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Decarbonising pre-1914 terraced housing in London: Key obstacles and improving owner-occupier uptake of retrofit projects

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Being a dissertation submitted to the faculty of The Built Environment as part of the requirements for the award of the MSc Sustainable Urbanism at University College London: I declare that this dissertation is entirely my own work and that ideas, data and images, as well as direct quotations, drawn from elsewhere are identified and referenced.

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Abstract

Today, housing generates 30% of the world's carbon emissions. In the UK, 80% of homes will still exist in 2050, and subsequently the Government's net zero greenhouse gas emissions target is a monumental challenge which can only be resolved through retrofitting the existing housing stock. This study looks to identify the obstacles that commonly hinder the uptake of retrofit projects and to unearth solutions to ensure that carbon reduction measures are widely adopted. The complexity of the UK housing stock, disruption, finance, legislation, workforce, along with owner knowledge, motivation and behaviour, frequently detract from the possibility of implementing energy efficiency improvements. The theoretical framework presented in this research portrays the external obstacles that often prevent such work from occurring, whilst highlighting the importance of the owner in facilitating the undertaking of retrofit projects, regardless of the influence of external factors. This study takes a qualitative approach, exploring the experiences of five owner-occupiers in London who have undertaken retrofit projects on their pre-1914 terraced homes. The results suggest that changes to current legislation are required to encourage decarbonisation. Additionally, a shift in the property market is needed so that retrofit measures are reflected in the value of housing. Furthermore, the workforce requires significant expansion, improved training and comprehensive retrofit knowledge. This is essential to endow the UK workforce with the capabilities needed to undertake this immense challenge.

1. Introduction

1.1 Background of the Study

The need to decarbonise housing around the world has become an increasingly crucial task in order to mitigate the effects of climate change. Housing generates 30% of carbon dioxide emissions, with the built environment accounting for roughly half of the climate and ecological damage globally (Day, 2016). In order to combat this crisis, the UK Government announced a new target of achieving net zero greenhouse gas emissions by 2050. The UK is recorded to have produced 361 million tonnes of carbon dioxide in 2018, therefore the challenge to reduce this to net zero is substantial (UK's CO2 emissions, 2020). Failure to achieve this will result in global temperatures exceeding the 1.5°C rise that the International Panel on Climate Change (IPCC) insists we must avoid. Scientists advise that surpassing this will be detrimental to the world as we know it (Ipcc, 2020).

Around 80% of the homes that currently exist will still be standing in 2050 (Baeli, 2013). All these homes will require adaption to ensure that their carbon emissions are considerably reduced, whilst ensuring homes are resilient to a dramatic shift in meteorological circumstance. The UK housing stock is one of the oldest and most diverse in Europe, with around four million properties dating pre-1914 (Rock and MacMillan, 2015). Decarbonising this vast quantity of the housing stock is a monumental task, therefore a serious shift needs to occur to allow for wide assumption of extensive energy efficiency measures.

As one of the oldest cities in the UK, London has an amalgamation of heritage properties of different tenures, that are incredibly inefficient, suffering from a wide variety of issues from subsidence to damp, and fiercely protected by conservation areas. London is highly susceptible to the effects of climate change, being prone to the heat-island effect and situated on the banks of a large tidal river.

This research is primarily concerned with identifying the obstacles that oppose wide adoption of energy efficiency measures in the pre-1914 housing stock. It will examine the ways in which these obstacles can be eliminated, and uptake increased.

In 2017 it was recorded that 63% of the population in the UK were owner-occupiers (Atkin, 2020). This study focuses on owner-occupied housing, the least regulated sector, and will examine five different houses in London, looking at the owner-occupier experience of undergoing energy efficiency improvements.

1.2 Research aims and questions

This research aims to positively impact the success rate of retrofit projects undertaken by owner-occupiers, whilst providing clarity on existing obstacles to retrofit and how these can be overcome. This study stands as a significant contribution to existing research with the aim of accelerating the shift to a zero-carbon future.

Aim: To identify solutions for the key obstacles preventing wide application of retrofit projects amongst owner-occupiers in London.

Main research question: What are the main obstacles preventing the adoption of retrofit measures in owner-occupied pre-1914 terraced housing in London?

The main research question above addresses the common constraints to retrofit that prevent uptake. The succeeding research sub-questions provide a more intimate examination

of what can be done moving forward and how common problems can be addressed to avoid the owner-occupied sector inhibiting the decarbonisation of the UK housing stock.

Research sub-questions:

- How can common obstacles that prevent retrofit be addressed?
- In what way can owner-occupiers be encouraged to undertake retrofit projects?
- How can we minimise the performance gap and maximise the efficiency of pre-1914 housing?

This research takes an original stance in addressing the owner-occupied stock in pre-1914 terraced housing in London. However, much of the information exposed by this paper will be transferable to other sectors and different housing types within the UK. The existing contribution to this field is limited and frequently examines issues in isolation or refers to just one case study. Looking at several examples of retrofit projects and obtaining multiple homeowner's opinions on the topic should provide a detailed understanding of what it is like to experience a retrofit project and what will improve the process moving forwards.

1.3 Structure of the dissertation

Following this introductory chapter, the dissertation will commence with a literature review where existing research surrounding the field will be examined, analysed and key points drawn. This review will enable the creation of a theoretical framework in Chapter 3, providing structure for the interview process and how the findings are presented. Chapter 4 will introduce the methodology which delivers the approach through which the research was undertaken. The

findings will then be presented in Chapter 5, followed by a discussion in Chapter 6 which will highlight the key findings. The discussion will also draw out elements that were not raised in the literature review and incorporate new, supporting literature. Chapter 7 will then draw a conclusion to this research and establish points for future research.

2. Literature Review

2.1 Retrofit definition

Marion Baeli (2013) defines retrofit as "the refurbishment of an existing property to significantly lower or achieve net zero carbon emissions". A whole house retrofit takes into consideration the building fabric, the building services and the implementation of low and zero carbon technologies, ensuring that all systems work together effectively as a whole to dramatically reduce carbon emissions. Swan and Brown (2013) argue that retrofitting considers installing systems in an existing building that were not available at the time of construction and, in most instances, this reduces fuel use, fuel costs, greenhouse gas emissions, and improves comfort levels.

2.2 Retrofitting pre-1914 housing in London

Cities such as London have been constructed over millennia and therefore contain non-homogenous buildings that were built using a variety of materials (Jenkins, 2010). Vergragt and Brown (2012) state that retrofit on a wide scale is difficult and to date existing retrofit programmes have been unable to find a generic solution. Without considering the date of construction and understanding the context in which the individual building was built it is unlikely that a retrofit will be a success.

London is vulnerable when it comes to climate change. Areas close to the Thames, along with parts of North and East London, are particularly at risk of being underwater within a few generations (Peracha, 2020). In *The Eco-Home Design Guide*, Christopher Day (2016) advises that retrofit ensures our existing dwellings are made resilient. European buildings typically last one hundred years but owing to the anticipated shift in global temperatures this is likely to decrease as more buildings are unable to cope with the changing conditions.

Marion Baeli (2013) advises that a deep retrofit typically has a strong impact on the property's carbon emissions, ideally reducing them by 80%. This is countered by The Retrofit Academy (2020) who advise that the decarbonisation of the national grid has led to a 50-60% carbon reduction being far more realistic and cost effective. Whilst ideally an 80% reduction is preferred, many barriers prevent substantial uptake of such extensive works.

Pre-1914 housing is typically constructed from traditional materials such as brick, stone and soft lime mortar which were used along with more hazardous materials such as asbestos. The concept of terraced housing became popular in the Victorian period as it allowed for saving on materials, labour and maximised the amount of homes you could fit on a piece of land (Rock and MacMillan, 2015). Retrofitting initially targets the fabric of the building to ensure an airtight building envelope, a vapour permeable construction and to retain thermal capacity (Retrofit Academy, 2020). This will significantly reduce the demand on the building services which can then be exchanged for low or zero carbon technologies. Swan and Brown (2013) state that suitable technologies have been developed and work, but we are just not using them. Peacock et al (2007) agree and comment that, given how knowledgeable we have become; it is disappointing that energy consumption has continued to grow.

2.3 Obstacles

2.3.1 Complexity of housing stock

The UK housing stock is old and complex, and therefore great consideration needs to be taken when undergoing retrofit works (Retrofit Academy, 2020). Vaughan (2020) advises that almost all pre-1914 housing has been altered in some way since the date of construction. Properties can vary in terms of building form. For example, the UK has terraces, semi-detached, detached houses, flats and mezzanines. These can all have differing tenures and have been constructed using a variety of methods (Vaughan, 2020). Marion Baeli (2013) maintains that there is no 'one size fits all' approach in retrofit. Henry Stewart Publications (2020) claim that any attempt at retrofitting on a wide scale has resulted in ignored or misdiagnosed defects and has exacerbated underlying problems. Vaughan (2020) agrees and confirms that retrofit needs to be approached carefully with bespoke solutions.

Post-World War II there was a huge shift from private renting to individual owner-occupation in the UK. The rent deregulation and rent control legislation in the 1950's and 1960's caused a 'rent gap' to emerge, meaning that property was valued according to its tenure status. According to Cole and Robinson (2000), "Owner-occupation was therefore seen as the means of experiencing and realising values of autonomy, personal independence and emotional security". The Housing Act of 1980 followed, allowing council tenants to purchase their homes, increasing levels of owner-occupation further.

2.3.2 Disruption

James Traynor (2019) advises that in order to implement significant energy saving measures, disruption to some extent is usually unavoidable. This is particularly the case with a whole

house retrofit where more rigorous targets are required, and owners often temporarily move out (Retrofit Academy, 2020). However, moving out is not possible for most owners for numerous reasons (Vaughan, 2020). This means living with dust, noise and certain rooms out of use, which is usually the case with refurbishment works (Vaughan, 2020).

Traynor (2019) believes that planned maintenance and deep retrofit should be aligned as this will minimise disruption. Vaughan (2020) agrees with this, adding that works could be aligned with moving house. Communication between the workforce and owner is key to avoiding disruption (Welles, 2020). This can be achieved through a step-by-step approach or a retrofit management plan that ensures the duration of the works are minimised and can limit the need for future works (Vaughan, 2020). Alternatively, Building Information Modelling (BIM) is considered a possible solution to disruption (Chaves et al, 2017).

2.3.3 Finance

The key problem with retrofitting usually comes down to capital cost (Jenkins, 2010). Vaughan (2020) states that a retrofit could cost between £30,000 and £50,000 and is frequently more. Financial aid is often required to overcome the high expense of projects as the upfront cost is frequently too much for the majority of the population (Vergragt and Brown, 2012). Vaughan (2020) agrees and believes that getting the economics right is essential for retrofit to become mainstream. Currently, energy is too cheap which makes payback periods ridiculous. Whilst long payback is an issue, property value often does not recognise the benefits of retrofit. All too often green buildings are seen as a luxury for those that can afford it, and this is a significant hurdle to overcome in order to improve wider uptake and adoption (*20 Ways to Advance Sustainability in the Next Four Years,* 2020).

