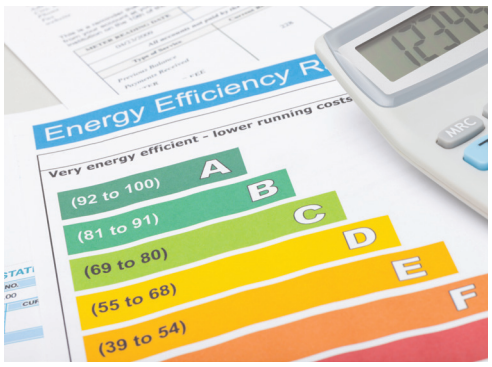
Centre on Innovation and Energy Demand



Warm Homes for All

A comprehensive policy approach for residential energy efficiency retrofit in the UK

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Research Councils UK Energy For a Low Carbon Future

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About the Centre on Innovation and Energy Demand (CIED)

Researchers at the Centre on Innovation and Energy Demand (CIED) are driven by an interest in accelerating prospects for a more sustainable energy future. Our primary focus is on the processes of innovation – both technological and social – that will contribute to this objective, using a range of multi-disciplinary social science approaches.

This report draws on recent published research at the Centre on Innovation and Energy Demand (CIED), as well as the UK Green Building Council (UKGBC), the Regulatory Assistance Project (RAP) and the Association for the Conservation of Energy (ACE).

Our work areas

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Executive summary

The multiple benefits of energy efficiency (EE) 'retrofit' mean it should be the cornerstone of the government's energy and housing policy. However, despite recent polices, the UK still has one of the least efficient housing stocks in Europe [1]. This report is focused on some of the solutions to this retrofit challenge, based on the aspirational targets for all UK homes to be EPC band C by 2035 and for fuel poor homes by 2030 – as set out in the UK Government's Clean Growth Plan [2].

One in ten UK households are in fuel poverty [3], yet for **every £1 spent on retrofitting fuel poor homes an estimated £0.42 is saved in National Health Service spending** [4]. Homes account for almost a **quarter of the UK's carbon emissions** [5], and through cost-effective investments to 2035 could save around one quarter of the energy currently used: an **average saving of £270 per household** per year [6]. Similar scenarios suggest between **66-86,000 new jobs could be sustained annually** [7] by this level of retrofit activity. This will require **approximately £85.2bn investment** at today's prices, which would deliver **benefits** (in terms of reduced energy use, reduced carbon emissions, improved air quality and comfort) **amounting to £92.7bn with a net present value of £7.5 billion** [6]. Additional benefits– including improved health, additional economic activity and benefits to the electricity system – **could be up to £47 billion** [6].

To achieve this, a comprehensive **'whole house' approach to residential retrofit** will be increasingly needed [8] - involving multiple measures with strategies for insulation, draught proofing, ventilation, heating systems and low carbon microgeneration [9].

EE has historically played a pivotal role in reducing the UK's energy use and carbon emissions. Total UK **household energy use decreased by 19% between 2002 and 2016, despite a 12% increase in the number of households and a 10% increase in population** [10]. The vast majority was driven by EE polices. Recent policies such as the Green Deal have failed, and the UK now has insufficient policies in place to deliver its medium and long-term targets for EE in residential buildings [7].

This report argues that new policies must address four interrelated challenges that continue to contribute to low household demand for residential retrofit:

1 A widespread lack of **information, engagement and trust** with households on the options for and advantages of EE retrofit.

2 Consumers often feel retrofit has **uncertain benefits and quality** owing to the absence of guarantees on performance and a low skilled supply chain.

3 To undertake a comprehensive retrofit, households face significant **complexity, disruption** and poor integration with the **timing** of wider renovation decisions.

4 Finally, the up-front **capital cost and split incentives** between landlords and tenants, or those looking to move, can be a major barrier.

