily adopted and viewed as the most effective technologies. Grade 'A' rated heating and DHW systems, solid wall insulation and doors and windows are the next most highly rated group, also already deployed at reasonable scale in the sector. This in turn leaves many of the renewable and low carbon heating systems falling at the lower end of the adoption curve and with a perceived lower level of effectiveness. Overall, the correlation between adoption rates and perceived effectiveness was 0.65 suggesting a moderate correlation between the variables.

The standard deviations in table 24 indicate the level of agreement among the sample with regards to the level of perceived effectiveness. Removing the result for wind turbines, that has a very small sample, the standard deviations range from 0.80 for photovoltaics to 1.21 for grade 'A' rated heating and DHW water systems. What might have been expected is that there would be less agreement with regards to the effectiveness of products where there is more potential uncertainty in their performance driven by installation or in use risks, leading to a wider variance of outcome. Air source heat pumps for example, with a number of recognised issues around specification and installation that might affect their performance (EST, 2010a), and MVHR with issues around commissioning and usability (Heaslip, 2012a; InnovateUK, 2014). However, despite being small differences, the results show simple measures such as draught stripping (1.16) and what one would consider mainstream grade 'A' gas fired space heating systems (1.21) and high efficiency white goods (1.15) at the higher range of the standard deviations, suggesting marginally less agreement among the respondents with regards to their effectiveness when compared to other technologies. As previously identified, this further indicates that the complexity surrounding the notion of effectiveness is worth further consideration in follow up research.

5.4 Resident engagement and perceived views

It is widely recognised that even the most advanced and efficient building fabric and technologies will not perform to their optimum if unaware occupants undermine their intended use (Love, 2008; Galvin, 2014). Indeed, technologies may not even be adopted at all if residents are not made aware of the benefits early on in a retrofit programme, engaged fully in decision making and given chance to fully understand the implications of the upgrades and the upgrade process. Again, drawing on the experiences of Registered Providers in the delivery of the Decent Homes Standard, even the prospect of simply bringing a property up to a recognised standard of decency through the provision of measures such as new kitchens, bathrooms and heating systems (DCLG, 2006a) bore the issue of refusals and inability to gain access. According to the sectors statistical data return to the regulator, there were 54,813 properties that did not meet the Decent Homes Standard in 2011, with 31,487 (57 per cent) reportedly due to tenant refusal (HCA, 2013b). These numbers excluded Local Authority owned stock, where an additional 217,000 units were reported as non-decent however the proportion caused by tenant refusals is not known. Whilst the reasons for refusals can be complex and often linked to a residents specific personal circumstance, retrofit measures such as those discussed in the previous chapter may be considered just as difficult to deploy at scale, if not more so given that many interventions are equally as disruptive as the fitting of a new kitchen or bathroom (Egbu, 1997; Bell and Lowe, 2000b; Dowson et al., 2012; Sunikka-Blank et al., 2012; CPA, 2014) but also often less appealing from an aesthetic and functionality perspective.

Where measures are accepted and adopted, another resident engagement related challenge is that the energy savings from the improved energy efficiency in practice generally fall short of those predicted. This is typically attributed to; 1) a lack of follow up support to ensure physical measures are being used correctly and efficiently, 2) improvements in energy efficiency encourage greater use of alternative service and 3) design and specification models typically fail to take into account human behaviour (Chahal et al., 2012). Behavioural responses such as these have come to be referred as the rebound effect (Sorrell, 2007; Love, 2008; Galvin, 2014).

Registered Providers are acutely aware of the importance of resident engagement and participation and already successfully employ methods such as operating full time call-centres and tenant liaison officers, media promotion and provision of board membership to residents (Reeves, 2006; Jones et al., 2011). Indeed, in her analysis of the sector's approach to housing management Franklin observed that whilst many Registered Providers reference their role in the management of property, houses and homes, the emphasis overall tends to be on a service about people rather than property (Franklin, 2000). This has also been observed in this study and in follow up dialogue with respondents where few consider there to be a need to 'manage tenants', rather a requirement to provide a service to them as customers. A possible consequence of this being that as customers, resident requests (or complaints) may stand to override certain good intentions that a Registered Provider might have. For example, seeking to have sustainable retrofit technologies installed or encouraging behaviours that help reduce energy consumption. This has been experienced on the ground on a number of large retrofit programmes and formally reported on by Affinity Sutton, a large national Registered Provider where as part of a pilot project a sizeable proportion of residents opted to decline the installation of measures or asked for certain measures to be removed or reverted back to an previous specification due to personal preferences (Affinity Sutton, 2011).

In light of the sustainable retrofit technologies deployed to date, survey participants were asked to indicate which tenant engagement strategies they had employed and to rank each in terms of effectiveness on a Likert Scale of 1-5, with 1 being not effective and 5 being highly effective. The question did not address the number of instances where a particular engagement method was employed, rather it identified which methods were most common and how effective they were deemed to be. Table 25 compares the level of adoption of specific tenant engagement strategies as compared to the average perceived effectiveness for the specific approach; where again the perception of effectiveness is open to interpretation. For example, the relationship between energy, technology and consumer behaviour is complex and multi-faceted (Burgess and Nye, 2008) and different tenant engagement strategies may be deemed only effective at addressing particular elements.

Table 25 - Tenant engagement strategies employed and perceived effectiveness. Source: Author survey results analysis.

Tenant engagement strategies employed	Number of providers adopting (%)	Mean perceived effectiveness of approach	SD
Focus groups	79 (61%)	3.49	1.04
Board membership	69 (53%)	3.52	1.28
Neighbourhood groups	56 (43%)	3.56	0.86
Tenant liaison officers	53 (41%)	3.94	0.84
Web-pages or e-mail	54 (42%)	2.71	0.99
Postal mail shots	53 (41%)	3.06	1.03
Surgeries / drop-ins	35 (27%)	3.79	0.98
Other	22 (17%)	4.11	0.74

It is very interesting that in terms of total number of Registered Providers adopting, focus groups and provision of a board membership position came out as most popular. Focus Groups, where a group of people are assembled to participate in a discussion about a proposed retrofit programme or the technologies to be used, were employed by 79 of the respondents (61 percent) but deemed one of the least effective methods overall. One potential explanation for this may be that in the past, focus groups have been predominantly used to engage with residents on the matter of kitchens and bathrooms – aesthetic upgrades that present choices – however, the discussion of energy efficiency measures is very different. There is far more technological complexity and asides from focus groups allowing the benefits and impacts to be discussed with residents, there are fewer choices presented to residents with regards to the specification of equipment or its visual appearance. In follow up research it would be interesting to gauge whether focus groups are deemed to be more effective for discussing certain home improvements more than others, for example external wall insulation schemes may present the option for residents to choose the colour of their render whereas the roll-out of floor insulation or new heating systems may present far fewer customer choices and be less straightforward to consult on.

Board membership for residents was the second most common, employed by 69 (53 percent) of respondents but only rated marginally more effective than focus groups. This is likely to be for similar reasons – impersonal, too high level, limited outreach and limited opportunity to provide input beyond visual impacts and perhaps the value for money argument with regards to certain proposed investments. Although well practiced, neither focus groups nor the provision of board memberships are perceived by the respondents as being highly effective means of fully engaging tenants in the subject of sustainable retrofit. It is however important to acknowledge that this is the perception of the social housing provider themselves and not that of the residents. Although not substantiated by the survey findings or elsewhere in literature, both methods may be deemed ineffective due to them tending to only tending to reach out to smaller groups of people or particularly interested individuals who are already sufficiently bought in to the organisations activities. Further research into this would require a more focussed study on the matter of resident engagement methods with a more detailed definition of both the term resident engagement and effectiveness.

Tenant liaison officers (41 percent), web-pages/email newsletters (42 percent) and postal mail shots (41 percent) were the next most commonly adopted strategies. Of these, web-pages and use of email was deemed by far the least effective method overall with a mean rating of 2.71, with postal mail-shots second least effective with a mean rating of 3.06. Each of these approaches are very common conventional means of canvassing and awareness raising that offer a relatively low cost of reaching large numbers of people but which typically reliant upon existing degree of interest in the subject matter being promoted. With a clear technology deployment strategy and a good grasp of resident demographics and household types, such engagement methods can be better targeted and made more effective (Smith and Swan, 2010; Chahal et al., 2012; Crilly et al., 2012) but as identified by this study, few appear to have the strategies in place, the internal know-how, nor the overall supply chain confidence and resources to fully exploit these mediums more effectively. The use of tenant liaison officers as a means to engage residents was ranked as the most effective of all the methods (3.94) when the smaller population ranking the 'other' category is discounted. Although more research is required in this area, this perhaps portrays a view that personable one-to-one support offered directly to residents in the comfort of their own home is what is needed to communicate what is a complex and multi-faceted service offer. Unlike the majority of other 'one to many' approaches, a liaison officer is able to read a resident's particular circumstance, placing emphasis on the system benefits that are most likely to appeal to their needs (comfort, well-being, reduced bills, health etc.) and easing any tension or uncertainty that perhaps exists around access, disruption or unintended consequences. Surgeries and drop-ins were ranked the second most effective with a score of 3.79, which further reinforces the view that the sector thinks highly of the provision of tailored one-to-one support. It was however also ranked as the least adopted, suggesting there remains issues around delivery models and perhaps the financial costs involved. Tailored advice via staff employed specifically for the purpose of course being more expensive than running large focus groups, putting up board membership or operating a website or leafleting campaign.

A total of 22 respondents named 'other' resident engagement approaches. Of these, 7 responses referred to the use of different types of forums such as asset management steering groups, climate change panels, and a resident investment group which may be considered similar to focus groups but perhaps with a more function – for example, meeting quarterly to review all sustainable retrofit activity rather than being a one-off project only forum. 5 respondents referred to the running of events that are either project specific or simply community focussed with an aim to raise general awareness. Depending on how these are run, such events may be considered effective in that they might work similarly to surgeries and drop-ins provided that the event is adequately promoted and staffed. 5 responses then fall in to the mail-shot and web category with mention of the use of resident newsletters and project specific websites. 3 respondents refer to other slightly more novel direct means of engagement, such as through financial inclusion visits, telephone calls and one-to-one consultations and the remaining 2 highlight the advantage of using demonstrator homes and accompanying literature. With much of the sector having embarked on pilot projects (Kelly, 2009), it is somewhat surprising that very few in the sector mention that they are exploiting these as open homes for their residents to visit.

Perceived tenant drivers

Respondents were also asked to indicate what they perceive to be the primary drivers and barriers for agreeing to retrofit. This question was aimed to compliment another survey undertaken by the University of Salford and the Tenant Participation Advisory Service which sought to gain the direct views of the residents themselves (Chahal et al., 2012). Table 26 below summarises the responses given for what the Registered Providers themselves perceive the drivers for retrofit to be for their residents, where each respondent was limited to selecting a maximum of two options.

Table 26 - Perceived tenant drivers for retrofit adoption. Source: Author survey analysis.

Perceived tenant drivers for retrofit	**Number of Responses (%)**
Reduced fuel bills and running costs	127 (98%)
Improving comfort	82 (64%)
Concerns around climate change	24 (19%)
Improving health	17 (13%)
Other (please state)	0

By far the highest ranking perceived driver for residents is that of reduced fuel bills and running costs (98 percent of respondents) followed by the associated improved comfort (64 percent). A highly predictable outcome where financial savings are suspected as being the biggest motivator – a notion regularly put forward by the wider research community in wider policy debate (Healy and Clinch, 2002; Jenkins, 2010; Hills, 2011; Hopper and Littlewood, 2011). Interestingly however, the survey administered by TPAS found that over a quarter (27.9 percent) of respondents to their survey of 251 residents adopted energy efficiency measures simply because they were not given a choice and that 16.7 percent accepted the measures on the basis of reducing their fuel bills. The savings available are unquestionably important but there is clearly a miscommunication risk here, where providers of social housing may consider the benefits of energy efficiency measures to be such that they can proceed without opening up dialogue with the residents. Work by Consumer Focus suggests people's acceptance of change will very much depend on how involved they feel they have been involved in a decision and that whilst regulation can play an important role in influencing some people's behaviours, it is likely to be most effective when used alongside other tools to encourage and support voluntary change (Consumer Focus, 2012). Even if residents are not offered the opportunity to refuse it is imperative that they are still consulted (Chahal et al., 2012). This will not only boost tenant satisfaction and their appreciation of the efforts being made to deploy such measures but it may also go some way in ensuring that residents are getting the best out their energy efficiency measures and offers the best chance of long lasting effects.

Despite improved comfort also being perceived to be a big driver, Consumer Focus has also observed that it is not commonly promoted as a benefit (Consumer Focus, 2012). Nevertheless, there does appear to be consensus among the sector, research community and residents that increased comfort is a big attraction that needs to be better communicated (Gilbertson et al., 2006; Shove et al., 2008; Boardman, 2012). The TPAS survey found that 9.2 percent of respondents accepted energy efficiency measures because they wanted to make their home more comfortable, whilst research commissioned by the Department for Energy and Climate Change during the development of the Green Deal policy found that whilst the main attraction of the Green Deal for participants were lower energy bills (67 percent), a more comfortable home was attractive for 46 percent (DECC, 2011b).