The Government has supported funding through schemes such as The Decent Homes Standard, The Warm Front Scheme, The Carbon Emissions Reduction Target, Community Energy Saving Programme, Energy Company Obligation, The Green Deal, Feed in Tariff (FIT), and The Renewable Heat Incentive (Swan and Brown, 2013). In July 2020 the Government announced a £2bn grant scheme, with homeowners able to receive up to £5,000 for energy saving home improvements, with lower income households able to receive up to £10,000. Under the Green Home Grant, the Government agreed to cover two-thirds of home improvements. This was an effort to kickstart the economy by creating thousands of jobs after the coronavirus outbreak (Sunak to unveil £2bn home insulation scheme, 2020).

2.3.4 Legislation

Regulation in the UK is progressively enforcing carbon saving initiatives through a top down approach. Approved Document L1B provides guidance on meeting building regulations in the UK and applies to existing dwellings which are undergoing refurbishment, extensions and conversions (Anon, 2020). The London Plan sets out additional targets that are more stringent than building regulations, with comprehensive targets to lower carbon emissions in London (*London's Response to Climate Change*, 2020).

During the Victorian and Edwardian periods there were minimal planning restrictions (Rock and MacMillan, 2015). Today, planning permission is required to monitor and control work, ensuring that projects conform to the heritage of local areas whilst causing as little disruption as possible (Crockford, 2014). Obtaining planning permission is often a wearisome process that lacks consideration for low carbon interventions. Crockford (2014) debates the struggle between preserving heritage and equipping homes for our current needs and addressing climate change. Max Fordham was limited to installing 5kw solar panels on his roof

when more were required. This demonstrates that the UK system can hinder property owners from undertaking works that could enable a significant reduction in emissions (Inside the Camden eco-home with energy bills of £200 a year, 2020).

Properties for rent and sale are required to achieve an Energy Performance Certificate (EPC) of an E rating or above. This was seen as a step in the right direction towards regulating the efficiency of tenanted properties and homes switching ownership (Crockford, 2014). The EPC targets are nowhere near stringent enough to enable the decarbonising of the housing stock, nor do they apply to owner-occupiers who have no intention to sell or rent their properties (Crockford, 2014).

PAS 2035 is a new retrofit standard introduced by the British Standards Institute that is launching a number of new roles into the retrofit process to ensure that projects are executed efficiently and perform as designed (Retrofit Academy, 2020). Voluntary standards can play a huge role in facilitating change (Vergragt and Brown, 2012). Examples include; the EnerPhit Standard and The CarbonLite Retrofit Standard. Standards can assist with improving retrofit projects by ensuring high levels of performance and standard of workmanship (Vaughan, 2020). However, Hodson (2015) informs us that a transition will occur if homeowners are prepared to act irrespective of the incentives and standards.

2.3.5 Workforce

Retrofitting is a relatively modern concept and as a result there are a limited number of tradesmen with extensive knowledge in this area (Swan and Brown, 2013). Retraining our existing workforce will achieve higher standards of work (Traynor, 2019). Vergragt and Brown (2012) agree and state that training is required along with improved ways to disseminate knowledge. James Traynor (2019) argues that the skills required to successfully retrofit are not

straightforward, but the lack of knowledge and poor craftsmanship often exacerbate issues in dwellings. Regular changes to key policies have led to confusion around new construction skills. This has resulted in a skills gap and a lack of contractors qualified in low-carbon construction (The Climate Change Committee, 2020). To date, a number of retrofit projects have been disastrous which has led to a lack of confidence in the workforce. Sustainable refurbishment involves a number of different trades and creates potential for clashes (Swan and Brown, 2013). The introduction of PAS 2035 will see the emergence of the role of the Retrofit Coordinator who may be able to eliminate the danger of companies and individuals working in their own interests, improve client trust and deliver better quality results (Retrofit Academy, 2020).

2.4 Owner Knowledge, Motivation and Behaviour

2.4.1 Owner Knowledge

Frequently, people do not have access to accurate information regarding the cost and benefit of retrofit projects and are consequently disincentivised from undertaking such works (Retrofit Academy, 2020). Makrodimitri (2010) advises that occupants ought to be knowledgeable about sustainable living before moving into energy efficient homes. This can be delivered through extensive handovers, easy access and storage of information, and will significantly improve the performance of those homes. Performance gaps are often found when this step has not been actioned sufficiently. However, Brown and Swan (2013) state that increased knowledge is not necessarily sufficient to alter behaviour.

Retrofitting does not need to be solely for environmental purposes as thermal comfort, low energy costs, improved health and improving property value can also be significant benefits to undertaking these works (Retrofit Academy, 2020). Christopher Day (2016) states

that sustainability is rarely the sole reason for wanting an eco-home. Many people desire comfortable homes that are cool in summer, warm in winter and have good air quality and sufficient ventilation (Peacock et al., 2007). Traynor (2019) believes that thermal comfort should be at the forefront of any retrofit project especially when considering Victorian and Edwardian housing which is draughty and often cold. However, Organ (2013) warns that a pro-environmental attitude may not lead to pro-environmental actions.

2.4.2 Owner Motivation

Generally, energy efficiency is not a high priority for most people as retrofit projects are time consuming, disruptive, expensive works with uncertain outcomes. A small-scale project in Worcester, Massachusetts examines the uptake of retrofit projects through the incorporation of community benefits, local employment, improving quality of life and air quality. Focusing on these elements led to uptake being higher than usual with people prioritising health and social aspects over energy conservation and climate change, particularly in areas where there are a number of social problems (Vergragt and Brown, 2012)

Organ et al (2013) support this, realising that people's needs are prioritised above environmental needs which makes the task of shaping motivations more challenging. Higher income groups are more likely to be environmentally concerned as they have already met all their basic requirements. This is only a small percentage of the population, and, in order for wider application to begin, retrofitting needs to appeal to those on lower incomes.

Motivation is an internal process driven by the direction and intensity of people's efforts (Organ et al, 2013). Swan and Brown (2013) debate that financial incentives don't necessarily change behaviour as when the incentive is removed behaviour often reverts. Organ et al (2013) explain that extrinsic motivation such as financial incentives are counterproductive

as they reduce intrinsic motivation such as needs and desires. The best way to break a habit is to remove the possibility of performing the behaviour (Swan and Brown, 2013).

2.4.3 Owner Behaviour

Occupants do not always behave efficiently or interact with technologies in the way that designers expect (Swan and Brown, 2013). Vaughan (2020) agrees and mentions that people struggle to change their behaviour once living in a retrofitted home. This can lead to performance gaps and reduced efficiency levels. Social motives such as: models who can demonstrate desired behaviour, messages from friends, social marketing and appealing to personal goals can help stimulate behavioural change and as a result improve the energy efficiency of the house (Swan and Brown, 2013).

Organ et al (2013) argue that self-identity plays an important role and affects the intention to behave in a certain way. If energy efficiency improvements were highly valued in society then more people would undertake works. Swan and Brown (2013) add that people regularly do not want to get rid of gas fires for aesthetic purposes. This is an example of a value-based norm that can affect the uptake of modern technologies. It is not driven by performance but by social rules and the way people view their homes and themselves. Behavioural change takes time, and this becomes a predicament when trying to rapidly decarbonise (Organ et al, 2013).

Swan and Brown (2013) advise that the number of devices in our home has increased dramatically resulting in domestic energy use increasing by 34% since 1990. With homes and technologies becoming increasingly efficient, the process becomes easier for homeowners to actually increase the amount of energy they consume on a daily basis. This is known as Jevons

Paradox and can be avoided if homeowners are knowledgeable and prepared to change their behaviour in order to adjust to the improvements installed in their home (Alcott, 2005).

3. Theoretical Framework

This chapter presents a framework based on a synthesis of information from the preceding literature review. Figure 1 depicts the path to achieving a successful retrofit, demonstrating what needs to be overcome in order to obtain maximum results. The obstacles identified in the literature review are broken into two categories, the external factors and the intrinsic. The external factors form Stage 1 and the intrinsic form Stage 2. The details of these stages will be explained in the following subsections.

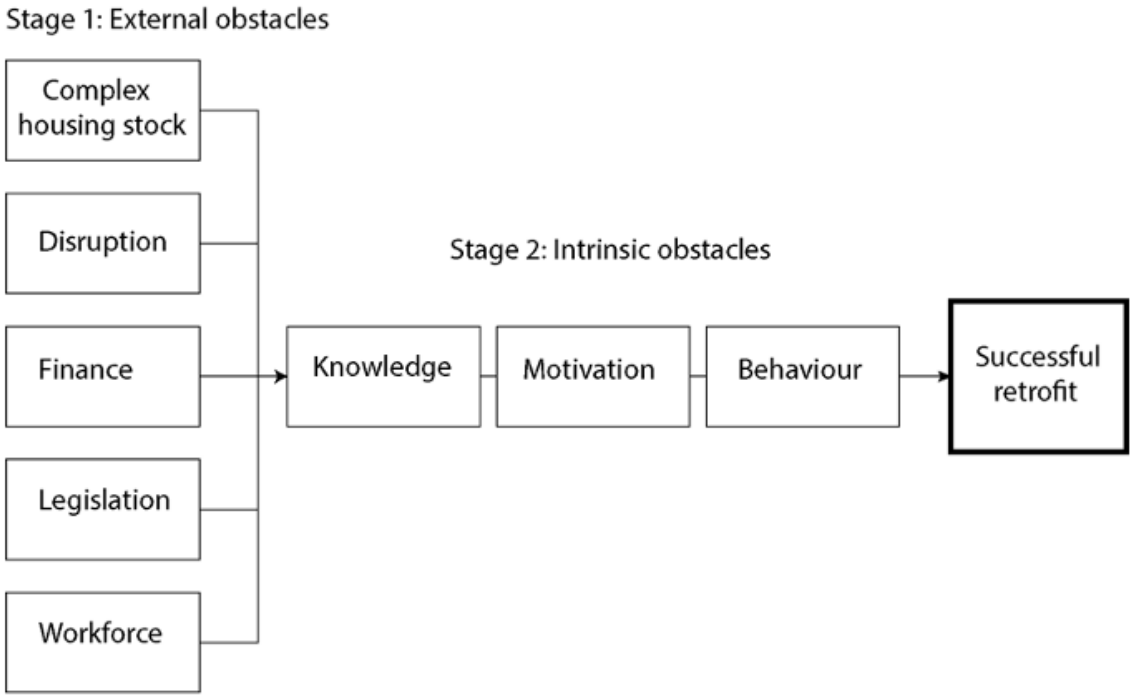

Figure 1. The path to a successful retrofit. Source: Author, 2020

3.1 Stage 1

The obstacles represented in Stage 1 are the external factors most commonly considered to stand in the way of owner-occupiers undertaking retrofit. However, it must be acknowledged that other obstacles do exist and may be equally, if not more, prominent in certain instances. In this case other obstacles should be treated as part of Stage 1. The obstacles in Stage 1 can be seen as the hard, pragmatic factors that have an external influence on a potential retrofit project.

The weighting of obstacles is dependent on the circumstance of the individual owner-occupier and their house. In some cases, multiple obstacles will be prominent. The greater the number of obstacles that a household faces, the less feasible the project will become. The lower the significance of the obstacles, the more likely the retrofit is to proceed. For example, disruption is usually unavoidable, but this can be minimised so that it is manageable (Traynor, 2019).