To overcome these interrelated challenges, we draw on best practice examples from three of the key elements for undertaking a retrofit: the installer **business model**, the **financing** and the role of **intermediaries**. To deliver the Government's targets a **comprehensive package of policy measures** will therefore be required as it is **unlikely** that the EPC band C goal can be **achieved through a single policy instrument**.

A major reason for the lack of retrofit uptake is the **limitations of the traditional 'atomised business model'**. Characterised by a piecemeal offering with a fragmented supply chain; a focus on single (rather than multiple, complementary) measures and no guarantees on performance; requiring multiple interfaces and adding significant hassle for the household.

Policy instead should seek to facilitate and promote **'integrated business models'** to include:

- wider renovation measures that appeal to the benefits of improved aesthetics, increased property value, comfort, health and wellbeing
- a simplified customer journey through an integrated supply chain, project co-ordination and a financing offer - reducing complexity and minimising disruption for households
- energy performance guarantees and service-based models providing certainty surrounding the performance of the retrofit and the quality of the installation

To address the up-front capital cost of retrofit measures and the split incentives faced by tenants and landlords, a range of **financing solutions** are needed. A **fuel poverty policy funded by general taxation** would be more consistent with addressing the co-benefits of health and social welfare. There is also a need for **repayable retrofit financing** for the 'able-to-pay' segment. This should include: a low *cost of capital* for retrofit finance, funding for *non-energy measures* and a *simplified customer journey* – with finance available alongside the retrofit and tied to the property, not the individual. Additionally, a range of **financial incentives** would promote demand - including a range of fiscal or energy supplier funded incentives, particularly effective at key *trigger points* such as when properties change hands.

To address the lack of information, engagement and trust with the wider public, and the complexity of whole house retrofits – **intermediary roles** are needed both at **project level** (e.g. individual retrofits) and the **broader market level**. Policy support is therefore needed to create dedicated intermediaries in every community to facilitate 'one-stop-shops' for retrofitting through which households can access advice on technological and financing options, as well as tradespeople, contractors and installers.

Comprehensive policy mix – recommendations

Political leadership

- **'Efficiency First' as a guiding principle** in the design of future energy policies
- **EE as an Infrastructure Priority** under the remit of the National Infrastructure Commission

Regulations

- **Minimum EE Standards (MEES)** across all homes moving to EPC band C in 2035
- New retrofit **quality assurance standard** such as a Home Quality Mark

Financial measures

- **Fuel poverty obligation** funded by general taxation
- Government-backed **low interest financing mechanism** secured to property and available at point of sale of the retrofit
- **Financial Incentives at trigger points**, options could include: Variable Stamp Duty; Variable Council Tax; 0% VAT on renovation work; Income Tax rebates, a Landlord's Energy Savings Allowance (LESA) or EE Feed in Tariff

Policy implementation and new institutions

- **National Retrofit Taskforce/Agency** with central Information Hub and a Data Warehouse
- **Consumer facing area-based one-stop-shops** based on Community Social Enterprise or Local Authority Arm's Length Management Organization (ALMO) delivery models
- **Market facing intermediaries** and standardised procurement frameworks to promote supply chain integration and integrated business models

1. Introduction

Carbon Dioxide (CO_2) emissions resulting from energy used in residential buildings constitute a significant proportion of total emissions in advanced economies such as the United Kingdom (UK). Aside from more efficient appliances and behavioural changes, emissions from the existing housing stock can be reduced by the **retrofit** of three main types of measure: improving the energy efficiency (EE) of the building fabric; adopting low carbon heat technologies; and building integrated electricity microgeneration, such as solar PV [11].

The Clean Growth Strategy, launched by the UK government on October 12, 2017, sets out ambitious long-term targets for EE, especially for buildings. This would require a significant increase of the current building improvement delivery rate. The targets specify that all homes as far as possible should reach **Energy Performance Certificate (EPC)[1] band C by 2035 and all fuel poor[2] homes by 2030** [2]. At the time of writing, government is consulting on several new policy measures, and has recently introduced minimum energy efficiency standards (MEES) for the private rented sector.