Motives linked to concerns relating to climate change and environmental impact (19 percent) and the benefit of improved health (13 percent) are both ranked much lower whilst no other additional drivers were suggested. Such prioritisation of climate change as an issue correlates well with the DECC Green Deal survey which found that 24 percent of respondents found the Green Deal attractive because it was a tool that would enable delivery of measure that are better for the environment (DECC, 2011b). Interestingly however, the sample for this Green Deal survey was in fact exclusively owner-occupiers (1,684 households) and private rented tenants (339) and indeed reflective of the housing sector professionals themselves who were responding to our survey. Although a far smaller sample, the TPAS survey had 251 social housing tenant respondents where only 3.6 percent of residents indicated that they accept energy efficiency measures based on concerns relating to climate change and the wider environment (Chahal et al., 2012). Although difficult to draw conclusions through triangulation of these three studies, it does correlate with other studies that have found distinct differences in opinion toward climate change based on their social grade, with climate scepticism found to be particularly common among individuals from lower socio-economic backgrounds (Poortinga et al., 2011). It is also interesting that few appear to make a link between improved comfort and the associated health and well-being benefits. This is well documented in the research community (Thomson et al., 2009) but here comfort is deemed to be a more substantive benefit to residents than health, with the TPAS survey also in broad agreement with only 4.8 percent of respondents stating that they accepted energy efficiency measures on the basis that the more comfortable environment would improve their health.

Overall, it is clear that whilst Registered Providers recognise the importance of understanding their customer base and are well versed in supporting their basic needs, there remains a need to foster awareness with regards to energy efficiency measures and the benefits of having a warmer, more comfortable and healthier home whilst also helping to combat rising fuel prices. Unfortunately however, there is little evidence in the sector with regards to the cost benefit of such engagement and awareness raising activity and there remain only a handful of studies in the public domain that have sought resident views on the matter of how and when best to engage on the topic (Affinity Sutton, 2011; Chahal et al., 2012; Gee and Chiappetta, 2012). Nonetheless, each of these studies begin to signal that, as with more main stream commercial marketing practices, better researched and applied resident engagement practices show the potential to take the roll out for large scale delivery of sustainable retrofit from a place where it is being stipulated to one where deployment is led by a clear resident driven desire for a lower energy home.

Perceived tenant barriers

Table 27 below summarises the responses given for what the Registered Providers themselves perceive the barriers for retrofit to be for their residents, where each respondent was again limited to selecting a maximum of two options.

Table 27 - Perceived tenant barriers for retrofit adoption. Source: Author survey analysis.

Perceived tenant barriers for retrofit	**Number of Responses (%)**
Lack of understanding about new technology	75 (58%)
Lack of awareness around implications of fuel cost	64 (50%)
Upheaval during installation	61 (47%)
Lack of awareness / concern around climate change	38 (29%)
Poor experience with upgrade programmes	6 (5%)
Other (please state)	7 (5%)

The range of responses given is much less one sided than perceived drivers, which is in itself telling. Closely ranked at the top of the table is a lack of understanding about energy efficiency technologies (58 percent), lack of awareness around the available fuel bill savings (50 percent) and the upheaval and disruption caused during installation (47 percent). Again looking at the TPAS survey as a comparator, 56 percent of tenants also state themselves that the main reason for refusing measures would be related to the upheaval during installation. Although this challenge is not unbeknown to the sector given the number of pilot projects and demonstrators that it has undertaken, it does raise a significant challenge which requires Registered Providers and the wider supply chain to consider ways in which to upgrade properties with minimal disruption to the welfare of tenants and occupants.

Interestingly, no residents in the TPAS survey identify their own lack of understanding about the fuel savings that are possible but they do acknowledge wider technology related issues. With 24 percent expressing concerns that the new technology would not work and 20 percent saying that they question their ability to use the technology and make the most of its benefits (Chahal et al., 2012). Indeed all three of these issues – lack of understanding and confidence in technology as well as lack of awareness of available fuel bill savings – may be considered interrelated and just a slightly different way of articulating a general lack of understanding about technology options. This is a substantial and deep rooted problem where low energy buildings in general have tended to be heavily promoted on the basis of advanced and highly technical solutions which to many can be intimidating. This phenomenon is slightly tempered in social housing domestic retrofit but still housing sector professionals, tenant facing staff and other outlets all air toward discussion about technologies such as hybrid heating systems, advanced multi zone programmers, solar thermal systems and solar photovoltaics rather than the less exciting yet more effective and far easier to adopt fabric improvement measures such as floor, wall and loft insulation and conventional efficient gas boiler systems. This is an area that requires further research but it is almost as if attempts to make low energy homes sound technologically advanced and innovative to attract adopters can in fact have an inverse effect, making people sceptical and unsure in their own ability to use the technology effectively. All issues that have been experienced with the adoption of mechanical ventilation heat recovery ventilation systems (InnovateUK, 2014), heat pumps (EST, 2010a) and solar thermal systems (Flaherty et al., 2012). Clearly for deep retrofit to be achieved nationally, such technologies will be required but there are certainly opportunities to improve the overall clarity of message being given to tenants and for the sector as a whole to develop processes and practices that minimise the risk of solutions not performing as intended in use.

A lack of awareness and concern about climate change is the next perceived barrier with 29 percent of responses and the only issue that is considered a driver when understood and a barrier where such understanding is lacking. Nevertheless, with it being such high profile macro level subject matter and a driver for so few, one does have to question how worthwhile it is to tackle this barrier to adoption. For example, in MORI's series on the most important issue facing Britain, the environment has not been the top issue since the late 1980s. At its highest point since 1997 (19% in January 2007 named it as a top issue) it was still behind crime, immigration and the NHS (Mcilveen, 2010).

A total of 6 responses (5 percent) implied that a poor experience with upgrade programmes could also be deemed a barrier to adoption for residents. For example, they may have already had issues with the way in which Decent Homes Standard upgrades were delivered on their home or generally disapprove of certain actions being taken by their landlord. This is unlikely to ever be completely unavoidable but does illustrate the importance of sustaining resident satisfaction throughout the property maintenance and upgrade cycle and could well become a much greater challenge for the sector if their upgrade implementation strategy is trigger point based and piecemeal rather than 'one hit' whole house retrofit. Generally the sector has performed very highly in resident satisfaction as it is an area that the regulator and the registered providers themselves closely monitor, with the median overall net satisfaction with the landlord reported at 78% in 2012/13 (Raine, 2014). Nonetheless, there is no room for complacency and with the retrofit supply chain still under developed; there remains plenty of scope to deliver even greater levels of customer service. This study has not looked beyond the social housing sector much but the wider home improvement market is notorious for provision of poor service with Consumer Direct receiving 70,000 complaints relating to domestic contractors in the year to March 2011, more than any other sector (HM Government, 2013). This alone is thought to cost the UK economy £1.5 billion each year, highlighting an opportunity area for Registered Providers who can demonstrate their ability to work hard with their supply chain partners to not only transfer existing customer service skills to new delivery partners but to also help develop the sector as a whole in to one that the wider public will become more accepting of.

A further 7 respondents selected the ‘other’ category (5 percent), where 3 refer specifically to elder generations as being a challenge to communicate with and win over. Again necessitating tailored one-to-one communication methods to help eliminate any scepticism or doubts that they may have. Another 3 refer to the interconnectedness of resident behaviours, technology and provision of adequate support and the final response in the other category relates to there being a specific challenge related to finding solutions for residents in homes that are off the gas grid with solid fuel heating systems – long serving tenants in such properties having become accustomed to localised high temperature space heating systems and not always happy with switching over to a heat pump that operates on the basis of lower temperatures but higher surface areas.

These three sets of questions relating to the sectors attitude toward engaging their residents and what they perceive to be the primary motives and barriers merely serve as a high level attempt to understand the current engagement strategies being adopted and general attitudes and, as such, begs a number of questions that are worthy of further research. As previously mentioned, the relationship between energy, technology and consumer behaviour is complex and multi-faceted (Burgess and Nye, 2008) and the delivery of retrofit at scale for any segment of the housing sector needs to have residents and property occupiers at the centre of the process if both adoption and in-use issues are to be addressed. Climate change and wider environmental issues are clearly not a big driver for social housing residents with issues around fuel poverty and reduced running costs being the biggest driver. This is closely followed by the associated improved comfort and wellbeing benefits which many realise cannot be ensured if residents are not properly engaged in conception and delivery of the retrofit package or given adequate support in the post-completion phase. Not giving residents any choice in the matter is not an effective means to attaining buy-in and could stand to scupper any hope of either ever deploying the measures or getting the expected performance. An understanding of the barriers and issues highlighted in this, and other studies, suggests an argument for a best practice approach to engagement with residents during the process to address apparent inconsistencies in approach. While some of these approaches may only be applicable in the social housing sector, it is clear that the findings do have implications for the wider roll out of deep retrofit throughout the housing sector.

5.5 Summary

Collectively, the responses given in this survey give a comprehensive portrayal of the social housing sectors circumstance and attitude toward sustainable retrofit. There is an evident willingness to take action and lead the housing sector as a whole but also some fundamental challenges such as balancing the degree of improvement needed with the ability to fund the works; reconciling emission reduction with existing planned investment and responsive repair programmes; managing the risks associated with applying new and emerging technologies whilst also working to the constraint of ensuring minimal disruption to occupied homes and; ensuring that affordable warmth is available to residents without compromising affordable rents. All despite limited financial resources, budgetary constraints, split incentives, and under-developed retrofit supply chains.

Whilst it is easy to point fingers and lay expectations upon central government to put in place the necessary policy frameworks and supply chain props, there are considerable opportunities for Registered Providers to develop and refine their own approaches and delivery models. Indeed, the big challenge is for the Registered Providers to position themselves in order to identify and capture the benefits made to homes, individual tenants, the wider community, and the local economy to make a clear case to funders and lenders for the impact of the investment now and into the future. Central to this will be gaining an enhanced understanding of the stock and its potential for improvement, whilst developing strong working relationships with residents and local authorities in order to make informed investment decisions. This in turn can help the sector to realise higher numbers of retrofits, regardless of the enabling trigger – be it a logistical, technical, social or financial. In addition, through embracing innovation, the social housing sector can demonstrate an ability to attain true value for money; realising efficiency savings that not only help to control costs but also help contribute to other forms of added value and social outcomes such as job creation, training and sharing best practice, all from their investments in retrofit projects.

In a bid to use the key findings from the survey and accompanying research to draw conclusions and recommendations that have practical application, the fourth objective of this study is to identify what innovation is required to improve the delivery of low carbon domestic refurbishment in the social housing sector. Whilst there are clearly many areas where innovation could be explored and advocated (technological, means of engaging residents, developing funding models, for example), the key term is *improved delivery*. The macro topic of how the wider market can better transition to low-carbon existing housing has already been explored in depth (Killip, 2013) with the challenge clearly recognised as one of bringing about systemic change, which "should be considered as much a *market breakthrough* phenomenon as a *technological breakthrough* phenomenon" (Unruh, 2002; Killip, 2013). Taking a process orientated view of the delivery approach within the social housing sector therefore seems most fitting. For example, we have seen in the literature review and survey results that only 14% of Registered Providers had a low carbon domestic refurbishment delivery strategy in place despite the matter ranking highly as a challenge facing the sector; also high ranking barriers that largely centre around risks associated with internal capability to deliver, knowledge and wider supply chain readiness; less than ideal confidence in housing stock data and; a degree of inertia in terms of transitioning from a baseline where basic measures have already been installed where practical to the deployment of more advanced technologies that are inherently more difficult to specify, procure, install, use and maintain.

Rather than focus on specific product innovation or the role of policy, regulation and the wider supply chain, the next chapter instead explores what Registered Providers themselves can do from an internal delivery process perspective in order to enhance the delivery of low carbon domestic refurbishment in the social housing sector. By developing a delivery model of several modular stages with gateways, the recognised challenges can be more effectively categorised and addressed in turn. This, it is hoped, will provide a flexible model that Registered Providers can easily relate to and apply to their working practices; ultimately improving clarity of direction and associated resource needs, reducing delivery risks and improving quality of delivery and outcomes.

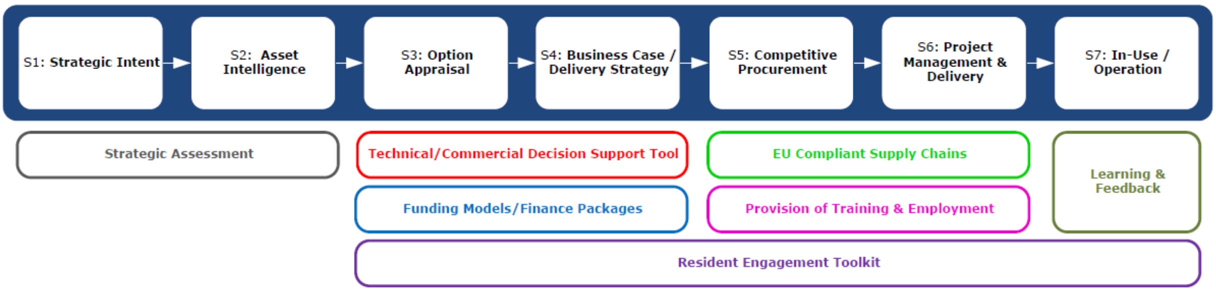
Chapter 6 - Developing a viable delivery model in the social housing sector

There are some distinct areas of concern that have been drawn out in this study, including issues relating to strategy, technical knowledge, supply chain capability and performance in-use. However, rather than propose radical isolated interventions in order to address such challenges in a piecemeal manner, it seems pertinent to review existing approaches to delivery as a beginning to end process and instead look at how a whole systems based approach to innovation may be applied. To this end, it is first worth reviewing existing asset management models and public sector programme management practices in order to determine a guiding structure that may be more easily recognised and adopted. This will in turn allow alterations to certain bad practices as well as new protocols and tools that address the documented key issues to be introduced in a phased and effective manner.