All of the obstacles should be overcome to some extent for a successful retrofit. For instance, if planning is prohibited by the local authority, this can have a significant impact on the quality of the retrofit and the performance of the building. This was seen at Max Fordham's house (Inside the Camden eco-home with energy bills of £200 a year, 2020). Arguably, in most cases, doing some retrofit work is better than nothing and therefore the obstacles do not necessarily need to be eradicated altogether, just minimised. It must be recognised that, while obstacles hinder the success of a project, they do not necessarily wipe out the possibility of doing any work at all. The external obstacles have been labelled 'Stage 1' as these are the initial barriers that need to be overcome in order for an owner-occupier to consider retrofit as a possibility.

3.2 Stage 2

Stage 2 is wholly intrinsic and can essentially block the path to a successful retrofit regardless of whether or not the external obstacles in Stage 1 are negligible. Three things must occur during Stage 2: firstly, an owner-occupier must know about retrofit and understand the benefits in order for them to want to undertake the work. The literature review demonstrated that a lack of access to correct information can lead to owners becoming disincentivised (Retrofit Academy, 2020). Without knowledge the owner-occupier will not be motivated to undertake a retrofit project, nor will they understand how to initiate the process or adapt their behaviour once the works have taken place. Lack of knowledge can result in poor quality work, a misunderstanding of why the process is necessary and the benefits gained.

The second element requires the owner to be motivated in order for a retrofit to occur. Previously, Organ (2013) advised that motivation comes down to how much effort is put into a task. For motivation to exist, knowledge must have already been obtained. External obstacles can be tackled but until an owner is motivated the project will not happen.

Finally, the owner-occupier needs to behave a certain way in order for the process to be set in motion and the house to be used in the correct manner. An owner can be knowledgeable about the retrofit process and motivated to undertake the works but until they take the necessary steps to start the process the retrofit will not occur. Additionally, a house that has been retrofitted functions very differently to a house that has not. In order to maximise efficiency, the owner-occupier must adjust their behavioural patterns, such as reducing how frequently the space heating is turned on. Adjusting behaviour prevents a case of Jevons Paradox (Alcott, 2005). As Swan and Brown (2013) mention in Chapter 2, without some adjustments a significant performance gap can occur, and this detracts from undertaking the works. Owner-occupier behaviour must be suited to the house post retrofit and this can only

occur if owners are both knowledgeable and motivated. It is for this reason that the diagram represents these three elements from left to right, the owner-occupier obtaining each one prior to moving further towards achieving a successful retrofit. This theoretical framework exposes focal areas that were used to inform the structure of the interviews and the findings in this research.

4. Methodology

4.1 Research Method

This chapter takes into account the methods used to undertake the research for this dissertation. The study takes a qualitative approach by analysing relevant literature, undertaking semi-structured interviews and a short survey to better understand the key obstacles that restrict retrofit uptake and to identify solutions for how each of these barriers can be overcome. A qualitative method is needed to provide the flexibility and pragmatism required to analyse the experiences of those that have already undertaken decarbonisation initiatives (Marshall, 1996). The approach is required to be sensitive to the contextual, social, economic and cultural factors that might affect uptake (Allender et al, 2006). This involves opinions and personal experiences rather than numerical representation.

4.2 Data collection and analysis

4.2.1 Semi-structured interviews

Semi-structured interviews took place with five property owners who had each undergone individual retrofit projects on the homes that they currently live in. The owners were either approached through connections with the Muswell Hill Sustainability Group or by direct contact. Each owner was supplied with a list of questions in advance which formulated the structure for the interview (see Appendix 3). This took on the structure of the theoretical framework portrayed in the preceding chapter.

4.2.2 Short survey

A short survey was sent out to the respondents. This was to gauge a better understanding of each owner's personal circumstance. This survey was anonymised and provides valuable information to understand the kind of owners undertaking retrofit projects to date.

4.3 Study areas and profile of respondents

The survey demonstrated that 75% of the owners interviewed were 61 years and above. Half of the interviewees had lived in their house for 6-9 years and half of the respondents had lived in their homes for 10+ years. All owners confirmed that they were environmentally aware prior to undergoing retrofit works, with four of the five respondents working in either sustainable housing, sustainable communities or clean and renewable energy. All properties are terraced houses. Incomes varied widely between owners, with 25% earning under £30,000 p/a, 50% earning between £30,000-£50,000 p/a and 25% earning more than £100,000 p/a. The figures

below were disclosed by the interviewees through the information that they provided during the data collection.

Interviewee	Property	House location	Total invested in energy saving items	Carbon emission reduction	Size (sq ft)	Year retrofit process began
Int.01	Prop.01	Highgate	£17,000 (exclusive of PV + woodburning stove)	85%	1,593	2006
Int.02	Prop.02	Muswell Hill	£40,000	61%	2,153	2010
Int.03	Prop.03	Notting Hill	£150,000	65%	3,200	2012
Int.04	Prop.04	Muswell Hill	£30,000	unknown	1,658	2014
Int.05	Prop.05	Alexandra Palace	£140,000 (includes other items such as kitchen refurbishment)	76%	2,314	2011

Figure 2. Housing profiles. Source: Research fieldwork, 2020

4.4 Limitations of the methodology

London has different regulations to other regions in the UK, therefore the data gathered may be not be representative of other areas in the country and the findings in this research may not necessarily be applicable to properties of different tenures. The information gathered for this research was taken from five owner-occupiers, the majority of whom work within sustainability. Therefore, opinions may not be representative of the wider population.

4.5 Positionality

For the last year the author has worked as a Sustainability Co-ordinator for a construction firm based in London. The author is a qualified Construction and Domestic Energy Assessor and is undergoing a Level 5 Diploma in Retrofit Co-ordination and Risk Management. Owing to the author's involvement with subject matter close to the topic of this research project, bias has been avoided by solely referring to topical literature and the information provided by the interviewees.

4.6 Ethics Statement

Prior to undertaking this research, a risk assessment and ethical clearance form were completed by myself and signed off by UCL staff (see Appendix 1). All interviewees were fully briefed on the research being undertaken and signed individual consent forms (see Appendix 2). The interviewee names, addresses and other personal information are anonymised to protect their privacy. The data obtained from this research has been saved in a secure and protected location to ensure complete anonymity.

5. Analysis of Findings

This section presents the results from the interviews and survey. Initially, the five properties will be familiarised to ensure comprehension of the individual retrofit projects and how they compare. The findings will be presented in a format that reflects the theoretical framework supplied in Chapter 3, beginning with Stage 1 and moving onto Stage 2.

5.1 An introduction to the properties

Prop.01 is a Victorian semi-detached house located in Highgate New Town. The house is situated in a protected area in Camden and the property has been intensively lived in for over one hundred years. Int.01 is an environmentalist who started their career in building resources and now runs an independent consultancy service specialising in improving the sustainability of existing houses. The Owner has spent the vast majority of their career focused on improving the energy efficiency of existing homes, “it’s what I’ve spent the last twenty plus years of my life particularly focused on” (Int.01). Int.01’s home was purchased in 2005 specifically to be retrofitted.

Prop.02 is a three storey Edwardian end-terrace property measuring 180 sqm and located in Haringey. The property has thirty-one sash windows with the majority of the works undertaken about ten years ago. Int.02 has owned the property for twenty-three years and was inspired to undertake a retrofit project in order to improve comfort levels, reduce energy consumption and to stop the windows from rattling. “We have always been environmentally minded, but at that point we realised what we needed to do to make the house habitable” (Int.02). Int.02 advised that undertaking this project seemed like a logical step and states that they implemented the vast majority of the measures themselves.

Prop.03 is a stucco fronted, five storey Victorian terraced house in Notting Hill. Int.03 describes the house as, “very up and down, everywhere is two rooms and stairs with a closet room stuck on the back by the Victorians” (Int.03). Int.03 moved into the house in 2010 and lived in the property for two years prior to undergoing the works. It was very run down when purchased, and the retrofit took place predominantly for comfort purposes. Int.03 has built a successful career in clean energy, transportation, infrastructure and sustainable development.

The house was not fit for habitation and therefore, extensive work was required anyway. The decision to make the house clean was subsequent to that as it made economic sense.

Prop.04 is a double fronted, two storey Victorian terrace in Alexandra Palace. It had been converted into two flats in the twentieth century, but the previous owners had cosmetically converted the building back into a house. Prior to retrofit the building services still existed as if there were two separate flats. Int.04 purchased the house to undergo retrofit works from day one to the best practice standard at the time. "We took the opportunity to put things right in the best way possible" (Int.04). The owners are retired and wanted to create a home that was comfortable and easy to heat. They were also inspired by the energy saving and cost saving benefits.

Prop.05 is an Edwardian terraced four-bedroom family home in Muswell Hill. "Our road was the entry to Muswell Hill and the houses on the road showcase and make a statement, which was the idea of the original design" (Int.05). When it was purchased in 2011, the property was not connected to the grid. Int.05 was not looking to explicitly undergo retrofit works as the property needed renovation works anyway. Int.05 are environmentally conscious, but the retrofit idea emerged over time after having conversations with friends. Int.05 works in sustainable communities and wanted to be consistent with how they live and work, focusing on implementing low cost, high impact measures.

5.2 Retrofit measures

The graph below offers a cross-comparison of measures installed in each property during the retrofit process. In all cases the fabric of the building was prioritised with wall, floor and roof insulation being installed in each. Solar PV was installed at each property to generate

electricity. However, the heating and hot water sources varied from property to property; and LED lights were installed across the board.

	Prop.01	Prop.02	Prop.03	Prop.04	Prop.05
Internal wall insulation	Yes	Yes	Yes	Yes	Yes
External wall insulation	No	No	No	Yes	No
Roof insulation	Yes	Yes	Yes	Yes	Yes
Floor insulation	Yes (not in hall)	Yes	Yes	Yes (in kitchen only)	Yes
Draught proofing	Yes	Yes	Yes	Yes	Yes
Double glazing	Yes	No	Yes	Yes	Yes
Triple glazing	Yes	No		No	No
Secondary glazing	No	Yes	No	No	No
Solar PV	Yes	Yes	Yes	Yes	Yes
Solar hot water	Yes	Yes	No	Yes	No
Heat pump	No	No	Yes	No	No
Fuel cell micro CHP	No	No	Yes	No	No
Woodburning stove	Yes	Yes	No	Yes	Yes
MVHR	Yes	No	No	No	No
Rainwater capture	No	No	Yes	No	No
LED lights	Yes	Yes	Yes	Yes	Yes
Sun panel	Yes	No	No	No	No

Figure 3. Measures implemented. Source: Author, 2020

5.3 Stage 1 – External obstacles and solutions

5.3.1 Complexity of housing stock

The data collected demonstrates that pre-1914 terraced housing is indeed complex, but this can be overcome through using a case by case approach, understanding the property completely, and ensuring work is carried out to a high standard. Respondents confirm; "our house actually goes further back than next-door and doesn't have three sides like a normal end terrace, it has three and a bit sides." (Int.02). The findings show that houses of this period can vary hugely, and each has individual characteristics that have to be tackled in a separate way, 'case by case' (Baeli, 2013). Prop.04 was converted into two flats in the sixties but converted back into a house by the previous owners. This led to there being "two supplies of gas, water, electricity" (Int.04) and demonstrates that pre-1914 houses have often been altered somewhat since the original date of construction (Vaughan, 2020).