Recent policy initiatives in the UK, such as the Energy Companies Obligation (ECO) and the Green Deal, have sought and failed to achieve the mass uptake of comprehensive residential energy efficiency retrofit (hereafter referred to as 'retrofit'). Further, the Competition Markets Authority recently found that domestic energy customers are overcharged by £2 billion every year [3]. This report will argue that such policies have failed to address four systemic challenges that constrain demand for whole house retrofits, and that a more comprehensive and wide-reaching policy approach will be needed to overcome each of these challenges.

The report is therefore focused on some of the solutions to these challenges from the perspective of three key elements of a retrofit: the business model, financing and intermediaries. This document then sets out how achieving these aims will require a comprehensive policy mix requiring political leadership, new regulations, financial measures and new institutions for policy implementation.

[1] EPCs are a measure of a building's energy efficiency and running costs, based on a standardised assessment procedure. Most EU member states employ some form of EPC and they are typically rated from A to G, with A being an exemplary dwelling.

[2] The definition of fuel poverty in the UK, is where fuel costs that are above average (the national median level), and these fuel costs leave a residual income that is below the UK's official poverty line (Department of Energy & Climate Change (DECC), 2013)

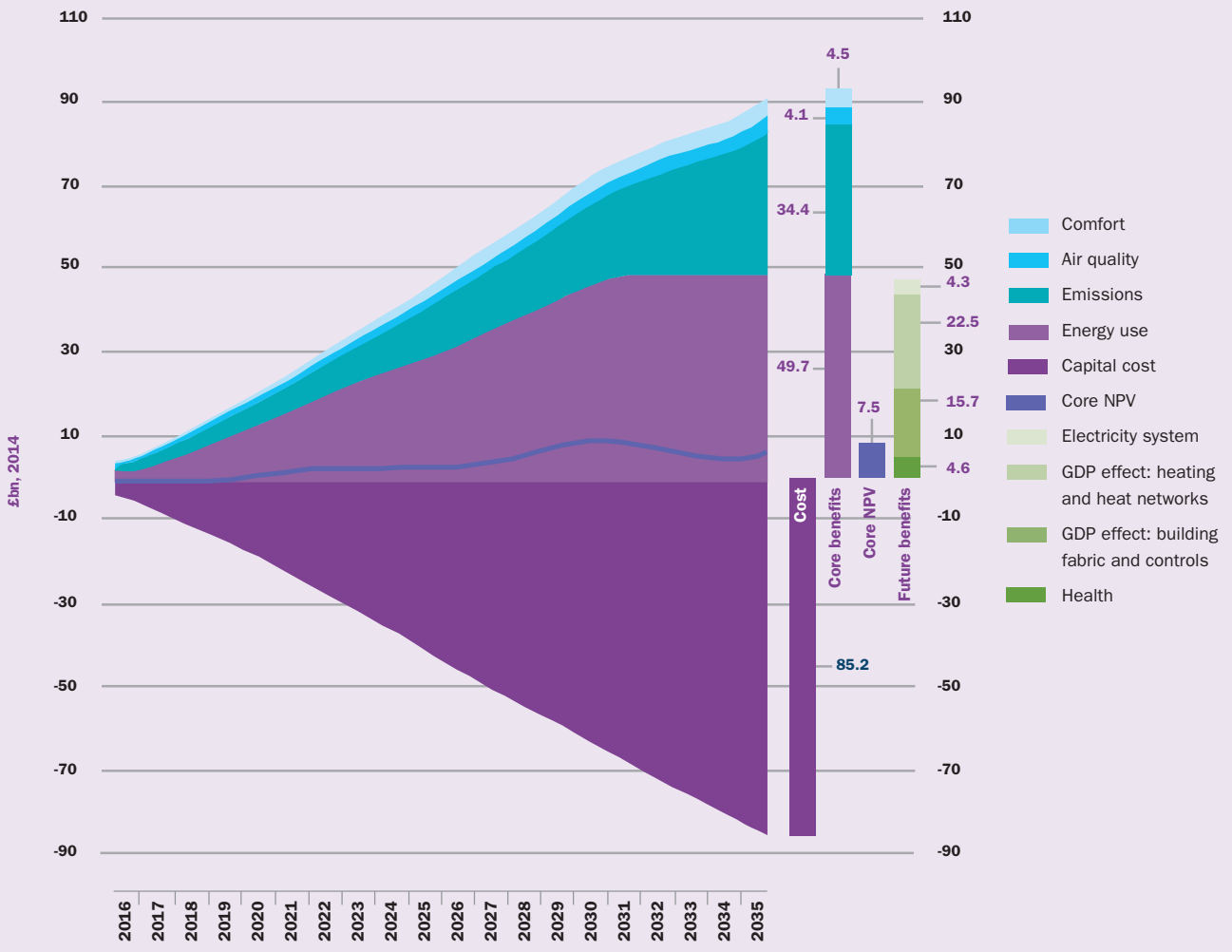
2. Background on retrofit and its potential benefits