Although now defunct, the UK Office of Government Commerce (OGC) was once the sponsor for best practice project, programme, risk and service management. The OGC also hosted the Achieving Excellence in Construction initiative which put in place a strategy for sustained improvement in construction procurement performance and in the value for money achieved by government on construction projects, including those involving maintenance and refurbishment (OGC, 2003). Of particular interest to this work is that the body also set out the OGC Gateway Review Process framework (OGC, 2004) which to this day remains one of most recognisable set of programme management principles, no thanks in many ways to the manner it reflects PRINCE2 project management principles (OGC, 2009) which were also established by the OGC and heavily promoted among public sector professionals, including those in housing.

Using this Office of Government Commerce (OGC) Gateway Project Review Process Framework as a basis, combined with latest best practice guidance published by the National Housing Federation (Jones et al., 2011), an outline retrofit delivery model covering 7 key modular stages is given in Figure 9 overleaf.

Figure 9 - Outline retrofit delivery process. Source: Authors own illustration



Whilst the modular stages themselves are important in contextualising the principle activities involved in delivering low carbon retrofit, there are a number of proposed innovations that underpin the model which seek to address the main challenges highlighted by the literature review and survey findings. This includes an evident lack of strategic direction and housing stock data needed to make informed investment decisions, concern around not only the availability of funding but also the cost-benefit associated with certain interventions, a perception of inadequate and unprepared supply chains and also a degree of inertia in terms of rolling out advanced technologies that are inherently more difficult to specify, procure, install, use and maintain. Clearly defined protocols and tools proposed here to help address such issues include: a methodical means of strategic assessment based on robust housing stock data; a retrofit decision support tool and a suite of defined funding models; properly appointed supply chain delivery partners and a supportive training and employment model; distinct knowledge capture and feedback loops and also; a resident engagement strand that spans from project conception through to in-use and operation.

In the following discussion each stage will be explored, with particular focus placed on how retrofit projects are initially conceived and the subsequent stages leading up to attaining sign-off and procuring the necessary goods and services. Although the management and co-ordination of onsite delivery and post completion evaluation, as defined under stages 6 and 7 are essential, they are well documented issues and are therefore discussed in less detail.

6.1 Stage 1: Strategic Intent

The way social landlords are regulated has changed significantly, with the DCLG Review of Social Housing Regulation making it clear that the ‘fundamental responsibility for effective service delivery lies with landlords, not the regulatory system’ (DCLG, 2010a). As a result, the options for developing homes and new business opportunities are now linked to the generation of income from increased rents and active asset management. This means clear decisions have to be made about the organisation's priorities, putting the onus on providers to actively manage their business as a whole and have a very clear understanding of the markets and communities in which they operate (Jones et al., 2011).

It is therefore critical that providers are clear as to how their activities link into the organisation's overall vision and strategy. Although intent is early in the programme lifecycle, there must always be demonstrable links to the business strategy. Key to the success of this first stage is seeking a shared understanding – between board, executives, staff and service users – of what the intended outcomes from sustainable retrofit are and how they relate to the overall business plan. At a high level, sustainable retrofit may overlap with a broad range of existing organisational policies and strategic objectives. Although these relationships are likely to be complex, sustainable retrofit may play a role in delivering upon tenant satisfaction goals, affordable warmth policies, environmental commitments and the organisations long-term asset management strategy.

Isolating this matter from the wider survey results, only 14% of responding Registered Providers stated that they had a strategic plan in place whilst a further 37% declared that they were in the process of developing a strategy. The remaining 51% declared that they have actively undertaken some retrofit works but without any strategic intent or commitment. Having myself embarked on a number of projects with asset managers, sustainability officers, surveyors and members within finance teams, it is also apparent that for those providers that do have some form of retrofit strategy in place, scope and quality varies considerably from organisation to organisation. In some cases, providers have produced a standalone strategic document; whilst in others the topic is integrated into a number of different departmental delivery plans.

Given the weight and importance of a properly conceived strategy, it is alarming that there is no clear direction being given by the regulator on this matter beyond that of its broader requirements to make available an assets and liabilities register and to submit annual Value for Money self-assessments (HCA, 2015a). Nonetheless, an action for all Registered Providers to take before embarking on any low-carbon retrofit activity should be to appraise its specific systems, procedures, policies and programmes to establish capability to deliver, ideally supported by indicative estimates based on evidence from similar initiatives. High-level risks and a level of ambition should also be identified at this early stage, wrapping it up into a clear retrofit strategy that is tailor-made to fit with existing policies and systems.

6.2 Stage 2: Asset intelligence

There is a very distinctive interdependency for social housing providers between having an understanding of the housing stock they manage and formulating a comprehensive and effective retrofit strategy. Both should ideally feed one another, for example; a strategy may outline procedures and standards for data collation, whilst good quality asset intelligence will be central in helping to develop plans for the continued good management and improvement of assets. A project start-up process must draw together the justification for the project based on the policy or organisational objectives that are to be secured, an analysis of the stakeholders whose co-operation is needed to achieve the objectives, and an initial assessment of the programme’s likely costs and potential for success (OGC, 2004).

Again, looking to the survey results, 27% of respondents openly reported medium to low confidence in their housing stock data, illustrating that even with the right intent, a sizable proportion of the sector is not ready to immediately act in an effective and targeted manner. Moreover, with the likelihood of there being some bias in the response given to this question it is probable that there are many more providers with less than favourable asset intelligence; making awareness raising of the importance of good asset data as well as stimulating innovation in asset information management more important than ever before.

Typically, asset information has been needed by providers for a number of purposes, including charging to lenders; producing regulatory reports; valuing market rent to derive ‘affordable rents’; active asset management (repair, maintenance, demolition, renewal); and to provide valuation for loan security or balance sheet purposes (Jones et al., 2011). With high levels of trading activity, demanding due diligence requirements on loan security and the need to understand market values, it has always been essential to maintain records to a high standard. Providers operating without up-to-date and robust information about the condition of their properties cannot make any informed, manageable business decisions.

With the advent of the sustainable retrofit agenda, the need for accurate information about the physical characteristics of the stock, the current energy performance and potential energy improvement opportunities has never been more important. This has typically required social housing providers to undertake increasingly rigorous assessments of their stock portfolios, far beyond detail usually gathered during conventional stock condition surveys.

Given the costs associated with implementing detailed surveys to determine the energy efficiency performance of individual homes, most social housing providers have stuck to a ‘Level 0’ approach, a low precision stock level survey, used because reporting obligations to date have only required an average SAP rating (e.g. to demonstrate compliance with Decent Homes and the Housing Health and Safety Rating System (HHSRS)). Today, the Level 0 data format is slowly being superseded by the Reduced Data SAP (RdSAP) format, which includes measuring floor areas and noting key fabric elements, but this has not been a high priority as the primary purpose of an RdSAP assessment is only to produce a mandatory Energy Performance Certificate (EPC) when a property is re-let or sold. The repercussions of past and present approaches to maintaining asset information has led to the social housing providers typically possessing RdSAP assessment data on approximately a 30 to 50% sample of their portfolios. Other information held tends to be a degree of Level 0 data, full address lists and varying levels of stock condition data.

Without complete RdSAP data sets, it has been considered acceptable practice to only commission RdSAP samples that are deemed to be adequately representative of different house types and ‘clone’ across the stock i.e. copy known data for individual dwellings to the records for other dwellings for which there is no data. Provided that the sample size is large enough, low-precision energy surveys and RdSAP analyses can produce reasonably accurate housing stock profiles. However, they do not provide accurate assessment of the precise energy performance of individual dwellings, nor adequately support improvement option evaluation, for which more detailed and comprehensive assessments, such as full SAP, are necessary.

Although it may seem excessive to go in to such detail as to the circumstances of the data held by many Registered Providers, it is important given that it applies to so many and affects not only an organisation’s ability to determine a strategy but also its ability to make informed investment decisions on which to act. Where the detailed discussion is also particularly important is when we consider the scope for innovation with regards to asset intelligence. For example, in instances where properties must be visited to collate further data, for example to gather RdSAP data, or to validate existing data held, an opportunity to further improve asset intelligence is presented. For little added cost, thought should be given to instructing surveyors to collect additional data items during the planned surveys or scheduled property visits. For example, this may include logging the following items not commonly considered at survey stage;

- Notable built characteristics such as eaves and verge overhangs, external wall finishes and flat roof parapets – all of which will influence wall and roof insulation solutions
- Significant facade mounted services such as mains electric cables, downpipes, soil vent pipes, flue outlets and satellite dishes
- Property perimeter conditions such as immediately adjacent highways, draining outlets and runs, footpaths and narrow alley ways
- Roof orientation, area, inclination and overshadowing
- Gas, electric and water meter readings where resident consent can be attained

Where this additional data can be recorded and logged in the asset register, detailed appraisal of the suitability of different retrofit measures can become much easier and less speculative. To further improve the appraisal process it can also prove enormously beneficial for providers to overlay physical stock data with tenant demographic data and wider tenure patterns to help maximise outcomes, smooth logistics and better correlate the relationships between energy, people and technology.

Indeed, the ability to accurately assess sustainable retrofit options will be largely dependent on the level of asset intelligence held by a social housing provider. With low-precision or incomplete data that has perhaps been cloned or contradicted by other surveys over the years, it will not be possible to confidently assess refurbishment options without further survey work. Anything less than a large representative RdSAP sample will lead to the need for extrapolation and assumptions. This approach may falsely rule out potentially viable energy efficiency improvements at an early stage, compromising opportunities to attain maximum carbon reductions and fuel cost savings.

6.3 Stage 3 and 4: Option Appraisal and Business Case

Both the literature and survey findings reveal that there is an inertia associated with a number of technical and financial aspects of low carbon retrofit. For example, organisational commitment and difficulties relating to forming of a business case for sustainable retrofit were identified as a sizeable barrier (41 percent of respondents), whilst other high scoring barriers included a lack of technical knowledge, a perception of long term risk relating to defects and non-performance and also supply chain risks relating to general readiness, skills, equipment/products and repair and maintenance capabilities. Similarly, when asked specifically about the perceived effectiveness of technologies, the well understood interventions such as cavity wall insulation, loft insulation and glazing upgrades were ranked far more favourably by respondents than more advanced measures such as solid wall insulation, heat pumps, mechanical ventilation and renewables. As discussed previously this issue appears to be more one of wanting to minimise investment risk rather than an outright lack of interest or commitment to the cause. Therefore the development of tools and techniques to improve the way in which technology options are evaluated and specified will be fundamental to the way in which low carbon retrofit is adopted in the social housing sector.

The gap in the market for a means of comprehensively assessing of the full range of technology options was such that in parallel with this M.Phil research, the research sponsor, Fusion21, sought to work with myself and the University of Salford to develop and build such a tool. Termed a retrofit investment decision tool, the package provides full SAP energy modelling capability supported by cognitive rules, to help shortlist suitable measures, impartial guidance notes and a register of key risk items. Full SAP 9.90 was chosen not only because it offers a comprehensive means of assessment but also because it was felt that an industry standard approach will be required. From an innovation context, this is important, as the development of tools, especially those that create new metrics, can be a complex exercise when a specific approach is entrenched within the client base. Any new approach in the measurement and modelling of performance was therefore rejected on this basis.

The product selection approach is more innovative. The common approach in the UK to date has been to select archetypes and pick a standard package of parts that might work for a specific product family. The view taken is that, rather than look at the properties, the products should be considered as a starting point. This has led to the development of a rule-based approach that identifies property factors that either lead to a product being rejected, or highlighted as carrying a degree of risk. For example, for external wall insulation, understanding the construction, conservation status, site exposure and flood risk will lead to the discounting of some products. The approach is an attempt to capture "cognitive rules", which are still in development in the emerging retrofit market. While the knowledge may exist, it is not always well distributed or, currently, formally captured in processes and decision-making.

With an industry standard modelling engine and cognitive rules in place to shortlist viable options, the final component of the decision support tool was the incorporation of a knowledge base. This is explicitly linked to any indicative modelling recommendations to flag key design considerations and issues such as standards, warranties and other commercial risks that may arise for the specific technical options. The knowledge base also contains information about available funding mechanisms and potential income streams that may be used to defray costs of specific options. A particular advantage of this unique knowledge base approach is that it may be added to and refined as lessons are learnt from completed projects.