This makes the task challenging, with each house requiring an individual approach to avoid mistakes and unintended consequences. Whilst this is a daunting prospect, the general concepts are the same in each instance. Respondents advised that "builders need to know basic concepts that they can then apply to each house" (Int.03). Knowledge is improving all the time, and this is only going to be optimised with frequency. A case by case method will hopefully lead to improved work quality. The respondents argue that owner-occupiers usually understand their homes better than tenants and therefore, doing whatever is possible will make some difference.

5.3.2 Disruption

Notably, all property owners interviewed advised that disruption to their lives occurred to some extent, with three of the five households remaining in occupation during the works. Looking back at whether they would go through the process again one respondent states, “we wouldn’t want to do all that, now we know what it involves, or at least we wouldn’t want to be in the house” (Int.04). The disruption caused is unequivocally greater if owners remain in occupation, however moving out is not always an option (Vaughan, 2020). Aligning retrofit with planned maintenance and refurbishment work has proved effective. It is clear that the economics of retrofitting are completely different if you are already renovating the house. Those undergoing extensive refurbishment works should be encouraged to implement low carbon measures. A respondent states:

> “It is a very profound job. I’m very against the idea that you should do low hanging fruit as it’s very disruptive and reduces the incentive to do further works, it’s much better to do everything at once.” (Int.03)

Nevertheless, it is clear that this is not always possible and if funds are tight then occupants may have to accept more disruption or be forced to break the work into phases carried out over a long period of time (Fawcett and Palmer, 2004). To many, the prospect of implementing a bundle of measures at once can be daunting. Respondents say: “do something, don’t get lost in the idea that you need to do this, and this, and this” (Int.02). Initially, it seems overwhelming and consequently people do nothing. Commence with one measure and once this is complete move onto something different. It boils down to personal circumstance and whether you feel comfortable undertaking the whole project in one go.

5.3.3 Finance

This research demonstrates that the degree to which carbon reductions are possible are controlled by the financial capacity of the household. Retrofit is rarely a financial priority and is more commonly perceived as an extravagance. The respondents confirm that retrofit is usually undertaken by older owners who are committed to the cause and have the money to do it as, “it’s a luxury in a way” (Int.05). The findings demonstrate that 75% of the respondents are over the age of sixty-one, and 80% have led a career within sustainability. This is supported by an interviewee who states, “we have lost the ability to plan this kind of thing as a collective, doing it as individuals means that those with enough money and the time to do it are the only people who are going to get it” (Int.04). Moreover, it is clear that the challenge lies in targeting younger families with lower incomes and limited environmental knowledge.

During the interview the respondents were asked whether they participated in any government schemes or received grants. All owners received financial aid in some capacity, most commonly through the Feed in Tariff for photovoltaic panels. The research confirms that grants enable retrofit projects to be feasible (Vergragt and Brown, 2012).

Frequently, owners perceive energy efficiency works as an expense rather than an investment. Owners are disincentivised as energy efficiency is not accurately reflected in the price of a property despite the house being fundamentally better once works are complete. If this were the case it could generate an increase in capital value and offer financial gains at the point of sale and potentially serve as a driver for retrofit (Miu et al., 2018). The interviewees remarked on the contentious position of the UK property market and its struggle to realise the value of retrofit measures as an asset. An economic shift will take place as, “in Australia, who are a couple of years ahead of us, a house with a lower Energy Performance Certificate has a higher market value” (Int.01). The majority of refurbishment work is understood to improve

property value, however retrofit is frequently disregarded. A study demonstrated that energy efficiency measures improved rents and sales transactions between 14.7%-19.7% in commercial buildings in London (Chegut et al , 2013). A gradual transition is apparent, and we can anticipate that this will ultimately recondition the residential sector.

The respondents were unanimous in agreeing that "a big incentive to do this is to reduce energy bills" as the reduction of fuel cost is possible straightaway. The reduction of running costs through retrofitting has led to fuel-poor homes being prioritised for retrofit in recent years. However, this reduced expense is advantageous across the board (Vilches et al, 2017). Despite retrofit measures decreasing costs, utility companies incessantly struggle to comprehend reduced meter readings in a retrofitted house. Three of the respondents were charged with excessive energy bills post retrofit based on assumptions made by the utility companies. When it comes to retrofit:

> The average utility is completely incapable of being supportive, and they don't want to, why should they, all you are going to do is reduce their revenue by being energy efficient (Int.03).

The interviewees agreed that this can usually be rectified fairly quickly with the utility company, however the error caused here can make it very difficult to analyse the success of the project as often the data you hold is incorrect. As energy efficiency works become more commonplace, utility providers must increasingly acknowledge minimal use of domestic energy.

Several of the respondents concurred that "really, we need utility prices to be higher, as it's driven by price for most people. The cost of gas is too low". Even with grants, people still have to use a quantity of their own money to carry out works and consequently it is easier to simply turn the heating up rather than go through the upheaval of a retrofit project.

An additional solution could be to encourage point of sale retrofit incentives (Miu et al, 2018). In most instances the rewards will be too low to encourage uptake. However, the introduction of a stamp duty rebate for those moving into properties could be plausible if the owner is given two or three years to claim once they have moved in. “You don’t want to be forced to do works too quickly when you don’t know the house”. At this point they will have a clear concept of the functionality of the house and will consequently do a really exceptional job.

5.3.4 Legislation

The findings highlight that local planning rules often determine what implementations are permitted, and this can significantly hinder retrofit projects. Obtaining planning in most boroughs of London is extremely challenging and those wishing to change the appearance of heritage buildings, regardless of energy saving benefits, are not looked upon favourably. A respondent confirmed that “I have been trying for five years to get permission from Camden to put insulation on the big flank wall” (Int.01). A second respondent experienced a similar struggle when seeking permission for a skylight. They were forced to install a skylight with a steel frame which acts as a thermal bridge, despite no one being able to see it (How to do a green home renovation, 2020). This struggle between preserving heritage and undertaking energy efficiency improvements is reminiscent of Crockford’s (2014) study and is frequently problematic. Instances like this prevent homes from performing as efficiently as they could. In order to combat this, there needs to be shift in UK regulation. The respondents confirm that “permitted development should be changed nationally” (Int.01). This would allow for a substantial shift and provide flexibility for homeowners to implement energy saving measures

without limitation. However, this needs to be handled with caution to avoid the dilution of quintessential British housing (Quinn et al, 2020).

5.3.5 Workforce

The knowledge and quality of work executed by tradesmen is frequently considered a significant barrier to the installation of low carbon measures. Four of the property owners experienced issues with tradesman at some point in the retrofit process. The respondents confirm, “it was very difficult to find tradesmen who knew what they were doing, and so, if I were to do it again, I would take more care in choosing the workforce” (Int.03). One interviewee explained that a plumber started cutting corners to save time and did not lag the pipework. Now when they turn on the hot water tap it runs cold for a considerable amount of time. As a result, this is; “energy inefficient, irritating for the user, and very expensive to change as you would have to open up the walls again” (Int.03). In this instance, remedial works would be in the region of £20,000-£30,000. Whilst corrective works may not always be so exorbitant, it remains that a limited number of tradesmen have sufficient knowledge or take the care required to enable the decarbonisation of existing dwellings (Swan and Brown, 2013).

It is possible that workforce knowledge can be significantly improved through enriched education at trade schools. The respondents identify that educational facilities are producing contractors who are not fully trained to work on retrofit projects, but really there should be no alternative way of building. Ideally, “we need to be churning out people in trade schools who are comfortable with this type of work” (Int.03). Moreover, if trades unions pushed for this it would mean higher value jobs for their members. The interviewees agree that these are not straightforward projects or skills, but once you have done one project then you are way up on the experience curve.

The end of the apprenticeship system was deemed controversial by many. However, a respondent made clear that this may have huge gains.

> Heating engineers are usually taught by their fathers, who have been taught by their fathers. It is not always a good thing to be trained by the previous generation as they can be change adverse. (Int.01)

The construction apprenticeship system has been identified as a constraint on the industry's output and productivity, with "pervasive shortages of intermediate skills" (Toner, 2020). Upskilling is required and this cannot be achieved by learning from previous generations who have never been obliged to attain the skills for building net zero housing.

Nevertheless, positive experiences are becoming increasingly commonplace. An interviewee shares a success story, advising on the fantastic job executed by their tradesmen. The installers recommended solar panels, to get on the Feed in Tariff prior to the discontinuance of the scheme (Int.04). This was one of several measures that were recommended, and the owners were delighted that these were all successful. As the most recent project this demonstrates that the upskilling of tradesman may prevail.

Copious tradesmen involved at each stage of the retrofit process can be confusing and complex. A respondent advises, "all the different contractors present a way, and what you have to work out is whether it's in their interests or in your interests" (Int.05). Swan and Brown (2013) previously referred to this, which highlights that it is challenging to comprehend the information relayed and whether the work being undertaken will pay off. The findings demonstrated that all the owners had to do a certain amount of project management. A respondent advises that; "it would be much nicer to go to one organisation that takes you through the whole journey" (Int.05). An integrated approach would have been valuable and made the process more transparent.

5.4 Stage 2 - Owner Knowledge, Motivation and Behaviour

5.4.1 Knowledge

Generally, obtaining knowledge is essential for owner occupiers if they are to undertake a retrofit project. In many instances retrofit is misrepresented as purely environmental. Christopher Day's (2016) claim that retrofit is rarely exclusively for an environmental agenda was confirmed by the respondents who were unanimous in agreeing that comfort levels and health were a major factor, if not a priority, in undertaking the works. One of the respondents confirmed that; "the idea was to have a house that was easy to heat, didn't need much heating, and is comfortable to live in" (Int.04). Peacock et al's (2007) argument is clearly reiterated, highlighting that thermal comfort and improved health are at the forefront of retrofit projects, but this is not yet widely recognised. When asked what inspired the owner to undertake a retrofit project one interviewee responded, "the house is now incredibly warm. Mid-winter there can be up to a 24°C difference between the outside and inside temperatures" (Int.02). A second respondent supported the preceding comment by affirming that, "it has made the house so much more comfortable" (Int.03).

Furthermore, a number of the respondents commented on the significantly reduced noise levels post-retrofit. This is an important consideration when dealing with terraced housing in a capital city where neighbours and traffic alike can cause substantial disturbance. Dissemination of such knowledge is important to advance education, provide clarity of purpose and alter minds (Nevárez-La Torre, 2010).

Without increased levels of knowledge, the population will never gain confidence in the workforce and the retrofit process. One of the respondents advised that, if you are in the mindset of being worried, "you would overthink the pros and cons and then not do the work" (Int.05). It is likely that an owner's confidence will be improved with a deeper understanding

of the process and the industry. This is needed to build back the trust that the industry is currently lacking. Concepts such as The CREBA resource centre in France provide knowledge platforms through online resources for responsible retrofit. Targeting owners, architects and the wider industry as a whole, the project aims to improve levels of retrofit and upskill the trade (Burgholzer et al, 2020).