Retrofit is the *"construction approach involving the action of introducing [retrofitting] new materials, products and equipment into an existing building with the aim of reducing the use of energy of the building"* [12]. This is different from renovating or refurbishing, which usually refers to work undertaken to repair homes so that they are in improved condition, or aesthetically more pleasing [12]. Retrofits of residential buildings have significant potential to reduce carbon dioxide emissions [5], fuel poverty [13], and improve occupant health and wellbeing [14].

One in ten UK households are in fuel poverty [13]. For **every £1 spent on retrofitting fuel poor homes, an estimated £0.42 is saved in National Health Service spending** [4]. Warm good quality housing is also linked to a range of mental health and wider socio-economic benefits [4].

Residential buildings account for almost **a quarter of the UK's carbon emissions** [5], with much saving potential yet to be realised – and the need to achieve near-zero emissions from the sector by 2050 [5]. Relatively conservative 'cost-effective'[3] investments to 2035 could save around one quarter of the energy currently used; an **average saving of £270 per household** per year at current energy prices. This saving is approximately equivalent to the output of six nuclear power stations the size of Hinkley Point C [6], with further savings available from building integrated micro-renewables such as PV panels. Similar scenarios suggest between **66-86,000 new jobs could be sustained annually** by this level of retrofit activity [7].

FIGURE 4: CUMULATIVE PRESENT VALUES OF INVESTMENT IN THE HOUSING STOCK IN THE 'COST-EFFECTIVE' SCENARIO
[SOURCE: PRODUCED FROM BEIS ET AL. (2016) USING OUTPUTS FROM CCC DATASET MODEL]



[3] The CCC define the cost-effective path as comprising measures that cost less than the projected carbon price across their lifetimes together with measures that may cost more than the projected carbon price, but are necessary in order to manage costs and risks of meeting the 2050 target [11].

This 'cost-effective' approach will require **approximately £85.2bn investment** at today's prices. Using Treasury guidance for policy appraisal, this would deliver benefits (in terms of reduced energy use, reduced carbon emissions, improved air quality and comfort) **amounting to £92.7bn** – an estimated **net present value of £7.5 billion**. The UK Energy Research Centre and CIED estimate that the value of additional benefits from these investments – including improved health, additional economic activity and benefits to the electricity system – **could be up to £47 billion** [6]. These costs and benefits are summarised in Figure 1.

To achieve these targets, an increasingly comprehensive whole house approach to residential retrofit will be needed [8]. Such an approach involves multiple measures with strategies for insulation, draught proofing, ventilation, heating systems and low carbon microgeneration [9]. However, the traditional policy approach to residential retrofit has tended to incentivise single measures and piecemeal interventions, that may cause damaging unintended consequences[4] [15]. Thus, a comprehensive whole house retrofit; where the entire building is treated as a system rather than as individual elements or measures, can mitigate such issues and achieve greater reductions in emissions [16].