Ultimately, the Fusion21 technical/ commercial decision support tool that is formed by the composition of the key component elements enables users to cost effectively devise a business case for a specific package of works. Without such a user led tool it can be particularly time and resource intensive for social housing provides to attain board level project sign off and approval. Figure 10 provides an overview of the best practice full option appraisal process.

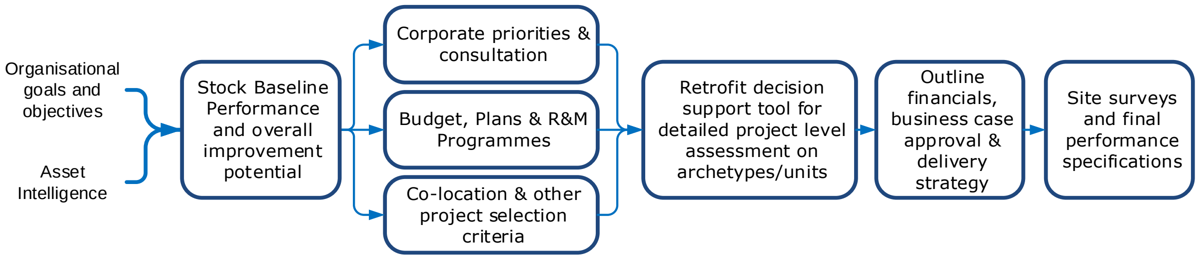


Figure 10 - The anticipated process of defining optimal retrofit improvement packages. Source: Authors own illustration

Once signed off, the final recommended package may be refined once competitive procurement has been undertaken and a lead contractor has been appointed. The final site survey stage may involve some non-destructive testing to verify construction methods used and assumed performance parameters, validating access arrangements and other key items that may have changed since the last survey, whilst also determining capacity for on-site storage facilities and any security issues.

For respectable levels of adoption, the technical feasibility study and option appraisal process should also be the start of a parallel resident engagement process. This is particularly important where tenant consent is required when looking to exploit pay as you save funding arrangements such as the Green Deal. Other key reasons for openly engaging residents ensuring they understand the rationale, process and benefits of any retrofit works to reduce refusals, minimise access and delivery complexities and ensure residents attain maximum benefits from any improvements installed. As has been identified in the sector survey, a sizable proportion of the social housing sector already appreciate the importance of adopting a resident engagement strategy but what is important here is that resident engagement spans the entire process – stages 3 through to 7 as a bare minimum. Beyond including residents in the initial review of acceptable technologies, Registered Providers should work through an initial pre-adoption consultation process, throughout the delivery stage and then also once works are complete and in-use so as to ensure optimal commissioning and operational performance.

6.4 Stage 5: Sustainable Collaborative Procurement

Although clear strategic intent, good asset intelligence and an informed business case are required prior to opening up a project to the market place, it is efficiency gains that can be achieved by social housing providers through collaboratively embracing procurement innovation that can ultimately drive the entire delivery model. Indeed, knowing precisely what to specify and procure can also help significantly in de-risking the implementation of certain technology options and ensuring the right elements of the supply chain are brought together to deliver on key performance criteria (Smith and Owen, 2011) – all matters identified as challenges in the literature and survey findings.

The initial drive to change and promote innovation in the construction sector, including how to procure in more efficient ways in order to bring improvements within the construction industry, was instigated by Government supported reports by Latham (1994) and Egan (1998, 2002) and Gershon (2004). The Gershon Efficiency Review sought to specifically push public service efficiencies, particularly through promoting the aggregation and reorganisation of buying functions to smooth delivery processes whilst realising savings in procurement. All three reports stressed the importance of innovation within the industry, contending that continuous service and product improvement, driving increased efficiency and profitability can only be achieved through innovation. Other benefits discussed include improved leadership, customer focus, integrated processes, integrated project supply chains, improved quality, and improved commitment from stakeholders.

Following the efficiency drives, a particularly successful example developed within the social housing sector was the Fusion21 model. Fusion21 is a social enterprise, formed in 2002 by 7 social housing providers in Merseyside with a remit to promote collaboration to drive efficiencies and help its clients realise wider social benefits such as the provision of training and creation of sustainable jobs. The organisation has since grown to operate its procurement frameworks nationally, helping to deliver its clients capital and cyclical procurement work programmes, create sustainable jobs for local people whilst also generating significant cashable savings.

The success of Fusion21's activities for its clients was later sought to be replicated by the Homes and Communities Agency (HCA) with its Social Housing Efficiency Programme (SHEP) which ran from 2005 to 2011, managed by the National Change Agent. The programmes objective was to improve efficiency in asset management works within the social housing sector by creating procurement consortia. There are now 14 consortia across England offering long-term supply chain partnering contracts in a bid to reduce project costs, improve delivery outcomes, customer satisfaction and provide some training and local jobs.

Many of the consortia models works by amalgamating demand, work-smoothing and selecting products from a focussed range of options in order to drive economies in the supply chain. Key to the success has been their approach to separating the procurement of materials from installation. This allows national scale consortia to deliver regionalised solutions, so that Small and Medium Sized Enterprises are able to compete for work. Moreover, as a social enterprise Fusion21 re-invests some the cash efficiencies saved through its procurement model to deliver training to the unemployed and develop skill bases in the local communities in which it operates. It is such models, addressing the linked issues of procurement, supply chain, skills and social issues that must to be more widely brought to bear on the retrofit challenge by Registered Providers.

6.5 Stage 6: Project Management and Delivery

Project management is the process by which projects are defined, planned, monitored, controlled and delivered such that the agreed benefits are realised. Projects are unique, transient endeavours undertaken to achieve a desired outcome or change (OGC, 2004) and project management is recognised as the most efficient way of managing such change (APM, 2006). What is meant by this stage 6 is the physical delivery of works and the need for these works to be project managed and delivered within time, on budget and to the specified level of quality. Unquestionably a key step within the wider process that concerns the coordination of the construction works on site including management of a workforce, health and safety aspects, waste and resources, programme management and so on – the well-established and heavily practiced discipline of construction works oversight and delivery.

With the Rethinking Project Management report (Winter et al., 2006) as well countless other Government and Industry construction project management studies, industry has already taken considerable steps to innovate and improve overall efficacy in the on-site delivery of works and there have been notable developments that the retrofit supply chain must ensure it adopts. For example, the Government's Plan for Growth, published alongside Budget 2011, highlighted the critical importance of an efficient construction industry to the UK economy (HM Government, 2011a).

Nonetheless, with an overall good practice approach to construction works management aside, what is yet to be realised with regards to the on-site delivery is greater whole process thinking. Rather than use of main contractors and delivery teams that act on instruction, Registered Providers instead need to encourage and stimulate the supply chain as a whole to step up to the challenges faced. For example, product suppliers and installers need to seek to quash the sectors evident uncertainty with regards to the effectiveness of certain solutions by actively working with the sector to develop new technologies and approaches rather than expecting the social housing providers themselves to completely front the adoption risks. Other challenges such as coming up with new systems and approaches that minimise disruption associated with the installation of certain measures or new site practices that help assure installation quality also need to be dealt with in this way. The weight and might of the social housing sector is unique in this regard and innovation in the development and delivery of retrofit measures stands to be best driven by extending the engagement with the manufacturers, suppliers and the installer base beyond that of just the delivery phase and out into early optional appraisal stages and through to the in-use, operation and evaluation.

6.6 Stage 7: In use, Operation and Feedback

There are technical, social and process factors which all need picking up on in the final stages of a retrofit project. From a technical perspective there is a need to understand whether the technologies installed in the properties perform as expected. Although the survey itself perhaps fell short in this regard in terms of the question relating to perceived technology effectiveness, the matter of performance in use is a well-documented industry concern in both the new build and retrofit sector (InnovateUK, 2013; ZCH, 2014) that can only be addressed if investments are made to investigate and understand performance – be it through in-situ non-destructive testing, long term monitoring and evaluation, qualitative post construction reviews with the delivery team and residents or a blend of all three. Such investigations may, for example, identify that a product or solution has been either incorrectly specified or detailed, incorrectly installed or not performing due to user or context factors.

The second strand concerns the occupants and the way in which they interact with their retrofitted home. Are the occupants reacting to the retrofits as expected, are they able to use the technologies and are they using them correctly and effectively? Putting in place protocols, tools and techniques for addressing such questions should never be discounted from a retrofit project. For example, it is assumed that 25% of potential fuel bill saving will be used to increase comfort in poorly heated properties (Camco, 2011); often referred to as Jevons Paradox whereby improvements in technology are offset by greater consumption. Appreciating exactly how much saving has been realised therefore requires in-depth pre and post-completion evaluation of energy consumption and user behaviours. Residents also need follow up support to ensure that the physical measures are being used correctly and efficiently, without which residents can be left dissatisfied or indeed incurring greater running costs than prior to the retrofit.

Finally, the process must be closed out with the conjoining and capturing of feedback loops, ensuring all insights from all stages of the delivery are fed into not only the next project for that provider but also for wider industry (Maqsood, 2006). Learning is partly captured from the post-occupancy evaluations (POE) (Turpin-Brooks and Viccars, 2006; Hadjri and Crozier, 2009) as described above but it generally also requires conscious steps toward organisational learning and knowledge management to taken (Henderson et al., 2013). At present it is widely recognised that the construction industry typically adopts single-loop learning in isolation, where symptoms of problems are solved as they arise in a form of fire-fighting (Henderson et al., 2013). Essentially where learning is present but it does not result in change in organisational behaviours, beliefs or values. What the research community and innovators in the construction sector argue however is that double-loop learning is needed. This is where existing organisation norms and assumptions are questioned to establish a new set of norms (Dainty, 2001). The practice allows problems and their root causes to be detected, uncovered and addressed in a fashion that establishes new ways of working. It is a heavily researched practice and precisely what needs to be recognised by Registered Providers and their wider sustainable retrofit supply chains before embarking on retrofit at scale.

There are already promising practices and conceptual solution's to many of the stages described here but the findings from this study suggest that few parties are fully embracing the retrofit challenge and addressing the delivery process as a whole. There are a large number of demonstrator and pilot projects, but those that have robust monitoring, not just of performance, but also of construction and in-use phases, are limited. Innovation in finding optimal ways to capture and widely circulate new findings and practices via effective communities of practice (Wenger et al., 2002) is an unquestionable priority.

6.7 Summary

Examining the delivery model as several modular stages with gateways gives a clear framework that findings from the literature and survey not only plot against but which also allows the recognised challenges to be more effectively categorised and addressed in turn. Particularly given that the stages are based on well-founded best practices (OGC, 2004) that readily relate to the existing asset management practices adopted by Registered Providers.

Low carbon refurbishment simply cannot take hold in the social housing sector if, for example, Registered Providers do not establish clarity of direction through the development of a delivery strategy. Nor can the delivery and performance risks that are currently deemed as barriers be overcome if the asset intelligence and option appraisal tools used to inform decision making are inadequate or if procurement practices, project delivery processes and feedback loops are not clearly defined.

Chapter 7 - Conclusions

The aim of this M.Phil thesis has been to draw upon existing literature, a large sample study of the social housing sector and active engagement with key sector stakeholders in order to develop a robust and coherent understanding of the current status of the social housing market with regards to the adoption and implementation of low carbon refurbishment of existing social housing stock. More specifically, the study has investigated the:

1. Context of the low carbon domestic refurbishment agenda and its impact on social housing generally
2. Perception of retrofit as a challenge in the social housing sector
3. Strategic intent in terms of the adoption and implementation of the low carbon domestic refurbishment agenda in social housing
4. Knowledge and capabilities of the social housing sector in terms of the adoption of low carbon domestic refurbishment
5. Perceived drivers and barriers for the adoption of retrofit
6. Adoption of specific low carbon domestic refurbishment technologies in the social housing sector
7. Adoption of resident interventions with regards to low carbon domestic refurbishment within the social housing sector

7.1 Knowledge, capabilities, drivers and barriers

When the relationship between fuel poverty and the national commitment to drastically reduce carbon emissions is coupled with the need to develop retrofit supply chain knowledge and capacity, the logical place to make a start with large-scale energy efficient refurbishment projects is with social housing. The agenda aligns well with the sectors remit to provide affordable housing, and any improvement works that help to mitigate fuel poverty amongst residents are, unquestionably, of high priority for all social housing providers.

Although the social housing sector only represents 18% of UK housing stock, (4.7m homes), it offers an existing infrastructure of housing association and local authority bodies that are already active in maintaining and refurbishing homes in a way that is acceptable to the occupant. As such, the social housing sector is well placed to provide a level of client led project management and supervision that does not naturally exist in the private sector - an important factor where the current supply chain and maturity of skills for sustainable retrofit do not yet exist in the UK (Jenkins 2010).

The sector differs markedly from other housing sectors in that it is regulated and heavily influenced by Government policy. This is exemplified by the works undertaken to meet the Decent Homes Standard from 2001 to 2010/11, which led to an average of £10,000 per home being invested in basic repair, weatherproofing, improved thermal comfort, modern kitchens and bathrooms (Power, 2008). Whilst not as complex as sustainable retrofit, Decent Homes shares many of the same issues, such as the need for high levels of private borrowing repaid via rental streams, volume procurement, large scale delivery of improvement measures, gaining access to people’s homes and engaging extensively with residents.