5.4.2 Motivation

Information, communication and education are key elements, but on their own they are not sufficient to convince owners to undertake retrofit projects or to alter their behaviour (Thomsen, 2020). Figure 1 portrays how obtaining motivation is key to a successful retrofit, prior to behavioural change being enabled. A common disincentive is the payback period often associated with retrofit measures. Suresh et al inform us that the useful life of most upgrades far exceeds the payback period (Suresh et al). In order to increase the application of retrofit projects, three of the interviewees advised that the concept of the payback period needs to be eradicated. One respondent emphasises that we do not expect payback periods on things we normally buy, for example, "a beautiful granite work surface has no payback period ever. Why do retrofit measures that are actually useful have to have a payback?" (Int.01). The idea of payback basically means that we consider the work as an expense rather than an investment and this is unlikely to motivate. A second respondent emphasises this by agreeing that if we can remove this idea of payback and see the work as a long-term investment then the property value might improve.

As previously mentioned, financial incentives in the form of grants and schemes were used by all respondents and can therefore be proven to motivate owner-occupiers. However, as the majority of the owners have a comprehensive understanding of sustainability, the extent to

which these financial incentives act as motivation remains to be questioned. Swan and Brown (2013) debate the success of financial incentives, advising that when the incentive is removed behaviour often reverts. Conceivably, financial incentives encourage those who were on the precipice of undertaking works already but are unlikely to have much sway over those who are not. Furthermore, it is unlikely to ensure that behaviour is aligned with the improved operation of the home post retrofit and this can lead to a performance gap.

5.4.3 Behaviour

For the purpose of this study, owner-occupier behaviour should be considered in two forms. Firstly, how an owner takes action to commence works on their property. Secondly, describing the owner's operational, day to day behaviour once in occupation in the more efficient home.

The findings showed that retrofit requires dedication and is equally demanding and rewarding. One respondent states; "it is interesting and satisfying but you have to commit time and energy and be prepared that these things don't just work off the shelf" (Int.03). The interviewees are united by the fact that all are dedicated to the cause and are prepared to work hard to achieve an efficient, comfortable home. This behaviour is not common in the majority of the population. One respondent demonstrated their dedication by installing the majority of the measures independently, and when the interviewer enquired about the challenge of installing underfloor insulation themselves, the respondent answered, "to this day, I don't know anyone else who has done it themselves" (Int.02). This process here is reflected in the theoretical framework whereby the probability of action taking place is higher if you have distinguished levels of knowledge and motivation. Organ (2013) believed that if energy efficiency improvements were highly valued in society then more people would undertake works and this is confirmed by the findings. However, the findings also show that the process

needs to become more straightforward for those that aren't able to dedicate themselves to the project fully.

A study of the Brunswick Centre in London showed that household energy use can sometimes be 2.2 times higher than average consumption (Ben and Steemers, 2014). This is due to the fact that occupants do not always behave efficiently or interact with technologies in the way that designers expect (Swan and Brown, 2013). The respondents confirmed that they "made a real effort to limit energy use" once the works were complete (Int.02). Changing occupant behaviour has been proven to reduce the energy consumption by half, and therefore this frequently has a greater impact than the retrofit measures themselves (Ben and Steemers, 2014). In order to mitigate this, the respondents recommend "monitoring usage, as this can significantly help to change behaviour as you can actually see what you are doing" (Int.02). People often reward themselves for improving efficiency by turning the heating up higher than normal. This needs to be managed so that homes can function optimally.

6. Discussion

This chapter will draw upon three of the key findings from the previous chapter, appraising the success through which each of the research objectives have been answered. The discussion will initially address how legislation could be adapted so that it looks more favourably upon carbon reduction measures. Secondly, the discussion will highlight the importance of retrofit being recognised as an asset by the property market. Finally, upskilling and expanding the workforce will be considered. In each instance we will evaluate how the point needs to be developed for implementation, along with associated drawbacks.

6.1. Change in Legislation

The literature review and findings demonstrate that owner-occupiers are frequently impeded by UK planning restrictions when undertaking retrofit works. This seriously jeopardises the chances of wide adoption and needs to be tackled head on. In order to overcome this barrier, planning officers will need to look more favourably upon retrofit measures and low carbon initiatives, and changes to permitted development rights may be required. This currently hinders the speed at which projects are completed and the quality of the work achieved, resulting in carbon reductions often being impacted negatively. Changes to permitted development rights in the UK are currently under consultation. However, these proposals have been widely criticized and are considered to focus too heavily on providing new land to develop instead of focusing on adapting the existing housing stock (Permitted Development, 2020). In the case of planning and permitted development rights, some caution is needed to avoid disturbing supply and demand, avoid diluting the housing stock and to ensure that property value is maintained (Bramley, 1998). Throughout this paper, the main research question has been addressed, with numerous obstacles to retrofit identified. However, legislation is one of the central elements inhibiting uptake today. Small adjustments to current policy must be made so that measures that do not impede the overall aesthetic of the property or disturb local wildlife populations are permitted. Failing this, we will be unable to sufficiently decarbonise the existing housing stock at the required rate. While this answers the research objective through discussing how the obstacle of existing legislation can be overcome, it must be acknowledged that further research into suitable policy adjustments is required.

6.2 Value in retrofit

One significant finding establishes that, in order to encourage owner-occupier uptake, property value must be increased by the implementation of retrofit measures. This is usually reflected to a certain extent when the house has undergone a whole house retrofit and refurbishment in a major way. However, this is usually representative of the refurbishment work itself or the square footage added, rather than representing the energy efficiency improvements and increased comfort levels. Moreover, the property market does not necessarily recognise an increase in value if more minor interventions are implemented. The findings confirm discussions in the existing literature and demonstrate that retrofit essentially creates a better home, surpassing what would be delivered if a general refurbishment took place. Zavadskas et al (2008) agree that this should be reflected in the value of the property and discuss the viability of retrofit measures through assessing the anticipated energy savings and trends in the increase of property value of renovated housing. If financial gain was obtained through property value, it would remove the focus from the payback period which commonly deters owners. This was not considered in the literature review; however, the study demonstrated that owners should consider measures an investment rather than an expense. If an owner is considering retrofit because of the payback, it will not be sufficient to convince them to undertake the work. The payback period on most measures is rarely good enough for this. The general consensus is that this shift is slowly occurring. However, acceleration may be achieved through greater dissemination of knowledge in all areas of the property market. Improved property value would provide sufficient motivation for the owners to undertake retrofit works. However, in order for this to occur knowledge of retrofit measures needs to become commonplace. How this dissemination should occur lies open for further research.

6.3 Upskilling and expanding the workforce

The study found that in order to roll out retrofit measures nationwide, a significant development in the quantity and quality of skilled labourers is required. The results show that in previous years tradesmen have often been found to lack the skills and knowledge required to execute successful retrofit projects. This is confirmed by numerous studies in the literature review. However, initiatives, policies and training are being rolled out in force and most interviewees recognised that the workforce has significantly improved in the last 5-10 years.

The key is to ensure that owners have the confidence to undertake projects, and this can be significantly aided if they have confidence in the workforce. Owner-occupiers undertaking work today should use knowledgeable tradesman with prior experience to ensure high standards are achieved and perception is changed. This will happen gradually over time. However, if this is to be accelerated, greater dissemination of knowledge is required. It is clear that low-carbon construction needs to become more appealing as an industry. This may be improved through more consistent Government policies and a straightforward approach to training (The Climate Change Committee, 2020). However, as with the preceding subsection, the means by which to do this are open for further research.

7. Conclusion

This study aimed to answer the research question; *what are the main obstacles preventing the adoption of retrofit measures in owner-occupied pre-1914 terraced housing in London?* An analysis of contextual literature enabled these obstacles to be identified and divided into two categories. First, external obstacles which include; the complexity of housing stock, disruption, finance, legislation and workforce. Secondly, the obstacles that are intrinsic to the owner-occupier including: knowledge, motivation and behaviour. The data retrieved from the

interviews supported the literature in confirming the presence of these main obstacles. The theoretical framework incorporated these barriers which was used to evaluate the findings from the interviews and survey and present a unique approach to understanding the retrofit process.

How can common obstacles that prevent retrofit be addressed? An analysis of the literature, along with the information supplied by the respondents, identifies numerous solutions, most importantly recognising the need for a change in current legislation, the importance of the property market recognising the value of retrofit and improving the capability of the workforce.

In what way can owner-occupiers be encouraged to undertake retrofit projects? Improved levels of knowledge, heightened motives and adjusted behavioural patterns may all contribute to encouraging uptake. Knowledge can be improved through educational facilities, marketing and learning platforms; including knowledge centres and internet resources. Owner motivation may significantly improve if the property market recognised the value of retrofit measures. This could be accelerated by incorporating community benefits and other social motives.

How can we minimise the performance gap in retrofitted properties and maximise the efficiency of owner-occupied houses? This can be enabled through improved knowledge and motivation, as with the above, but fundamentally through owner behaviour. This might be adjusted through monitoring energy usage, models demonstrating desired behaviour, influence from friends and appealing to personal goals and self-identity. Extensive handovers and access to information when a property switches ownership is definitely valuable.

This research hopes to endow the reader with a greater understanding the barriers preventing the decarbonisation of the existing housing stock in London. The findings may apply to other areas of the built environment but to what extent will require further

examination. Future policies should look to relax permitted development and the planning process in favour of low carbon initiatives, whilst preventing the dilution of the diverse housing stock. Additional research should build on the findings from this study so that the shift to a low carbon future can be accelerated.

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Appendix 1

Risk Assessment and Ethical Clearance

RISK ASSESSMENT FORM

FIELD / LOCATION WORK

The Approved Code of Practice - Management of Fieldwork should be referred to when completing this form

http://www.ucl.ac.uk/estates/safetynet/guidance/fieldwork/acop.pdf

DEPARTMENT/SECTION

BARTLETT SCHOOL OF PLANNING- SUSTAINABLE URBANISM MSC

LOCATION(S)

ONLINE

PERSONS COVERED BY THE RISK ASSESSMENT

CHARLOTTE ROE

BRIEF DESCRIPTION OF FIELDWORK

I will be undertaking 3-4 1 hour interviews online over skype. The interviewees will be the owners of the properties which I am using for my case studies. There will be approximately 20 questions which will be provided to the owners in advance of the interview and each owner will be situated in their own home for the duration of the virtual interview. The interviewee does not have to answer any questions that they are uncomfortable with but they have agreed in advance to share the details of the project including the associated risks and complications and have also agreed ot provide photographs of the properties in question. Owing to Covid 19 there will be no site visits.

Consider, in turn, each hazard (white on black). If **NO** hazard exists select **NO** and move to next hazard section.

If a hazard does exist select **YES** and assess the risks that could arise from that hazard in the risk assessment box.

Where risks are identified that are not adequately controlled they must be brought to the attention of your Departmental Management who should put temporary control measures in place or stop the work. Detail such risks in the final section.

ENVIRONMENT	**The environment always represents a safety hazard. Use space below to identify and assess any risks associated with this hazard**
e.g. location, climate, terrain, neighbourhood, in outside organizations, pollution, animals.	Examples of risk: adverse weather, illness, hypothermia, assault, getting lost. Is the risk high / medium / **low** **Low**

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk

	work abroad incorporates Foreign Office advice
YES	participants have been trained and given all necessary information
	only accredited centres are used for rural field work
	participants will wear appropriate clothing and footwear for the specified environment
	trained leaders accompany the trip
	refuge is available
	work in outside organisations is subject to their having satisfactory H&S procedures in place
YES	OTHER CONTROL MEASURES: please specify any other control measures you have implemented: Interview dates are flexible and therefore adverse weather can be avoided as can illness. All interviews will take place online with no site visits owing to Covid 19 which minimises risks associated with the environment by a significant degree.