[4] Such as mould growth, poor air quality and interstitial condensation; can result from to poor detailing, and insufficient consideration of building physics, airtightness and ventilation

3. Recent UK policy on residential retrofit

Improved EE has played a pivotal role in reducing the UK's energy use and carbon emissions. On a temperature corrected basis, total UK household energy use decreased by 19% between 2002 and 2016, despite a 12% increase in the number of households and a 10% increase in population [10]. Per-household energy consumption fell by 37% between 1970 and 2015, with most of this decrease (29%) occurring since 2004 [10]. EE improvements in individual homes have offset the 46% increase in the number of households, the 5.6°C increase in average internal temperatures and the rapid growth in appliance ownership over this period, with the result that total household energy consumption has increased by only 7% in 45 years [10].

Although rising energy prices and the 2008 recession contributed to recent trends, the bulk of the reduction in per-household energy consumption can be attributed to public policies to improve EE [10,21–23]. Of particular importance have been the major home insulation programmes funded by successive 'supplier obligations' (SOs) such as the Carbon Emissions Reduction Target (CERT - 2008 to 2012) [24] and ECO – 2013 onwards. Since 1994, energy and carbon saving targets imposed on electricity and gas suppliers have allowed them to recover the costs through a levy on household energy bills. Also important were the requirement for condensing boilers within the UK Building Regulations and the progressive tightening of EU standards on the EE of electrical appliances [22]. Evaluations of these policies have shown them to be highly cost-effective, both in terms of the cost savings to participating households and in terms of broader societal welfare [25–27]. This experience supports the argument that market forces alone cannot deliver all cost-effective investments in residential buildings, owing to multiple, overlapping market failures and entrenched social norms and practices. Instead, policy intervention can be used to increase the uptake of residential retrofit through a mix of regulation, public engagement, financing and incentives.

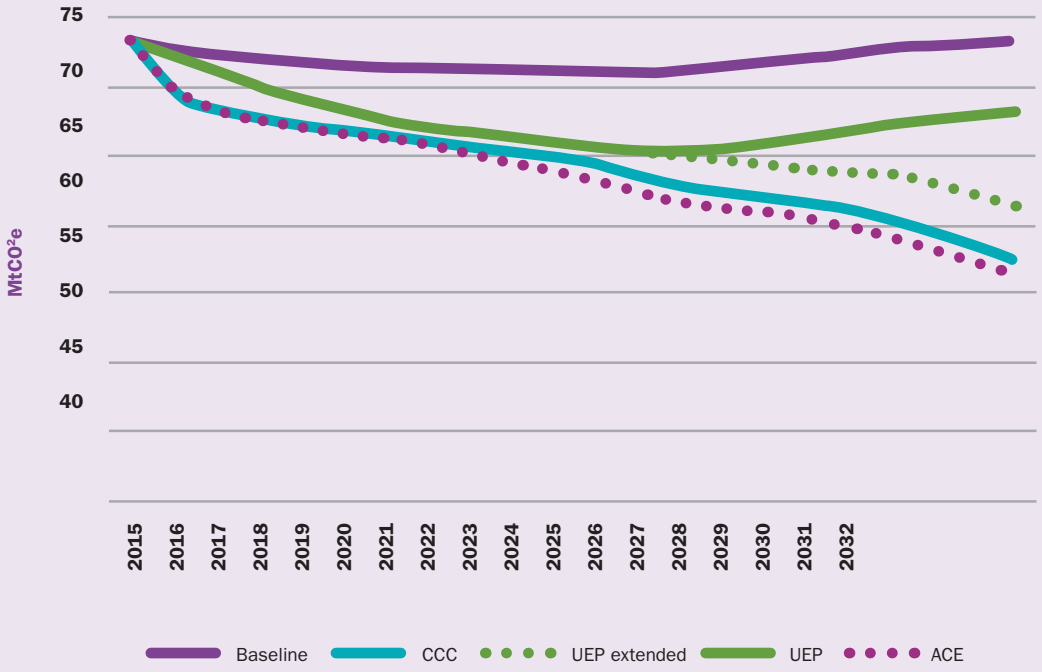
Despite dozens of instruments in the broader EE policy mix targeting residential buildings [20] and the apparent success in reducing energy demand through policy, in more recent years there has been a marked shift in the policy landscape. Previously, SOs supported relatively low-cost EE measures, and dedicated grant programmes funded through general taxation provided support for low-income households to invest in EE measures. The last version of such grant programmes, Warm Front, was terminated in England in 2011 and the government decided to radically change the way EE was delivered in the UK.