The findings show that the social housing sector is aware of sustainable retrofit as an important issue and that there is a clear degree of strategic intent. Nonetheless there is also clearly still some way to go with there being an evident lack of strategic direction and the housing stock data needed to make informed investment decisions, concern around not only the availability of funding but also the cost-benefit associated with certain interventions, a perception of inadequate and unprepared supply chains and also a degree of inertia in terms of rolling out advanced technologies that are inherently more difficult to specify, procure, install, use and maintain.

7.2 Policy issues

Ultimately a number of linked issues will drive or hamper the desired market formation for sustainable retrofit. The first issue is policy. The study was during a time of uncertain policy, which to some extent has been resolved in the sense that little support to social housing providers is likely to be forthcoming (Conservatives, 2015). Though with proposals such as an extension of the right to buy policy into the social housing sector and the prospect of social housing rent reforms that could lead to a 1% annual reduction in budgets, the sectors capacity to act could yet be further challenged – with both initiatives potentially polarising the sector into choosing to focus either on the construction of new homes or deep renovation of existing.

In concert with this are the issues with the implementation of energy efficiency policy initiatives such as failure for the Green Deal to adequately serve the social rent market, radical changes to the Energy Company Obligation mid-term, delays and uncertainty surrounding the domestic Renewable Heat Incentive, short notice cut back being made to the Feed-in-Tariff and sporadic half-baked initiatives such Green Deal Home Improvement Fund Vouchers and Green Deal Communities. If the UK Government wishes to deliver the market transformation it desires, policy uncertainty will need to be reduced. Policy makers must also recognise that decisions with regards to social housing are not made in a vacuum. Decisions that reduce income and funding support is a real and very valid concern for the sector and one that can stand to significantly impact the ability of social housing providers to engage with the sustainable retrofit agenda.

7.3 Organisational priorities

The second issue is the organisational perspective. What are the drivers for individual organisations to engage with the sustainable retrofit agenda? There is a view from the respondents that sustainable retrofit is important but other organisational priorities such as the need to build new homes, combined with the need for a well-defined business case and access to finance are all facts of life that low carbon aspirations come up against. Social housing providers will not be inclined to engage in sustainable retrofit if it does not deliver for the organisation and its residents. In shaping the market, the social housing providers and their residents are taking on risk. Low levels of knowledge concerning sustainable retrofit, in both social housing providers and their supply chains, means that there are risks of non-performance of installations. In the longer-term, this could also mean defects in properties, potentially leading to negative health effects for residents. Social housing providers' first obligation is to their residents. Market-making, no matter how desirable for the UK Government, should not be pursued at the risk of residents health or financial well-being. Presently, the view is that the sector is being asked to take on the risk of engaging with an immature market sector, so that less experienced and well-resourced clients in the private sector can procure more confidently. The UK Government needs to more clearly spell out its position in the regard. Effectively understanding and assessing the barriers for social housing to engage with the kinds of programmes that will build the desired skills and knowledge will then be required.

7.4 Technology adoption and performance in use

The third issue is that the sector needs a better understanding of real energy use, including behavioural issues. The range of differences in energy use between similar properties may indicate that the physical nature of the property is a much weaker indicator of energy use than demographics, economic and weather data, as used in National Energy Efficiency Database (DECC, 2011f). Some sensitivity analysis should be undertaken to understand what factors have the biggest impact based on real data. In addition, there are clear gaps between some of the claims for performance, modelled performance and the actual performance of building products (Bell and Lowe, 2000b; EST, 2010a; Flaherty et al., 2012; Drew et al., 2013). Registered Providers and the wider housing sector needs to build an evidence base that helps us better understand what real performance is, otherwise we are potentially making false choices based on modelled information.

Despite such challenges and very real concerns, Registered Providers have sought to proceed with what they can. This is of course partly thanks to at least some funding finding its way in to the sector but also largely due to the sector's natural inclination to do what it can to support its customers and the convenient fit that many existing planned investment programmes already have with the sustainable retrofit agenda. For example, the survey shows some predictable patterns of adoption of retrofit technologies with low technology, grant-funded options being almost universal, while more complex technologies, particularly those based around new approaches to heating, such as biomass or heat pumps, less widespread. The social housing sector is starting to engage with these newer technologies, although the data does not indicate whether these are commonplace within the Registered Provider's stock, or merely demonstrator projects.

Considering effectiveness, there is a question as to what social housing providers actually know about the performance of retrofits and how they may be defining the term effectiveness. This limitation of the study does highlight the importance of the research community needing to understand the different definitions and perspectives of what effective solutions might be. There needs to be a better understanding of effectiveness as viewed not only by technical staff, but also residents. This can only be achieved through effective monitoring and evaluation of retrofit projects to build an evidence base that a social landlord can access. Large-scale monitoring projects such as FutureFit (Willey, 2012) are not widespread. This needs to change, projects need to be undertaken and the results widely disseminated.

7.5 Interlinking policy, process, people and technology

The full breadth of financial, legal, technical and socio-technical challenges discussed have, to a large extent, prevented the rollout of energy efficiency improvements to existing social housing properties to date, despite financial incentives and the clear benefits for both the providers and the residents. Although there is very rightly a strong consensus that better defined, more transparent regulation and fiscal support is required to stimulate the market, it is also critical to acknowledge that retrofit at scale is a complex process and requires innovative new whole system based delivery approaches if it is to be both effectively managed and delivered at scale. While many of the ideas identified within the newly proposed delivery process exist, there are clear benefits to be gained from thinking beyond established models in a more holistic manner.

Delivery of retrofit at scale is a different type of problem from the technical solutions that are offered up to deliver a demonstration project. There are wider issues that need to be addressed and it is still an emerging market. The policy, process, people and technology issues interlink and, as such, require a coordinated response that addresses all of these factors. Social housing providers must also play their part and seek to develop clear strategic intent and realise a shared internal understanding of what the intended outcomes from sustainable retrofit are and how they relate to the overall business plan. They must also actively build on their asset intelligence and, at the very least, build up complete data sets on their stock portfolios. With these two corner stones in place, the remainder of the retrofit delivery process can be very cost effectively realised through the bringing together of existing software such as the cognitive rule based retrofit decision tool developed for Fusion21 and wider construction sector best practice with regards to procurement, organisational learning, knowledge management and feedback.

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Appendices

Appendix 1 – Summary of the survey questions

Appendix 1: Overview of survey questions

<u>Social Housing Retrofit Questionnaire: The State of the Nation</u>

1. What type of social housing organisation are you? (Tick **one**)

- Housing Association (traditional)
- Housing Association (LSVT)
- Housing Co-operative/ Community based HA
- Local Authority
- Arms Length Management Organisation
- Other

2. How many homes approximately do you manage? (Tick **one**)

    - <250,
    - 251-1000,
    - 1001-5000,
    - 5001-10,000,
    - 10,000 – 50,000,
    - >50,000

3. What best describes the geographical spread of your organisation's activity? (Tick **one**)

    - National
    - Regional
    - Local

4. In which regions do you operate? (Tick **as many as appropriate**)

    - North West
    - North East
    - Yorkshire and Humberside
    - East Midlands
    - West Midlands
    - South West
    - East of England
    - South East
    - London

5. What do you feel is the hardest challenge facing the Social Housing Sector at the moment? (Tick **one**)

    - General Economic downturn,
    - Reduced development programme,
    - Housing benefit cuts,
    - Sustainable retrofit,
    - Social Instability / ASB,
    - Threat of restriction of role to 'welfare housing'
    - Other (please state).

6. What is your current progress with achieving the Decent Homes Standard – i.e. 95% of properties to meet Decent Homes Standard? (Tick **one**)

    - 95% complete now;
    - Will complete 95% by Dec 2010;
    - Will achieve 95% by Dec 2011,
    - Will achieve 95% later than Dec 2011.

7. What is the average SAP* rating of your properties? (Type **number**)

8. Which of the following best describes your organisation's current approach to the sustainable retrofit of your properties? (Tick **one**)

    - Strategic plan in place and delivering
    - Developing a Strategic plan
    - No plan as such but a number of projects undertaken
    - A Few Pilot projects only
    - None

9. When do you anticipate your organisation adopting a retrofit strategy? (Tick **one**)

    - Have already
    - 2010/2011
    - 2011/2012
    - 2012/2014
    - In +5 years time
    - Do not anticipate adopting a retrofit strategy

10. Which of the following best describes your level of confidence in your stock condition and asset management data? (Tick **one**)

    - Very High
    - High
    - Medium
    - Low
    - Very Low

11. Do you chiefly rely on internal or external skills and knowledge to help you understand the retrofit agenda? (Tick **one**)

    - Internal
    - External

12. What sources do you rely on to gather new information about retrofit approaches? (Tick **maximum of 3**)

    - Manufacturers
    - Installers
    - Consultants
    - Industry Reports
    - Networks (e.g. other RSLs, NHF)
    - Internet
    - Universities
    - Government Advisory Services i.e. Carbon Trust

13. Which technologies have you installed or trialled on your properties? (**Tick as many as applicable**)

    - Air Source Heat Pumps
    - Biomass Boilers
    - Cavity wall insulation
    - CHP Boilers
    - Draughtstripping
    - Grade A appliances with supplements (e.g. gas-savers)
    - Ground Source Heat Pumps
    - Loft Insulation
    - Mechanical Ventilation/ Heat Recovery
    - Photovoltaics
    - Solar Thermal
    - Solid wall insulation solutions
    - Supply of high-efficiency white goods to residents
    - Thermally efficient Door and Windows
    - Wind Turbines
    - Other - Please state:

14. For those technologies you have used, please rate them from highly effective to not at all effective with **1 being not effective** and **5 being highly effective**.

    - Air Source Heat Pumps
    - Biomass Boilers
    - Cavity wall insulation
    - CHP Boilers
    - Draughtstripping
    - Grade A appliances with supplements (e.g. gas-savers)
    - Ground Source Heat Pumps
    - Loft Insulation
    - Mechanical Ventilation/ Heat Recovery
    - Photovoltaics

- Solar Thermal
- Solid wall insulation solutions
- Supply of high-efficiency white goods to residents
- Thermally efficient Door and Windows
- Wind Turbines
- Other - Please state:

15. Which tenant engagement strategies have you employed to inform and engage residents around the retrofit agenda? (Tick **as many as applicable**)

    - Focus Groups
    - Board Membership
    - Neighbourhood Groups
    - Tenant Liaison officers
    - Web-pages or e-mail
    - Postal mailshots
    - Newsletters
    - Surgeries/drop-ins
    - Other – please state:

16. For those strategies you have used, please rate them from highly effective to not at all effective with **1 being not effective** and **5 being highly effective**.

    - Focus Groups
    - Board Membership
    - Neighbourhood Groups
    - Tenant Liaison officers
    - Web-pages or e-mail
    - Postal mailshots
    - Newsletters
    - Surgeries/drop-ins
    - Other – please state:

17. What are the key drivers to encourage your organisation to install sustainable retrofit measures in your stock? (Tick the **3 most important**)

    - Government Policy and Targets
    - Organisational Commitment
    - Available Finance
    - Resident Demand
    - Climate Change
    - Fuel Poverty
    - Maintaining Asset Value / stock condition
    - Maintaining lettability of property
    - Reduced fuel bills and running costs for tenants?

18. What are the key barriers which are preventing you installing sustainable retrofit measures in your stock? (Tick the **4 most important**)

- Lack of funding support
- Lack of technical knowledge
- Lack of equipment supply chain
- Lack of installation skills supply chain
- Resident resistance
- Too much long term risk – e.g. defects or non-performance of equipment
- Lack of repairs and maintenance supply chain
- Lack of robust business case
- Lack of policy and Government intervention
- Commercial difficulties such as failure to establish a viable business model/strategy
- Other organisational priorities – e.g. development / community investment

19. What do you think are the main drivers for your tenants in adopting retrofit solutions in their homes? (Tick the **2 most important**)

- Concerns around climate change
- Reduced fuel bills and running costs
- Improving comfort
- Improving health
- Other (please state)

20. What do you think are the main barriers for your tenants in adopting retrofit solutions in their homes? (Tick the **2 most important**)

- Upheaval during installation
- Lack of awareness/ concern around climate change
- Lack of awareness around implications of fuel costs
- Lack of understanding about new technology
- Poor experience with upgrade programmes
- Other (please state)

Appendix 2 – Review of low carbon refurbishment technology options undertaken on behalf of Fusion21

Appendix 2: Review of available domestic low carbon refurbishment options

Date: September 2010

By: Luke Smith, KTP Associate (Salford University) on behalf of Fusion21 (KTP sponsor)

This appendix explores the available and emerging technical refurbishment options in depth and begins to consider the advantages and disadvantages of each of the approaches. Much of the insight is drawn from practical experience as well as industry guidance such as that published by the BRE, The Energy Saving Trust, the Construction Products Association, AECB and the Energy Efficiency Partnership for Homes.