EMERGENCIES	Where emergencies may arise use space below to identify and assess any risks
e.g. fire, accidents	Examples of risk: loss of property, loss of life

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk

	participants have registered with LOCATE at http://www.fco.gov.uk/en/travel-and-living-abroad/
	fire fighting equipment is carried on the trip and participants know how to use it
YES	contact numbers for emergency services are known to all participants
YES	participants have means of contacting emergency services
	participants have been trained and given all necessary information
	a plan for rescue has been formulated, all parties understand the procedure
	the plan for rescue /emergency has a reciprocal element
YES	OTHER CONTROL MEASURES: please specify any other control measures you have implemented: All participants will be interviewed from their own homes over the internet and therefore will be aware of the safety procedures such as emergency exits within their own house. I too will be in my own house and am aware of the safety procedure in the event of an emergency.

EQUIPMENT	**Is equipment used?**	**NO**	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. clothing, outboard motors.	Examples of risk: inappropriate, failure, insufficient training to use or repair, injury. Is the risk high / medium / low ?		

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**
	the departmental written Arrangement for equipment is followed
	participants have been provided with any necessary equipment appropriate for the work
	all equipment has been inspected, before issue, by a competent person
	all users have been advised of correct use
	special equipment is only issued to persons trained in its use by a competent person
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

LONE WORKING	Is lone working a possibility?	YES	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. alone or in isolation *lone interviews.*	Examples of risk: difficult to summon help. Is the risk high / medium / low? Risk is Low. I will be working on the project on my own from home during Covid 19 lockdown, however, I have housemates who are also confined to the same house and this therefore minimises the risk of not being able to summon help in case of an emergency.		

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
	the departmental written Arrangement for lone/out of hours working for field work is followed
	lone or isolated working is not allowed
	location, route and expected time of return of lone workers is logged daily before work commences
YES	all workers have the means of raising an alarm in the event of an emergency, e.g. phone, flare, whistle

YES	all workers are fully familiar with emergency procedures
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

ILL HEALTH	**The possibility of ill health always represents a safety hazard. Use space below to identify and assess any risks associated with this Hazard.**
e.g. accident, illness, personal attack, special personal considerations or vulnerabilities.	Examples of risk: injury, asthma, allergies. Is the risk high / medium / **low** **Low**

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**
	an appropriate number of trained first-aiders and first aid kits are present on the field trip
	all participants have had the necessary inoculations/ carry appropriate prophylactics
	participants have been advised of the physical demands of the trip and are deemed to be physically suited
	participants have been adequate advice on harmful plants, animals and substances they may encounter
	participants who require medication have advised the leader of this and carry sufficient medication for their needs
YES	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

In the event that someone is unwell on the day the interview will be re-arranged.

TRANSPORT	**Will transport be required**	**NO**	**NO**	**Move to next hazard**
		YES		**Use space below to identify and assess any risks**
e.g. hired vehicles	Examples of risk: accidents arising from lack of maintenance, suitability or training Is the risk high / medium / low?			

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**
	only public transport will be used
	the vehicle will be hired from a reputable supplier
	transport must be properly maintained in compliance with relevant national regulations
	drivers comply with UCL Policy on Drivers http://www.ucl.ac.uk/hr/docs/college_drivers.php
	drivers have been trained and hold the appropriate licence
	there will be more than one driver to prevent driver/operator fatigue, and there will be adequate rest periods
	sufficient spare parts carried to meet foreseeable emergencies
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

DEALING WITH THE PUBLIC	**Will people be dealing with public**	**YES**	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. interviews, observing	Examples of risk: personal attack, causing offence, being misinterpreted. Is the risk high / medium / low? Low risk as will be conducting interviews with members of the public (owners of the case study properties) over Skype. This minimises any risks.		
CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**		

YES	all participants are trained in interviewing techniques
	interviews are contracted out to a third party
	advice and support from local groups has been sought
	participants do not wear clothes that might cause offence or attract unwanted attention
	interviews are conducted at neutral locations or where neither party could be at risk
YES	OTHER CONTROL MEASURES: please specify any other control measures you have implemented: Interviewees will not be required to answer any questions that they are uncomfortable with. We will be following a set structure of questions which will not allow for discussion off topic.

WORKING ON OR NEAR WATER	**Will people work on or near water?**	**NO**	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. rivers, marshland, sea.	Examples of risk: drowning, malaria, hepatitis A, parasites. Is the risk high / medium / low?		

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**
	lone working on or near water will not be allowed

	coastguard information is understood; all work takes place outside those times when tides could prove a threat
	all participants are competent swimmers
	participants always wear adequate protective equipment, e.g. buoyancy aids, wellingtons
	boat is operated by a competent person
	all boats are equipped with an alternative means of propulsion e.g. oars
	participants have received any appropriate inoculations
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

MANUAL HANDLING (MH)	**Do MH activities take place?**	**NO**	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. lifting, carrying, moving large or heavy equipment, physical unsuitability for the task.	Examples of risk: strain, cuts, broken bones. Is the risk high / medium / low?		

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk

	the departmental written Arrangement for MH is followed
	the supervisor has attended a MH risk assessment course
	all tasks are within reasonable limits, persons physically unsuited to the MH task are prohibited from such activities
	all persons performing MH tasks are adequately trained
	equipment components will be assembled on site
	any MH task outside the competence of staff will be done by contractors
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

SUBSTANCES	**Will participants work with substances**	**NO**	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. plants, chemical, biohazard, waste	Examples of risk: ill health - poisoning, infection, illness, burns, cuts. Is the risk high / medium / low?		

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**

	the departmental written Arrangements for dealing with hazardous substances and waste are followed
	all participants are given information, training and protective equipment for hazardous substances they may encounter
	participants who have allergies have advised the leader of this and carry sufficient medication for their needs
	waste is disposed of in a responsible manner
	suitable containers are provided for hazardous waste
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

OTHER HAZARDS	**Have you identified**	**NO**	**If 'No' move to next section**

[redacted]	**any other hazards?**		**If 'Yes' use space below to identify and assess any risks**
i.e. any other hazards must be noted and assessed here.	Hazard: Risk: is the risk		
CONTROL MEASURES	**Give details of control measures in place to control the identified risks**		

Have you identified any risks that are not adequately controlled?	**NO**	**NO**	**Move to Declaration**
	YES		**Use space below to identify the risk and what action was taken**

Is this project subject to the UCL requirements on the ethics of Non-NHS Human Research?	NO

If yes, please state your Project ID Number

For more information, please refer to: http://ethics.grad.ucl.ac.uk/

DECLARATION

The work will be reassessed whenever there is a significant change and at least annually. Those participating in the work have read the assessment.

Select the appropriate statement:

Y E S	I the undersigned have assessed the activity and associated risks and declare that there is no significant residual risk
Y E S	I the undersigned have assessed the activity and associated risks and declare that the risk will be controlled by the method(s) listed above

STUDENT

Charlotte Roe

NAME OF SUPERVISOR

Your response

Respondent: **Charlotte Roe** Submitted on: Thursday, 28 May 2020, 10.20 AM

Ethical Clearance Pro Forma

It is important for you to include all relevant information about your research in this form, so that your supervisor can give you the best advice on how to proceed with your research.

You are advised to read though the relevant sections of UCL's Research Integrity guidance to learn more about your ethical obligations.

Dissertation Details

1

Response is required

*

Please select your programme of study.

Sustainable Urbanism

2

Response is required

*

Please provide your current working dissertation title.

Decarbonising pre 1914 terraced housing in London: Key obstacles and improving owner-occupier uptake of retrofit projects

3

Response is required

*

Please select your supervisor from the drop-down list.

Juangbhanich, Lisa

Research Details

4

Response is required

*

Please indicate here which data collection methods you expect to use. Highlight all that apply.

Interviews

Focus Groups

Questionnaires (including oral questions)

Action research

Observation / participant observation

Documentary analysis (including use of personal records)

Audio-visual recordings (including photographs)

Collection/use of sensor or locational data

Controlled trial

Intervention study (including changing environments)

Systematic review

Secondary data analysis

Advisory/consultation groups

5

Response is required

*

Please indicate where your research will take place.

UK only

6

Response is required

*

Does your project involve the recruitment of participants?

'Participants' means human participants and their data (including sensor/locational data and observational notes/images.)

Yes

Appropriate Safeguard, Data Storage and Security

7

Response is required

*

Will your research involve the collection and/or use of personal data?

Personal data is data which relates to a living individual who can be identified from that data or from the data and other information that is either currently held, or will be held by the data controller (you, as the researcher).

This includes:

- Any expression of opinion about the individual and any intentions of the data controller or any other person toward the individual.
- Sensor, location or visual data which may reveal information that enables the identification of a face, address etc. (some postcodes cover only one property).
- Combinations of data which may reveal identifiable data, such as names, email/postal addresses, date of birth, ethnicity, descriptions of health diagnosis or conditions, computer IP address (of relating to a device with a single user).

Yes

8

Response is required

*

Is your research using or collecting:

- special category data as defined by the General Data Protection Regulation*, and/or
- data which might be considered sensitive in some countries, cultures or contexts?

*Examples of special category data are data:

- which reveals racial or ethnic origin, political opinions, religious or philosophical beliefs, trade union membership;
- concerning health (the physical or mental health of a person, including the provision of health care services);
- concerning sex life or sexual orientation;
- genetic or biometric data processed to uniquely identify a natural person.

No

9

Response is required

*

Do you confirm that all personal data will be stored and processed in compliance with the General Data Protection Regulation (GDPR 2018)?

Yes

10

Response is required

*

I confirm that:

The information in this form is accurate to the best of my knowledge.

I will continue to reflect on, and update these ethical considerations in consultation with my dissertation supervisor.

Yes

Appendix 2 - Example interviewee consent form

UCL DISSERTATION CONSENT FORM

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Study: Decarbonising pre 1914 terraced housing in London: Key obstacles and improving owner-occupier uptake of retrofit projects

Department: The Bartlett School of Planning

Name and Contact Details of the Researcher: Charlotte Roe – 07710225876
char_roe@hotmail.com / ucbqclr@ucl.ac.uk

Name and Contact Details of Supervisor: Lisa Juangbhanich –
a.juangbhanich.11@ucl.ac.uk

Name and Contact Details of the UCL Data Protection Officer: data-protection@ucl.ac.uk

Thank you for considering taking part in this research. The person organising the research must explain the project to you before you agree to take part. If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

I confirm that I understand that by ticking/initialling each box below I am consenting to this element of the study. I understand that it will be assumed that unticked/initialled boxes mean that I DO NOT consent to that part of the study. I understand that by not giving consent for any one element that I may be deemed ineligible for the study.

		Tick Box
1.	*I confirm that I have read and understood the Information Sheet/ explanation for the above study. I have had an opportunity to consider the information and what will be expected of me. I have also had the opportunity to ask questions which have been answered to my satisfaction and I would like to take part in an individual interview	
2.	*I understand that I will be able to withdraw my data up to 1st August 2020 OR 6 weeks after the interview	
3.	*I consent to participate in the study. I understand that my personal information *(details of the house, retrofit project, energy bill data and photographs)* will be used for the purposes explained to me. I understand that according to data protection legislation, 'public task' will be the lawful basis for processing.	