Insulation

Whilst approximately a third of heat loss occurs through the walls of most properties, it is important to ensure continuity around the entire envelope of the building to successfully conserve energy. Working from the ground up, the following insulation measures should be addressed:

- *Ground floor insulation*
    - Solid & suspended floors
- *Wall insulation*
    - Cavity wall
    - Solid Wall – Internal and External
- *Roof insulation*
    - Pitched roof
    - Flat roof

Ground floor insulation

Solid Floors:

Most homes built post 1950 are likely to have solid concrete floors or use suspended concrete systems. Solid ground bearing floors are considered difficult and costly to insulate. In almost all cases the temperature difference between internal spaces and the ground is significantly smaller than the temperature difference between the internal spaces to outside air. In general, recent research[1] has shown that solid ground floor insulation as an addition to well-insulated walls and roof, contributes very little to the building's overall thermal performance. The designer should balance the extra benefit(s) attached to installing a new slab with the cost, marginal carbon gains and disruption involved.

An additional factor to consider in reviewing the viability of the solid floor insulation is its location within the build-up. The likely heating use patterns of the occupiers will often dictate whether to install insulation below or above the slab:

- Where a quick heating response time is required, for example when a family returns home in an evening, insulation above the slab should be considered.

[1] George, M.D.J; Greens, A J & Graham, M.2006, Stimulating simulations. Building for a Future, Volume 15, No 4, Spring 2006 pp.28-32

- Where heating is used over more prolonged periods, for example where a space is occupied throughout the day, the thermal mass provided by a slab over the insulation should be considered.

Table 1 illustrates the possible options and the advantages and disadvantages of each approach;

<table>
<tr><th>Method</th><th>Advantages</th><th>Disadvantages</th><th>Opportunities</th></tr>
<tr><td>Upgrade existing slab – Add insulation and new floor deck on top of existing floor</td><td>- Simple and easiest way of improving thermal performance but can be compromised by knock on requirements else where
- Insulation above the slab increases heating response time</td><td>- Raised floor level – skirting/ radiators/ reduced door heights.
- Unequal step heights at stair cases
- Big step up at external doors
- Requires remedial work is undertaken on slab before installing insulation</td><td rowspan="3">- If the property is void insulating the floors is a relatively straight forward process (same as a new build floor).
- If solid floors are not taken up then the only means to add insulation is on top of the existing slab.</td></tr>
<tr><td>New slab – dig out old slab and create new build up with insulation above the slab</td><td>- The insulation can be used to run services and underfloor heating
- Insulation above the slab increases heating response time</td><td>- Considerable upheaval for tenants
- No significant amount of thermal mass to ‘buffer’
- Point loading on insulation must be considered
- Floor coverings should be durable
- High cost</td></tr>
<tr><td>New slab – dig out old slab and create new build up with insulation below the slab</td><td>- Provides thermal mass, particularly effective in southward facing rooms. Acts as a thermal buffer
- Thickness of insulation is less restricted
- Slab takes the loading</td><td>- Considerable upheaval for tenants
- Rooms are slower to heat in comparison with an above-slab condition but heat is stored
- High cost</td></tr>
</table>

<u>Suspended floors:</u>
Most houses built before the 1950’s will have suspended timber floors and these tend to be much easier to insulate. Large air gaps between floor boards and skirting may also be filled using sealant, such as silicon to minimise draughts. In all cases however it is important to maintain sub-floor ventilation beneath the suspended timbers to prevent rotting. Table 2 below illustrates the possible approaches to insulating suspended floors:

<table>
<tr><th>Method</th><th>Advantages</th><th>Disadvantages</th><th>Opportunities</th></tr>
<tr><td>Rigid slabs - friction fitted between joists</td><td rowspan="3">- All are quick to install
- Lightweight fabric lends to a relatively quick heating response time
- Minimal additional loading to the structure
- A cheap and easy ‘quick fix’ is to eliminate the draughts using sealant</td><td rowspan="3">- Provision of continuous ventilation restricts the efficiency of the insulation. Attaching a breather membrane to underside of the joists should help
- Very important to maintain continual flow of air to prevent joists rotting
- No thermal mass
- Air leakage through floor boards can be a problem if not adequately sealed</td><td rowspan="3">- Rotten floor boards or damp penetration is likely in older properties and will require lifting, thus providing an opportunity to insulate
- If the property is void insulating the floors is a relatively straight forward process</td></tr>
<tr><td>Insulation quilt – installed upon mesh or netting to suspend between or fixed to the undersides of the joists</td></tr>
<tr><td>Blown insulation – contained by mesh or boarding beneath the joists</td></tr>
</table>

Wall insulation

Cavity wall:

Most properties constructed after 1930 are likely to have cavity walls. Cavity wall insulation is presently considered as a simple and cost effective means of reducing heat loss through a building fabric. However moisture problems, reduced air circulation/ventilation, resultant cold spots and inadequate damp proof courses are often encountered. A survey carried out by the BRE shows however that there is no evidence that filling cavities with insulation resulted in any greater incidence of damp problems than in walls with empty cavities. The study showed that the structural condition of the cavity wall is the critical factor in avoiding damp penetration. Table 3 below lists methods available to insulate cavities and the advantages/disadvantages of each:

Method	Advantages	Disadvantages	Opportunities
Blown polystyrene/other similar oil derived products	- High thermal performance - Cavity Insulation Guarantee Agency (CIGA) offers 25 year guarantees - Cheap and common	- Cavities of less than 50mm cannot be insulated - Loose fill can be affected by settlement and result in cold spots - Derived from petrochemicals and highly polluting production process - High embodied energy - Finished product can give off unstable residues which may outgas - Any alterations/cuts made in the wall flood the room with beads, unless if bonded	- All systems can be installed quickly and easily at any stage but structural integrity and appropriate detailing per each individual property is critical - Improved insulation levels can be achieved at a later date by adding a layer of internal or external insulation - Thermal imaging may be used to identify poor workmanship
Blown mineral derived products – mineral wool, glass wool, cellular glass	- Low cost - Industrial waste content - Recyclable - Inherently non-combustible and resistant to rot - Cavity Insulation Guarantee Agency (CIGA) offers 25 year guarantees	- Thermal performance reduced by 75% to 105% with a 1% change in moisture content by volume - Urea formaldehyde content - Loose fill can be affected by settlement and result in cold spots - Cavities of less than 50mm cannot be insulated - Loose fill can be affected by settlement and result in cold spots	
Plant/animal derived – cellulose, cotton, flax, wool, cork	- Breathable and Hygroscopic (humidity control) - Low embodied carbon - Renewable - Reusable	- Expensive - Dust given off during installation high risk of inhalation - Thermal performance may be improved if compacted but difficult in a cavity	
Injected polyurethane systems	- Provides best thermal performance of all cavity insulants - Doesn't settle and offers best continuity - 50+ life and doesn't degrade - Moisture resistant and can improve structural integrity, high compressive strength - Can be used in all cavity widths (see Kirkgate House, Edinburgh) - Recyclable and reusable	- Derived from petrochemicals and highly polluting production process - High embodied energy - Finished product can give off unstable residues which may outgas - Can crack with movement in the cavity and cause tracking	

Solid wall:

There are approximately 7 million (31% of all homes) solid wall properties in the UK. These properties are considered 'hard to treat' and the market for such measures is presently in its infancy and considered an 'emerging market'. Solid walls can be insulated either internally or externally however not all buildings will present an 'either/or' scenario. It is likely that a combination of external and internal insulation will evolve to meet the needs of the brief.

A combination of both external and internal insulation may be required, for example where the appearance of the front facade is to be maintained to comply with planning requirements, or, the facade borders a pavement. In these instances, it is common to apply internal insulation to the front wall and external insulation to other walls. Continuity, adequate overlapping and understanding of cold bridging is critical in all cases. Where a terraced house is refurbished and the adjoining properties remain un-refurbished, the party walls will need insulating.

The Tables 4 and 5 overleaf consider the advantages and disadvantages for the internal and external insulation options;

Table 4 - Internal insulation:

Method	**Advantages**	**Disadvantages**	**Opportunities**
Whilst not a definitive list, some internal insulation approaches include: - Insulation-backed plasterboard applied directly to the wall or mounted on battens to create a service void - Insulation fitted between battens and finished with plaster boarding - Flexible thermal linings (aerogels)	- Maintains the external appearance of the building (no planning issues) - Internal spaces warm up quickly - Can be undertaken incrementally as and when rooms require works internally e.g. when fitting a new kitchen the internals of external walls can be insulated	- The adding of insulation reduces internal space, and, in historical buildings, will likely compromise decorative features. - Radiators, fixings and services need to be addressed. - The necessity to minimise encroachment on space will restrict choice of materials. Depending on budget this may possibly restrict the achievable u-values. - Depending on how many rooms require insulation on the walls – residents may have to re-locate for the period of the works	-If internal plastering work has to be carried out, this presents an ideal opportunity to add internal wall insulation -If major works such as rewiring, installing a complete heating system or fitting a new kitchen or bathroom are undertaken internal insulation may be installed at the same time

Table 5 - External insulation:

Applying insulation externally will change the appearance of the building, for example render or brick slips may be applied. This might be an intended benefit, or it might be considered detrimental to valued historical building.

Method	**Advantages**	**Disadvantages**	**Opportunities**
Whilst not a definitive list, some internal insulation approaches include: - Wet render on insulation/insulated render - Timber, tile and slate cladding - External insulating dry lining - Bespoke systems - Multi foils	- External insulation usually provides the designer with a greater flexibility in the choice of insulation materials and insulation thicknesses to obtain optimum u-values - External insulation will preserve the existing internal thermal mass. Thermal mass may be important in regulating the internal room temperatures - A complete external insulation system is the best way to minimise thermal bridging - Will not require decanting residents - Protects the walls from the weather	- Living spaces will be relatively slow to warm up - Junctions between the added insulation and other elements (eaves, verges, openings etc) will need re-working - Replacing windows at a later date may become difficult if not considered prior - Rain pipes, satellite dishes, drains and balconies may be problematic - Later puncturing from service runs in future years.	- If external render has to be replaced or extensive pointing of brickwork is needed, there is an opportunity to insulate externally - Change in appearance usually requires planning permission

Roof insulation

The insulation methods likely to be adopted in the roof will largely be dictated by how the roof space has been designed and is used. For example a pitched roof may be a 'warm' roof or a 'cold' roof with loft insulation only. The roof may also be a ventilated roof space (most common) or some roofs may be 'unventilated' through the use of a breathable sarking membrane with a low vapour resistance. Some roofs may be inhabited or a whole-house retrofit strategy may require a warm roof in which to accommodate equipment such as MVHR systems.

The vast majority of existing roofs will be of the 'ventilated' type. Though if the roofing needs replacing a designer may opt to replace the roof with the better-performing 'unventilated' type. Table 6 overleaf illustrates approaches to insulating a pitched roof.

Method	Advantages	Disadvantages	Opportunities
Rafter level insulation on, under or between the rafters. *Another consideration may be insulated plasterboard on the underside of a sloping ceiling.*	- Creates a warm roof space - Easier to connect the roof insulation to external wall insulation – critical in ensuring continuity.	- For retrofit it is most likely that insulation will be added internally. If an impervious sarking felt is to be left in place it is important to create a ventilated air space between the felt and the added insulation. This often entails tricky detailing, especially at the eaves. - If the roof space is inhabited thickness of insulation is usually restricted.	- When reroofing insulation should be addressed - If modifications are being made to the heating system wet systems will likely be removed from a cold roof space – the roof can then be insulated more thoroughly
Loft Insulation at joist level – may be insulating quilt or blown insulation	- Cheap and cost effective to top insulation levels to between 250 and 300mm thickness - Minimises heated volume of the dwellings (best option if roof is uninhabited)	- Ventilation at the eaves must be maintained as sarking felts are often impervious – this makes it difficult to fully insulate properly - Difficult to insulate around trussed rafters, in to difficult to reach areas and around services such as tanks and pipes. - Electric cables must be kept on the cold side of the insulation and down lights must boxed or not insulated over.	- Can be installed at almost any time with minimal disruption

Table 7- Flat roof

Flat roofs are the most prone to incurring defects. If the option exists to replace the flat roof with a pitched type, then this course should be seriously considered.

The majority of existing flat roofs will be of the 'cold roof' type. Though common and workable in many instances; problems of maintaining cross ventilation within the roof often lead to condensation issues and thermal bridging which inherently reduces the thermal performance. The optimum solution is to opt for a 'warm roof' build up where insulation is located over the waterproofing layer.

Method	Advantages	Disadvantages	Opportunities
Warm deck – insulation on top of existing roof finish and another water proofing layer added	- Renews water proofing layer on the roof - Insulation is fully sealed from the elements	- More work and additional layers such as a vapour control layer is needed increasing the cost - Insulation is fully sealed from the elements	- Both approaches would be suited to overlay existing flat roof systems providing existing deck and waterproof membrane is sound

Inverted warm deck – existing water proof layer retained and loose fitted water proof insulation added above it and held down with ballast	- Insulation layer protects the existing roofing membrane from thermal stress, UV light and mechanical damage	- Roof loading is increased - This solution isn't fully sealed and cold air and water can reach to the warm side of the insulation. - Higher risk of condensation	- Likewise both approaches would be suited to total renewal. A cold roof build up is not recommended on flat roofs.

Air Tightness and ventilation

Air-tightness is critical to the thermal performance of a building. What must not be ignored however is the need for a combined, consistent air-tightness and ventilation strategy. The objective is to provide a balance by minimising heat loss due to air leakage whilst maintaining indoor air quality.

In a high-performance building where insulation is optimised, the proportion of overall energy then lost through warm air leaking through gaps/cracks in the fabric to the outside becomes relatively high. In this situation warmed air is replaced by cold air from the outside, causing draughts and discomfort. Constantly heating this replacement air is inefficient and compromises the overall performance of the heating system. The implementation of a strategy to enforce air-tightness using materials, careful detailing and construction, is considered key to realising maximum thermal performance.

At the same time, adequate ventilation is required to remove moisture and pollutants to provide fresh air for the occupants and to provide a means of cooling in the summer (a serious consideration as global temperatures are on the rise and our stock becomes well insulated). If increasing insulation levels, minimising heat loss and air movement adequate means of ventilation is needed – put succinctly 'build tight, but ventilate right'.

Method	Advantages	Disadvantages	Opportunities
MVHR –Address all air leakage points (windows, doors, walls, floors, roof and services) seal all joints with tape and make good. When very air tight ventilate less than $5m^3/m^2/h$ by mechanical means such as MVHR.	- Air leakage/heat loss is almost completely eliminated and heat recovery efficiencies of over 85% can be realised - Continuous supply and extract improves comfort levels and air quality - Operational power consumption is very low – approx 0.5 W/l/s - Simple to operate 'whole house system'	- Difficult and thus expensive to comprehensively seal and prevent all air leakage in existing builds often designed to breathe. Air leakage rate must be less than $5m^3/m^2/h$ @ 50Pa. - MVHR = high capital cost, ducting system is difficult to retrofit and insulated space is required for the kit (warm roof required) - Filters require regular replacement - Low efficiency systems and high fan powers can outweigh benefits - There is a cultural/behavior issue ensuring tenants keep the house sealed i.e. do not open windows	- All air tightness and ventilation strategies should be addressed when fabric improvements are made. For example installing any form of floor, wall or loft insulation presents a good opportunity to ensure insulation continuity and good air tightness. This in turn requires a good ventilation strategy

Positive input ventilation - air tightness improved where reasonably practical to below $10m^3/m^2/h$ (less than building regs) and mechanical input pressurises the dwelling and is allowed to escape through background ventilation/vents	- One central air input system as opposed to multiple fans and inlets/outlets - Low cost and easy to retrofit	- Fans typically run continuously at low speeds so important to ensure they are a low power type - Resident express concerns of noise and running cost. - May not suit some house types as positive input often mounted in roof space and supplies air via central hallway or stairwell - Background ventilators must be permanently open	- Air leakage pathways may be identified using pressure testing and smoke pencil tests to ensure the most comprehensive air tightness. - If extract fans need replacing there is an opportunity to install low wattage replacements with humidity control and valves or even fit a heat recovery room ventilator - Major refurbishment works may present an opportunity to achieve very high levels of air tightness and whole house MVHR at reasonable cost
Localised Mechanical Extract – air tightness improved where reasonably practical to below $10m^3/m^2/h$ (less than building regs) and local extract fans in wet rooms (kitchen/bathroom/utility) provide adequate air changes + operable trickle vents and windows	- Low power fans can replace existing systems at a low cost – these should be fitted with a humidistat controller - A single-room heat recover ventilator may be used as an alternative that recovers 60% of heat from the outgoing air to preheat incoming replacement air	- Self-closing valves required on extractors to prevent heat escaping when not in use - A degree of reliance on the user to ventilate other rooms adequately – humidity controlled vents could be an alternative (good quality units should be used as some leak air when closed) - Air quality may be poor if air tightness is high and extract/replacement rates are less than $4\ m^3/m^2/h$	
Passive stack ventilation – air tightness improved where reasonably practical to below $10m^3/m^2/h$ (less than building regs) and ventilate wet rooms (kitchen/bathroom/utility) with passive stack system + operable trickle vents and windows	- Requires no electricity, so no CO^2 - User friendly – background ventilation provided by opening windows and vents. Passive stack works naturally with nor user input - Very low maintenance	- Self-closing valves required on stacks to prevent heat escaping when ventilation not required - Vertical or near vertical ducting from wet room to roof required – not possible to incorporate in some dwellings - A degree of reliance on the user to ventilate other rooms adequately – humidity controlled vents could be an alternative (good quality units should be used as some leak air when closed)	

Windows and Doors

Windows and doors are typically responsible for 15% of heat loss from a property and largely contribute to improving the thermal comfort of the occupants, as well as reducing fuel bills. Nevertheless there are numerous different scenarios to consider.

A common barrier is that the appearance of windows in an old house often contributes to its character. This is particularly true of historic buildings and buildings within conservation areas. Consultation with a Local Authority planning / conservation officer is recommended at an early stage in order to determine a window treatment strategy. Refurbishment, high performance single glazing panes, high performance secondary glazing, shutters and insulated blinds or curtains are common approaches.

If there are no planning restrictions and existing windows are old, single glazed and leak air around their casements and frames they must be replaced at the soonest opportunity.

Dealing with more recently installed windows, such as those fitted to meet the decent homes standards, that are likely double-glazed, well-made and reasonably air-tight (check pre-refurbishment air-tightness testing), is slightly less straight-forward. Approach will largely depend upon budget, the window size (effect on overall heat loss) and ability to carry-out any remedial works such as draught-stripping, replacement of single glazed panes with double glazed, or the addition of secondary glazing.

The performance of a window in not only determined by the U-value of the glazing, but also the U-value of the frame, the proportion of the frame in the window, the solar transmittance of the glazing i.e. its g-value, and also the air tightness of the unit as a whole. Fortunately all these factors are taken into account by the British Fenestration rating Council (BFRC) system, who provide a simple A to G rating for windows they have assessed.

Whilst windows are high cost and cover a small surface area of the overall building fabric (the process by which SAP calculates credit is based on surface area improvements). As improvements to other fabric elements are made windows will become the source of highest heat loss but more importantly are closely linked to thermal comfort felt by tenants. The Passivhaus standard comfort level criteria dictates that the there should not be more than 4 ^{o}C between any surface and air temperature.

In a building where the walls are well-insulated the temperature difference between the wall surface and room temperature is minimal, but the temperature differences between glazing and room temperature (assuming an indoor room temperature of 21^{o}C) can be significant according to glazing type:

- between single glazing and air temperature can be around 20 ^{o}C
- between double glazing and air temperature will be around 8 ^{o}C (providing good air tightness this is acceptable)
- between triple glazing and air temperature will be around 4 ^{o}C (i.e. within Passivhaus comfort criteria)

New and replacement doors, whether un-glazed or partially glazed, should contain insulation between the two outer surfaces. Insulated doors can currently achieve U-values as low as 0.8W/m^{2}K, which is a significant improvement over solid timber doors which achieve typically 3.0W/m^{2}K. The main energy saving feature however is in the reduction of air leakage. This is often achieved by the use of multi-point locks to ensure that the door seals are properly compressed. The table below illustrates some of the replacement options;

Method	**Advantages**	**Disadvantages**	**Opportunities**
Highest thermal performance – triple glazed high performance window units and insulated external doors	- Insulated window frames minimise overall heat loss - Three panes of glass with gaps filled with low conductivity gas give optimum performance - Optimal thermal comfort/acoustic performance/security	- Products will likely be imported from Europe - High cost and not likely to be viable on project that have recently had double glazing - Long pay back period (40+ years)	- It is important to recognise that windows are replaced infrequently and good quality windows will last for 50 years so it makes sense to install the best that can be afforded. - Install high performance windows and doors when replacing old

High performance double glazing units and insulated external doors	- Can way out perform normal double glazed units - Argon filled double glazing can achieve a U-value of 1.0 (Pultec)	- Triple glazing can perform better. Choice of windows will depend on financial circumstances and required performance	- Window replacement should only happen when wall insulation can also be afforded so that both can be installed at the same time (windows correctly positioned in the openings and air tightness addressed) - Replacement windows should be supplied and installed by a company registered with Fenestration Self-Assessment (FENSA www.fensa.org.uk) who 'self-certify' compliance with part L1B
Refurbish existing window units and doors – may include adding nano films, vacuum glazed panes, replacing seals and resealing the units. Secondary glazing, thermal blinds and curtains may also be considered	- Carbon cost effective - Short payback period and easy to install - Emerging new films positioned internally can largely minimise the most significant losses (radiation through the glazing)	- Maintenance and durability concerns – films will likely need replacing approximately every 20 years	

Space Heating

Once the best practical standards of insulation and air-tightness have been programmed, the proposed refurbishment should be thermally modelled to determine what will probably be a much reduced space heating load. A new heating system should be planned to meet this new load.

A decision will be taken on whether to use the existing boiler or replace it. Likewise, the existing heat distribution system will need reviewing. What will probably be the case, will be that both the boiler and the radiator (or other) system will be over-sized for the revised heat load.

If the gas boiler is of the old non-condensing type, operating efficiency requirements will indicate it requires replacement with a new correctly-sized gas condensing boiler (the best boilers are durable and maintain their condensing efficiency). A slightly less conventional alternative worth considering might be a bio-fuelled boiler using, for example, wood pellets or chips. If choosing the latter, the designer should be aware that the installation needs to be matched with an assurance of fuel supply and consider the management of the system i.e. fuel ordering, cleaning etc. Such systems are unlikely to be practical once the fabric insulation have been addressed.

The Construction Products Association suggests that 91% of British homes have central heating, 87% of which have gas central heating and around 40% of boilers are combination type, providing heating and 'instant' hot water from the same boiler. Wet central heating systems are by far the most common and most likely to be encountered in a retrofit project.

The main factors which need to be taken into consideration when choosing a new system are:

- Fuel type - In terms of CO2 emissions the best choice will be between gas (where available) and wood fuel. If choosing a wood-based system consideration should be given to availability of fuel supply.
- Boiler size - The size of the boiler needs to be carefully calculated based on projected hot water and space heating demand – particularly where a building has undergone significant insulation and air-tightness improvements.

- User needs - The pattern of use might determine the type of boiler selected. If, for example, a large family uses hot water at the same time, a system including hot water storage would be preferable on the other hand, a combination boiler is likely to be perfectly adequate for a small flat; another consideration might be a boiler's capacity to heat a space in reasonable time.

- Space - The amount of available space can also determine both the boiler type and also the adopted system. Where space is at a premium, or if locating a feed tank and its associate pipe work in a loft is undesirable, then a form of combination boiler is possible choice whereas if hot water storage is important for example if the system is to be integrated with solar heating or a heat pump, then a system that includes a storage system will likely be preferred.

- Renewables - The inclusion of renewable sources of heating energy, particularly solar thermal, should be a consideration. The selection of a gas heating system will be determined in large part depending on whether ancillary sources of heating are to be accommodated.

Method	Advantages	Disadvantages	Opportunities
Ultra efficient gas boilers – system/approach adopted will largely depend on what is installed and on the chosen water heating approach	- Most common primary heating solution and cheap to run - Gas fuel is low carbon and most preferred non renewable - Boiler efficiencies of over 90% readily available + may be improved further with add-ons such as gas saving - Understood by tenants and easy to control / programme. TRV's give temperature control in each room. - See EST – CHeSS specifications HR8 and HC8 for best practice	- Property must be on gas - More sophisticated programmers are available but also need a sophisticated user - the exhaust will appear as a continuous plume of steam which can be off-putting in some positions and gives less flexibility in placement options - Regular maintenance and fine tuning is required to attain best efficiencies. Durability of advertised efficiencies is a concern.	- Regular servicing of heating equipment will ensure that high efficiencies are maintained. All central heating systems should be controlled with a time switch or programmer, thermostatic radiator valves (TRV's) and a room thermostat that switches the boiler off when the boiler is up to temperature. Upgrading controls is a fairly cheap and cost effective measure
Biomass – wood pellets/chips	- Considered best Offer a greater carbon reduction possibility than the closest efficient alternative, LPG, and are a much better choice than oil - Fuel source once well-established is a renewable - Can be controlled much in the same way as a gas boiler - The fuel for biomass may be a waste product, adding value to by products. - Growing biomass crops produce oxygen and use up carbon dioxide	- Require space to store the wood chip fuel - A necessary well-functioning market for wood chips and particularly wood pellets has yet to develop in the UK - Air pollution associated with wood has raised concerns - There is a need for a back up system down due to the widely fluctuating load pattern on the system - Frequent delivery of wood chips required and weekly cleaning and removal of ash should be taken in to account - Carbon impact to grow and harvest fuel	
Air Source Heat Pumps – whilst in some circumstances can be used on their own, they will usually be installed in conjunction with a boiler heating system	- Cheaper and easier to install than GSHP's - Whilst performance values vary widely, the best performing systems that are well designed and installed operate well and can achieve a COP of 2.8 to 3 in the UK (similar to that of gas) - Air-to-air or air-to-water possible	- Far less efficient in winter - It is argued that in generating one unit of energy, a gas boiler emits around a third of carbon than the equivalent electricity grid unit – a ratio of 1:3. Since most heat pumps operate in an overall like-for-like COP range of 2 – 3, the likelihood is that mains gas fuelled condensing boilers will most commonly produce a smaller carbon footprint (until the grid electricity becomes greener) - Nosier than GSHP's	- When a boiler breaks down, is more than 10-15 years old, or when the heating system is being modified, the opportunity to install and efficient 'A' rated boiler and advanced controls should be taken (the hot water