4.	**Use of the information for this project only** *I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified *(unless you state otherwise, because of the research design or except as required by law).* Anonymity is optional for this research. Please select from the following 3 options: I agree for my real name and role/affiliation to be used in connection with any words I have said or information I have passed on. I request that my comments are presented anonymously but give permission to connect my role/affiliation with my comments (but not the title of my position). I request that my comments are presented anonymously with no mention of my role/affiliation.	
5.	*I understand that my information may be subject to review by responsible individuals from the University for monitoring and audit purposes.	
6.	*I understand that my participation is voluntary and that I am free to withdraw at any time. I understand that if I decide to withdraw, any personal data I have provided up to that point will be deleted unless I agree otherwise.	
7.	I understand the potential risks of participating and the support that will be available to me should I become distressed during the course of the research.	
8.	I understand that the data will not be made available to any commercial organisations but is solely the responsibility of the researcher undertaking this study.	
9.	I understand that I will not benefit financially from this study or from any possible outcome it may result in in the future.	
10.	I agree that my anonymised research data may be used by others for future research. [No one will be able to identify you when this data is shared].	
11.	I understand that the information I have submitted will be published as a report and I wish to receive a copy of it. Yes/No	
12.	I consent to my interview being audio recorded and understand that the recordings will be: EITHER destroyed within *3 months after the data has been collected* or destroyed following transcription. OR Stored anonymously, using password-protected software and will be used for training, quality control, audit and specific research purposes. To note: If you do not want your participation recorded you can still take part in the study.	
13.	I have informed the researcher of any other research in which I am currently involved or have been involved in during the past 12 months.	
14.	I understand that other authenticated researchers may have access to the dissertation once published and therefore have access to the anonymised data provided from the interview.	
15.	I am aware of who I should contact if I wish to lodge a complaint.	

16.	I voluntarily agree to take part in this study.	
17.	I hereby confirm that I understand the criteria as detailed in the Information Sheet and explained to me by the researcher.	

_____	_____	_____
Name of participant	Date	Signature

_____	_____	_____
Researcher	Date	Signature

Appendix 3 - Interviewee questionnaire

Research questionnaire

Property:

Owner:

Date of interview:

Approach to retrofit and technologies used

1. Please can you give an overview/ description of your house? i.e. location, date of construction, type of construction, orientation, length of ownership etc.

2. What inspired you to undertake a retrofit project?

3. What implementations did you incorporate into the project? i.e. renewables, building fabric improvements etc.

4. Please provide the u-values (floors, walls, roof, doors and windows) and wall build up details (before and after) if building fabric was improved.

5. How much have these improved the energy efficiency of the house? i.e. Details of how much energy is saved per year, amount that carbon emissions have been reduced by etc.

6. What do you feel was the greatest success of the project?

7. Is there anything that you would do differently if you were to undertake the project again?

8. What do you feel were the biggest challenges that you faced when undergoing the retrofit project?

9. Do you feel that these were common challenges for similar retrofit projects or were the challenges presented here unusual?

10. How did you overcome these challenges?

Financing and government standards

11. How much did you originally budget for the project and how much did it cost overall?

12. Were you able to use a government funded scheme or grant? If so, please provide details.

13. To what extent did the retrofit works reduce the cost of your annual energy bills?

14. Did you achieve a set building standard or certification during this project?

Contractors and retrofit execution

15. How did you find the contractors that you used?

16. Were they specifically trained in low carbon construction, local companies etc? Did you experience any issues with skill sets? Please provide details.

17. How long was it originally anticipated that the works would take?

18. How long did the project actually take?

19. How easy did you and those working on the project find it to source the relevant materials and technologies?

20. Were you in occupation during the works? Please provide details.

Owner knowledge, motivation and behavioural change

21. What do you think is needed to improve uptake of retrofit projects amongst owner-occupier?

22. What piece of advice would you give to other owner- occupiers embarking on similar retrofit projects?

23. Any other comments:

Do you have any questions for me?

Thank you

Appendix 4 - Transcriptions

Approach and technology

Int.01 is a Victorian semi-detached house located in Highgate New Town. The house is orientated to the North West and situated in a protected area within Camden. The property has been intensively lived in for over one hundred years. The owner is an environmentalist who started of their career in building resources and now runs an independent consultancy service specialising in improving the sustainability of existing houses. The owner is a founding member of SuperHomes, a network of energy aware households that are pioneers of green living. The owner's home was purchased in 2005 specifically to be retrofit. Owner has spent vast majority of career focused on this area. She believes that they are an incredibly good form of housing and Victorian houses in particular are usually built very well but they leak badly.

The owner primarily focused on reducing the need for energy through concentrating firstly on the building fabric and implementing internal wall, roof and floor insulation, installing double glazing throughout the house and triple glazing was installed on the French windows. The services were stripped out. A wood burning stove was input for space heating, solar thermal for hot water and 1.68kWP PV on the roof. The boiler is located as close as possible to rooms that use water and all pipework is well insulated to reduce heat loss.

The property's air tightness has been significantly improved to 5.56 air changes per minute. This is achieved by the installing of an air tightness door. The average Victorian house is about 30 air changes per minute. This surpassed new build standards at the time and is therefore an astonishing achievement. LED lights were installed throughout which amounts to less than 500 watts if all lights are on in the house. A sun panel was implemented on the first floor to improve the levels of natural light entering the property. It is believed that the works reduced the carbon emissions by between 75-80%. The bulk of the works occurred in 2006 but measures such as

the PV, the wood burning stove and a weather compensation unit to reduce gas consumption were installed at a later stage.

When asked what the greatest success of the project was, the owner declared that they had managed to successfully turn the house into a comfortable and efficient twenty-first century home. It has been recognised by The Sustainability Commission as an exemplar project and was the only house at the time with energy efficiency improvements that English Heritage recognised as not being a desecration to the heritage of the house. Works with the Victorian Society who have now agreed that it is possible to carry out such works without ruining them.

If the owner were to undertake the project again, they confirmed that they would be bolder in their approach, especially with regards to insulation and air tightness and would perhaps consider PassivHaus which was not around at the time this project was undertaken. The owner advised that at the time there was very little information about how to retrofit and this was the biggest challenge. In order to overcome this they had to pull on their past experience, do a lot of research, use contacts made from their career and closely monitor the works to ensure everything was being executed correctly.

Int.02 is a three storey Edwardian end-terrace property measuring 180 sqm in total. It is south facing with 31 sash windows and located in Haringey, North London. It is, like case study 1, a registered SuperHome and the majority of the works were undertaken about ten years ago. The Owner has owned the property for 23 years and was inspired to undertake a retrofit project in order to improve comfort levels, reduce energy consumption and stop the windows from rattling. The Owner and family have always been environmentally minded and therefore undertaking this project seemed like a logical step. The owner is very hands on and implemented the vast majority of the measures himself. Replacing the windows was the first step. They used Perspex secondary glazing which he fitted himself. Believes that this is a better

option than double glazing double glazing doesn't sort the issue of the frame. The gaps in the suspended floorboards were filled and sheep's wool was installed for insulation. The Owner did this by cutting trap doors in the floorboards and going installing the wool himself by climbing into the void underneath suspended floor. Insulation was also installed in the attic which was converted when the house was bought. This was installed between the joists. Sempatap internal wall insulation was also implemented. 2m2 of solar hot water was installed along with two wood burning stoves and fan to assist with the distribution of heat. 2kWP PV was installed which provides two thirds of the electricity for the house. Draught excluders and thick curtains were installed for extra warmth and a porch was installed to improve the air tightness. Over the last ten years these measures have meant that the electricity usage has been reduced by nearly 5kwh per day and gas consumption has improved by around 30kwh per day. The fuel for the wood burning stoves comes from the owners own woodland and is therefore sustainably sourced. The owner declared that they felt using their own wood was one of the more enjoyable and successful parts of the project and that installing the underfloor insulation was the most satisfying part as it is very rare that someone is willing to do this themselves. Have to be lithe and get stuck in. If they were to undertake the project again, they stated that they would have installed the porch first, made the internal wall insulation thicker and installed another foot of insulation in the attic by dropping the ceiling further. The biggest challenged they faced was the lack of information available to them. What information was available was difficult to trust and knowing what to believe. In order to overcome this, he did the majority of the work himself and had the courage to give it a go.

Int.03 is stucco fronted Victorian terraced house in Notting Hill. It was constructed between 1860-5 and is a five-storey house totalling around 3,200 sq. ft. The owner moved into the house in 2010 and lived in the property for two year prior to undergoing the works. It was very run down when it was purchased, and the retrofit took place predominantly for comfort

purposes. The owner has built an extremely successful career in clean energy, transportation, infrastructure and sustainable development. The house was not fit for habitation and therefore extensive work was required anyway. The decision to make the house clean was subsequent to that. The economics of deep clean retrofit make more sense when you are already going to undergo extensive refurbishment works. The owner implemented wall insulation, underfloor heating, efficient appliances, double glazed sash windows. Included low energy lighting, an outdoor tank that collects rain water to flush the loos, solar panels, a heat pump and a fuel cell. This has reduced energy consumed in the house by about half and all the electricity they use is effectively free. Thermal performance was improved by about 65-70%. Owner feels that before anyone carried out a retrofit, they should move into the property and get a proper feel for the house so that they know where the issues lie. Switch to Octopus and build up proper data on the house before carrying out the work as this will significantly improve quality of retrofit. When asked what the greatest success of the work was, the owner advised that the comfort levels were the best. He said that there are a number of collateral benefits that get ignored by nay-sayers but actually the overall benefit is that actually you are just creating better houses. The owner would advise that anyone undertaking similar work should take great care when choosing their tradesman. They had difficulties finding competent tradesman with the right skills for the job. In order to overcome this, he had to project manage the works himself and pay for builders to learn on the job. The owner has advised that issues often lie with the local authorities and what they are willing to give consent to in planning. Start with airtightness and insulation. Another challenge was getting sufficient data before and after the works. You want to wait until its bedded in and everything is up and running and then do good analysis, but you need to be careful with energy bills as they didn't believe that the fuel costs were so low so were doing estimates of how much owner should have been paying. Inaccurate utility details. Need to make sure readings are accurate before you start.

Int.04 was constructed in the late 1980's and is a double fronted, two storey Victorian terrace in Alexandra Palace. The property had been converted into two flats in the late 20th century but the previous owners had cosmetically converted the building back into a house prior to the existing owners purchase but the building services still existed as if there were two separate flats. The owners purchased the house to undergo retrofit works from day one to the best practice standard at the time. The owners are both retired and therefore wanted to create a home that was comfortable and easy to heat. They were also inspired by the energy saving and cost saving benefits. The roof was renewed and reinforced, and the loft insulated. External wall insulation was installed at the rear of the property. Double glazed windows were installed throughout and LED put into the house. Smaller and more efficient radiators were also installed. The windows make a considerable difference to blocking out the sound of the traffic outside. Solar PV were installed with a 3kw battery and a diverter and cylinder which allows excess electricity to be turned into hot water. A drainage system was installed around the rear of the house to keep water away from the external insulation and a wood burning stove was installed for space heating. Internal wall insulation was installed at the front of the house. The kitchen was completely renewed with efficient appliances and underfloor heating. Floor insulation was only installed in the kitchen. The owner declares that the greatest success is the evenness of temperature and comfort levels both in summer and winter. It is also a plus that they do not have to worry about energy bills. It is difficult for them to know what they would do differently if they were to do the project again as things have moved along and improved greatly since, but they perhaps would have installed trickle vents on the windows as otherwise windows have to be opened for ventilation. The biggest challenge was living in the house while the works were ongoing. Had to move a lot of stuff into storage.