Ground Source Heat Pumps - whilst in some circumstances can be used on their own, they will usually be installed in conjunction with a boiler heating system	- Relatively constant COP compared to ASHP - Very efficient at cooling - Quieter and longer life expectancy than air source heat pumps	- More expensive and difficult to install than ASHP - The ground loops require space close by to the building - Three times more expensive than a gas fuelled boiler & radiator system - Requires a low temperature differential between the ground and the output e.g. low final temperature system such as underfloor heating or oversized radiators	system should be upgraded at the same time) - Major refurbishment work should include a review of heating options, with the possibility of installing low carbon alternatives in combination with improved time and temperature zoning & controls
Electric storage heating	- Suitable for off gas where heating demand is very low and no realistic alternatives - Underfloor or fan assisted off-peak storage heaters are the best options - Low tech and easy to operate/control - Could be efficient in small, low load flat with good insulation	- High carbon intensity - By far the most expensive system to run when powered by the grid and at peak rates - Should not consider if property is not very well insulated and has not got good thermal mass.	
Micro-CHP	- Generates both heat and electricity in one unit. 4-8kW of heat for every 1-3kW of electric - Can be the same size as a conventional domestic boiler - Can be powered by a wide range of fuels - An rapidly emerging technology	- Requires a large heating load for long periods of the day and of the year to be efficient (inefficient for shot run cycles). Community/district scale CHP may be best in a social housing context - Lack of technical understanding/knowledge - Units currently have low life expectancy - High capital costs and installation costs	
District heating	- Biomass heating on a district/community scale is common in Europe, as is CHP, use of surplus heat from industrial processes, and incineration e.g. waste incineration - Good for high densities of people - System can provide space heating and hot water	- A long term investment strategy is needed (reduced investment in building heating equipment) - Connections to individual homes can be expensive	

Hot Water

With a downsized, more efficient space heating system, producing domestic hot water (DHW) becomes the highest thermal load in the property. Whilst many of the above space heating systems have the capacity to also provide water heating, - the installation of water efficient appliances and use of solar energy is the highest contributor to cost-effective energy efficiency.

A well-designed and properly installed solar domestic hot water system will typically produce between 50 – 60% of a home's annual hot water needs. In summer a solar collector will produce between 80 – 90% of requirements, with the figure falling to around 20% during the winter months.

Method	Advantages	Disadvantages	Opportunities
Solar hot water	- Can more than half the hot water demand on a conventional gas system - Will qualify for financial support under the Renewable Heat Incentive (RHI) as of April 2011 - Whilst collectors work best orientated to the south but they work quite well when orientated between south-east and south-west, a larger collector may overcome poor orientation - Evacuated tube collectors are more efficient than flat plate collectors, especially in overcast conditions	- Requires more than just the solar thermal array - combined cylinder containing a solar heat exchanger (twin-coil)/storage tank and pipe work required. Solarsyphon solution should be a consideration (heat exchanger). - The sun doesn't shine at night so means of storage required - Clouds and rain reduce the panel performance - An auxiliary heat source is required i.e. gas system/biomass or other heat producing appliance also required	- As part of the planned refurbishment, the immediate installation of a solar thermal system might be considered inappropriate. However, it might still be prudent to provide fixings and pipe work to enable an installation to be easily installed at a later date. - Yield from solar is dependant on the collector size and type, angle of incidence, shading, size of tank and the geographic location - Micro bore pipe work serving each appliance separately can be used to reduce the 'dead leg' between the boiler and the appliance - Ensure cylinders and pipe work is all well insulated for all system approaches - Check with the local planning authority that collectors are acceptable
Ultra efficient gas boilers – gas condensing combi, regular boiler and hot water storage cylinder	- Hot water available on demand - Already installed in most homes through the Decent Homes standard - Most common approach and best understood by installers, users and specifiers	- Efficiency of many combi boilers is low if producing hot water only - Many combi's have limited functionality in terms of adding other heat sources such as solar/heat pumps	
Electrical water heating i.e. immersion heating	- Best suited to 'intelligent electrical power distribution systems' i.e. heating water when grid demand is low and turning off when load is high (Economy 7) - With well insulated storage and a renewable power source this approach is a viable option	- Expensive to run at peak rate - High carbon intensity if electrical power is from non renewable sources - Would not suit users with a high hot water demand e.g. large family properties	
GSHP, ASHP, and biomass and other unconventional methods	- All may be used as a hot water solution in parallel with providing space heating - Advantages much the same those listed above for space heating	- Solar water heating far outweighs the performance of these options - Disadvantages much the same os those listed above under space heating. - All these solutions better suit space heating demands than hot water	

Electric Power and Micro-Generation

Once energy efficiency measures have reduced the heat and electricity demand as far as in practicable, low and zero carbon technologies will be required to reduce the dwelling's energy use in order to achieve an 80% reduction in CO^2 emissions. Today electrical power represents high-grade energy as conventional electrical power is drawn from the national grid, where, in most part, it is generated inefficiently using fossil fuels.

The proportion of energy generated from fossil fuels is likely to be reduced through the introduction of large-scale renewable energy along with a re-vitalised nuclear industry. However, renewable systems at a domestic or community scale can offer a significant contribution in both reducing the dependence on the grid and to the proportion of electricity used in the home.

To put things in to perspective; using a unit of electricity in the home produces about three times as much carbon dioxide emissions as using a unit of gas. A unit of electricity is also about four times more expensive than a unit of gas. Therefore energy saving electrical appliances, good housekeeping, and micro-generations systems can make a significant impact on household fuel costs and emissions[2]. Research by the Construction Products Association (CPA) suggests that as more is done to reduce fuel used for heating, the more significant are emissions from electricity use.

However, where micro generation measures have been incentivised in Germany it has been found that electricity usage by some tenants actually increased. This is largely due to the 'flexibility' of electricity in that our lifestyles can, and are, becoming increasingly electricity intensive through the adoption of large televisions, computers etc, all being used simultaneously. Resident behaviour and understanding is therefore a critical component to also address.

There are lots of simple measures that can be adopted at the very early stages of the retrofit process to minimise electrical power usage. For example; low energy lighting, grade 'A' white goods and low energy appliances, voltage optimisation units and raising resident awareness of the issues are all considered' low hanging fruit'.

Unlike the renewable energy technologies employed to produce heat such as solar hot water and heat pumps, the production of electrical power can be more complex and demanding on capital investment, technological sophistication and planning. Because economies of scale are likely to be involved, domestic-scale solutions will not always be the best. Often larger communal or dedicated off-site generation will be favoured over equipment installed in individual dwellings. Before designing to install renewable power technologies as part of a refurbishment project, consideration should be made to the implications and possibilities of planning at a larger scale.

The table below illustrates the options to minimise electrical consumption in more depth and looks at the advantages and disadvantages of each:

Method	**Advantages**	**Disadvantages**	**Opportunities**
Quick wins to reduce electrical demand – low energy lighting, grade 'A' appliances, voltage optimisation and resident awareness	- Many can be installed at any time and are extremely carbon cost effective - Lighting and appliances are often replaced frequently, presenting regular opportunities to install low energy equivalents - Tenants bills are visibly reduced and most importantly they become engaged in the energy conservation process	- Some appliances may not be due replacement – sending working appliances to land fill should be avoided and benefits properly weighed - May be extremely difficult to encourage lifestyle change to help minimise consumption among some residents - Quality of quick win technologies can vary considerably	- Low energy lamps can be installed at any time. They are extremely cost effective and residents begin to become engaged in reducing their energy use - When appliances are being replaced, choosing the most efficient can as much as halve electricity use. Investment in the best possible electrical appliances is worthwhile. - Major refurbishment work should include a review of lighting and electrical appliances.
Solar Photovoltaics	- Electricity generated by installations and exported back to the grid qualifies for the 'feed-in-tariff' - Demand for solar PV is growing and prices are expected to slowly decline - It's a 'tried and tested' technology - Can be more cost effective if designed to be integral to the building, serving the same structural and weather-protection properties as traditional alternatives. This would suit a reroofing programme. - Hybrid system alongside micro CHP may overcome shortfalls of PV in the longer term	- Certain components i.e. inverters require replacing approx. every 10 years - Panels are very sensitive to shading and orientation (as close to due south as possible best) – often difficult to identify the suitable properties - Should only be installed once other measures to reduce consumption have been undertaken as capital costs are extremely high - Difficult to store the power generated during the day so is most commonly just sold back to the grid - PV will put extra loading on the roof structure - There may be planning consent issues	

[2] SAP 2009 version 9.90 (with corrections, May 2010), Table 12: Fuel prices, additional standing charges, emission factors and primary energy factors, publish on behalf of DECC by BRE. www.bre.co.uk/sap2009

Micro CHP	- Generates both heat and electricity in one unit. 4-8kW of heat for every 1-3kW of electric - Community scale CHP is common in Europe and well proven - Can be the same size as a conventional domestic boiler - Can be powered by a wide range of fuels - An rapidly emerging technology and considered to become a leading technology in the generation of both heat and power	- Requires a large heating load for long periods of the day and of the year to be efficient (inefficient for shot run cycles). Community/district scale CHP may be best in a social housing context - Lack of technical understanding/ knowledge - Units currently have low life expectancy - High capital costs and installation costs - Presently unlikely to generate all of the electrical needs of the home - Heat is often over produced and some is often 'dumped' as a waste product	The position and switching of lamps should be carefully considered in relation to tasks and day lighting. - Through FiT the investment in PV could act as an investment model to fund other retrofit measures (a backwards approach but financially viable) - Orientation, inclination, mounting, and type/size of PV module should be carefully considered - Consideration should be made to the implications and possibilities of planning electrical generation at a larger scale
Fuel Cells - Convert a chemical energy (hydrogen, natural gas, methanol, etc) and an oxidant (air/oxygen) into electricity	- Considered an ideal technology to use in micro CHP applications as they offer more viable (lower) heat to power ratios - Operates like a battery but does not run down or require recharging - Could aid to shift from current centralised power distribution to distributive networks in the longer term when a greater proportion of energy supply originates from renewable sources	- Very few examples of installed CHP fuel cells in the UK - Requires a supply of fuel and an oxidizer - Uptake will require increased understanding, an effective framework of legislation, standards and codes of practice governing commercial manufacture, planning, and safe operation and maintenance.	
Wind turbines	- Large wind turbines on windy sites are an extremely cost effective way of producing low carbon electricity - Homes linked to a community wind turbine or to an off-site wind farm is a very viable option.	- Power output is proportional to the cube of wind speed i.e. halving the wind speed will result in a reduction of output by a factor of 8. - Small building mounted turbines are not a cost effective improvement measure. Outputs in urban areas are often as low as 25 kWh/yr (£12 annual saving)	

Outline domestic retrofit specification

Findings in this report recognise the wide range of issues associated with applying some of the measures listed below. The outline merely seeks to highlight the specification likely to be required to best attain 80% (approx.) reduced emissions.

Floors

- Insulation — Proper floor and perimeter insulation where possible
  Achieve U values that meet or exceed Approved Document L1B (2010) ≤ 0.25W/m^2-K

Walls

- Insulation — Cavity, Internal or External insulation
  Achieve U values that exceed Approved Document L1B (2010) < 0.30W/m^2-K
- Air-tightness — 5m^3/m^2/h @ 50pa (Current Building Regulations recommend (2010) < 10m^3/m^2/h @ 50pa)
- Ventilation — Passive measures and humidity sensors as a minimum
  Moisture control and adequate ventilation is critical

Roof / Loft

- Insulation — Joist level insulation as a bare minimum
  Achieve U values that exceed Approved Document L1B (2010) < $0.20W/m^2$-K

- Air-tightness — $5m^3/m^2/h$ @ 50pa (Current Building Regulations recommend (2010) < $10m^3/m^2/h$ @ 50pa)
- Ventilation — Passive measures and humidity sensors as a minimum
  Moisture control and adequate ventilation is critical

Windows and Doors

- Performance — 1.5 W/m^2L at worst for the whole window; daylight transparency – 60%
- Quality — Durable, secure, sympathetic to context and from sustainable source

Space Heating

- System — Grade A boiler + a heat pump or biomass if off gas
  Alternatively; Community scale heating, micro CHP, or electric (where demand is very low)
- Controls — Comprehensive and user friendly controls

Hot Water

- System — Minimum option: Grade A boiler
  Preferred option: Solar hot water
  Alternatively; Biomass, Micro CHP, heap pumps or electric (where demand is very low)
- Optimisation — Water conservation measures to reduce minimise usage
- Controls — Comprehensive and user friendly controls

Electric Power and Micro-Generation

- Lighting — Low energy lighting – LEDs or CFL's
- Appliances — Grade A / A+ / A++ only
- Generation — Photovoltaics self-funded via Fit to offset lights and appliances
  Alternatively; Community scale generation or Micro CHP and Fuel Cells

Energy consumption patterns

- Awareness — User displays of electricity consumption
- Behaviour — Education, information and user manuals

- End -