Int.05 is an Edwardian terraced four-bedroom family home in Muswell Hill. When it was purchased in 2011 and the property was not connected to the grid. The owner was not looking to explicitly undergo retrofit works as the property needed to undergo renovation works anyway. The owners were not scared of a project but environmentally conscious and the retrofit idea emerged over time and after having conversations with friends who are involved in that world. Owner wanted to be consistent with how they live and how they work as work in sustainable communities. They looked at low cost high impact measures and implemented internal wall insulation, underfloor insulation and insulation in the attic. They installed solar panels and two wood burning stoves for space heating with an efficient boiler for backup. Electric wall heaters were already in place at the time of purchase. However, foil was installed on the back of these to maximise efficiency. They also had weather compensation units, but these did not work. First years wood was from the building works and contractors now drop off wood at their house from other building sights in order to save them going to the dump. Their bills have been reduced by about a quarter. The property now qualifies as a SuperHome and the owners declare that the greatest success was the amount that they learnt from the project. It took them on a very positive journey. If they were to undertake the project again, they would use non-toxic paint and maybe have used less contractors. They had a number of people doing different things which made it difficult to know who was telling you the right thing and hard to project manage. The biggest challenge was that it was difficult to know the right journey through. Lots of disjointed information. In order to overcome this the owner had to project manage himself.

Finance and standards

Int.01 explained that they spent around £17,000 on the energy improvement work. This excludes PV and wood burning stove. Clear Skies government grant paid for half the solar thermal which amounted to £2000. Means that they do not normally pay for hot water between April and October. The Camden ECO grant covered a significant amount of the insulation costs. The Solar PV was installed when the Feed In Tariff came in and therefore the owner gets paid for more than the electricity they use. The owner was unable to specify exactly how much the cost of energy bills was reduced by as they were not in occupation prior to the works taking place and the project was not trying to achieve a certain standard. Wanted to do external insulation but not possible with planners. Triple Glazed windows cost around £2,500 and double-glazed sash windows cost around £5,000. The quality of windows and doors is something that she feels has improved leaps and bounds since early 2000's.

Owner doesn't believe in the concept of payback period as you wouldn't ask for the payback on a new kitchen installation or carpet. So why are energy efficiency improvements that are useful any different?

Int.02 advise that they did not originally budget for the works. They completed the works over a period of time but believe that total amount spent probably comes in the region of £50,000. A lot of this cost does not include labour time as the owner installed a number of the measures himself. He believes that the wool for underfloor insulation was around £2,000, the windows cost around £3,000 and the wood burner cost around £3,000. He believes that the solar PV cost around £8,000 and the solar hot water cost around £5,000. For the solar hot water, he used the Hot Roc government grant and was in the second round of the Feed In Tariff for the solar PV and fuel cell. He carried out all the work himself apart from PV, solar thermal and

installation of wood burner. Agrees with case Study 1 about the concept of payback period being ridiculous. With PV this is actually the cheaper option so makes completely sense.

Int.03 says that some people believe you should reduce stamp duty for green homes but believes that the problem with this is that you have poor quality work undertaken by people who are keen to sell their home as quickly as possible and the commitment is not there. There is a possibility that stamp duty reduction for those moving in is a better solution, however people should not be forced to do this work straight away but after a couple of years so that they have a chance to understand their house and work out what the best course of action is for undertaking retrofit works. A profound jobs is needed.

Frustrated with planning as they would only permit a skylight with a steel frame. This acts as a thermal bridge and increases heat loss from the property which was very frustrating for owner. Spent around £750,000 on the works in total with around £150,000 being spent on the energy efficiency works. Solar panels were installed on the Feed In Tarriff and the Heat Pump was installed on the Renewable Heat Incentive. Total works will have a payback period of 25-30 years.

Idea that it costs more to do it than not to do it based on the assumption that the money as an expenditure rather than an asset. Doing any retrofit works should be seen as an asset. The works make the property more valuable and therefore if you were to sell it on why wouldn't they make their money back?

Int.04 originally budgeted around £30,000 for these works to take place. It cost about this but this doesn't include the roof works or the windows. Very difficult to budget. They used the Feed In Tariff for the PV and the external wall insulation was obtained through the Green Deal. However, obtaining this was arduous work. Two environmental surveys required. Once for

each grant. For the green deal you had to get an energy savings specification and architectural survey and they had to agree in order to get the grant. Very pressured and involved lots of different bodies. Pay about £100 for gas and electric per month and that doesn't include what they get back from FIT. Don't have data from before as didn't know the house.

Int.05 budgeted and spent around £140,000 but this also includes kitchen and bathroom works that were not specifically energy efficiency improvements. They are on the first-generation Feed In Tarrif for PV got 56p just before it changed. They've now paid this back after 10 years. Paid £6,000 for 10 solar panels. They get £600-£700 per year for this from the FIT. £250 for environmental audit. Budget was tight and they were renting so needed to get it done as quickly as possible. They were not in occupation during the works.

Contractors and workforce

Int.01 advised that the competency of the builders used was pot luck and the only company known by the owner at the time. There are problems with workforce but were pleased with the workforce used but have advised that contractor knowledge has come a long way since then and architecture has improved significantly, and people care a lot more than. It was originally anticipated that the work would take six months but overall it actually took less than this and the builders agreed to do all the redecoration works within this time frame. The owner was not in occupation for the majority of the works. General understanding is improving massively but at time of construction was knowledgeable. Contractors are often trained by the previous generation which means they are often more change adverse.

Int.02 did not experience any issues with skills sets as they did most of the installing themselves. However, for the solar hot water and PV the installers were qualified, and the

owner was very happy with the work done. The issue that was experienced was in the attic where they had to redo insulation work as builders didn't go a good enough job as wasn't tight to the joists. They never set a period of time that the works needed to be completed in and as the project has been done in parts the work overall took around 16 years from start to finish. Did another project more recently and only took around a year as knew exactly what he was doing. They found the materials easy enough to source but advised that it would be challenging for those with little or no experience in the field. The owner was in occupation throughout the works. Never used building company, he did most of works, however in the instances where he didn't have time to finish, he would start the works and then show a contractor how it was done and then get them to do the rest.

Int. 03 experienced a number of issues with the workforce involved in the project. The lack of knowledge was challenging and discovered that there is a massive skills gap in the industry. They believe that this is less bad now than what it was but nevertheless we should be churning out skilled and knowledgeable tradesman in low carbon construction. He used Be Green Systems that is a renewable energy installation company that ended up working on the house. The project ended up taking the best part of two years and the owner was not in occupation during the works. Would advise that one should take care that the people you employ have done similar projects. Apprenticeships should support the training of this type of construction as it means higher value jobs for their tradesmen. Taking a risk to use tradesman who don't feel comfortable with what they are doing, have no knowledge with moisture management and other aspects of work. There needs to be a better way to protect high value jobs. Not straightforward projects or skills. Once you have done one project you are way more qualified than the majority of people. Hopefully this will come with time as shift towards greener homes happen.

Int.04 lived in the property whilst the works were occurring which they found challenging Unable for the works to be done room by room and was incredibly dusty throughout the whole duration. They were generally happy with the contractors work and all the people they employed were specifically trained in low carbon construction. It was originally anticipated that the project would take three months but it ended up taking one year. Contractors advised company to use for solar panels while feed in tariff was still going. Used contractors they felt they could trust to do a quality job or have worked with before. When governments pull the plug on grants a lot of skilled workforce lose their jobs.

Int.05 advises that there were tensions between the contractors used as they had conflicting ideas about how the works should be executed. The builders that they used presented themselves as green builders, but the owner is uncertain of how knowledgeable they really are. Didn't trust them to do the solar panels. Had to get specialist in to do this who did a good job. Owner had to make the decision of which products to use. The project was predicted to take 4 months and was completed within this time frame. The owners were not in occupation during the works. Very few places you can go to where you get completely impartial advice. Usually people have something to sell at the end.

Owner-occupier uptake and motivation/ behavioural change

Int.01 believe that in order to improve uptake of retrofit projects there needs to be a significant change within building regulations and how they are enforced. There needs to be national changes to permitted development and planners who currently make things unbelievably difficult need to be more forgiving for energy improvement measures. The owner advises that for others planning on undertaking similar works, a whole house approach is

needed but this doesn't necessarily have to take place at the same time but can be done over years with the project being broken down into parts. It is also important to get someone to check the details so that you don't make mistakes. Proved that it is possible to make good quality existing houses energy efficient. Whatever the motivation; whether it's for comfort, to save the planet, or to cut costs, it doesn't matter as it still achieves the same thing.

Int.02 believe that the disruption and dust caused by works significantly reduces people's desire to undertake such projects. They believe that people are driven by price and cost is the biggest deterrent and therefore if utility prices were higher people would be more inclined to undertake works. The owner would advise perspective undertakers of retrofit projects to do something no matter how big or small. They believe it is very overwhelming as there is so much that you can do but it is about having the confidence to do what you can to make a difference. They believe that DIY saves a lot of money if owners have the ability to be able to do so. You have to have the confidence to go for it and not worry about the bad reviews that you read on the internet. The owner monitors usage very closely and advises that this can really help you to see the impact and benefits of the work you have done.

Int. 03 believes that in order to motivate others to undertake retrofit works costs need to be reduced significantly. At the moment it costs more to do it than not to do it and this should be the other way around. The right policies could make people see this as an investment. If owner sells house, he would make all his money back. The owner thinks that people should be able to see data and numbers on the energy they are using rather than an A-G scale on an EPC. People respond better to relevant data that can be applied to their lives. The owner would advise that in order to undertake such a project you really have to commit to it. It is satisfying and interesting, but you do not reap the rewards straight away need to be prepared to put some energy into it. Not ready be bought off the shelf yet.

Int.04 believe that much more financial help is needed in order to motivate others to undergo retrofit projects. The disruption is a big turn off so without financial incentive it is unlikely that people will be willing. There also needs to be improved awareness as there is a lack of knowledge. The owners would advise that other owners should decide what will give them the biggest return for the disruption and to consider everything including total cost. In the ideal world they believe that a whole terrace would undertake works together as this would minimise the work being done on an individual level.

Int.05 believe that the process needs to become simplified in order to encourage uptake. People have got to understand the benefits. People associate retrofit with being more expensive which is not necessarily the case. People should consider if they are already undertaking renovation works, they should incorporate environmental benefits. Won't cost that much more but will make a considerable difference. Would advise other owners to ensure that everything should be use led not design led to ensure it works in practice and is easy to maintain. Also advises that you should look at what you are trying to achieve through renovation and then incorporate energy efficiency measure where you can. Look at what has low cost and high impact. The owner believes that people are financially driven and if they can therefore see how much they will be able to save they may be more inclined to undertake works. Behaviour needs to be changed as you cannot guarantee that people are going to use the technologies properly once they are living in the house.