Through the introduction of the Green Deal in 2013, a private sector on-bill-repayment loan scheme, the government intended to trigger substantial investment in EE retrofits whilst the supplier obligation would fund only the costlier EE measures. It is now widely recognized that this approach failed - the Green Deal was effectively terminated in 2015 and funding provided through SOs has been significantly reduced [28]. As a result, the uptake rate of EE improvements has stalled since 2012 [5].

The UK now has insufficient policies in place to deliver on its medium and long-term targets for energy efficiency in residential buildings (Figure 2). The Government's Updated Energy and Emissions Projections (UEP) fall well short of the targets for the Carbon Budgets set out by the Committee on Climate Change (CCC), with even these projections now at risk from the failure of recent policies for the sector.

FIGURE 2 PROJECTED EMISSIONS FROM RESIDENTIAL BUILDINGS, BASED ON CURRENT BASELINE, UPDATED ENERGY AND EMISSIONS PROJECTIONS (UEP), UEP WITH EXTENDED AMBITION, CCC CARBON BUDGET TARGETS, AND ASSOCIATION FOR THE CONSERVATION OF ENERGY (ACE) MODELLING

. TAKEN FROM THE REGULATORY ASSISTANCE PROJECT AND ACE - BUILDINGS AND THE 5TH CARBON BUDGET REPORT [7]



The Clean Growth Strategy outlines an aspirational target for all homes to reach Energy Performance Certificate (EPC) band C by 2035 and all fuel poor homes by 2030, with recently introduced minimum energy efficiency standards (MEES) for the private rented sector. We argue this is a good start, but that policy needs to go much further if these goals are to be realised. This requires both adjusting the ambition levels of existing policies and the implementation of new instruments. In particular challenges remain in creating demand for retrofit from households, alongside a lack of capacity and organisation in the supply chain. Equally these aspirational targets will need to be enshrined in legislation and backed by a range of financing and incentive schemes.

4. Key challenges for residential retrofit

The limited uptake of cost effective EE measures; characterised as the 'energy efficiency gap' [29], is the focus of much academic and policy research. This literature has tended to identify key 'barriers' to uptake as the theoretical basis for understanding this gap [1,30].

However, the focus on barriers has tended to characterise household decision making in terms of rational economic choices, whilst downplaying social and contextual factors [31]. This framing also carries the inherent assumption of pre-existing *demand* for retrofit once these barriers are removed [32]. This framing has come to dominate the design of recent policy initiatives such as the Green Deal and ECO, which were predicated on households saving money on their energy bills [28].

We argue that this framing is problematic, primarily because it misrepresents how and why home renovation decisions are made, and by whom. This report instead frames the problem in terms of four interrelated challenges that continue to contribute to low household demand for residential retrofit.

1. Information, engagement and trust

A lack of knowledge of the specific options and benefits of retrofit remains widespread amongst households in the UK [33]. While many of the technologies and tools exist to retrofit existing buildings, their uptake is not widespread, largely due to a lack of household interest [34]. Public engagement and marketing schemes have tried to generate demand, but tended to be top-down [28], short term, and focus on specific subsidy schemes [4]. This has also created a supply chain largely reliant on short term policy incentives [35]. Complicated government programmes such as the Green Deal have often been difficult for households to grasp [33]. Households who do decide to retrofit, often have to interact with multiple tradespeople and installers, who influence decisions on technology choices and subsequent use [36]. These challenges of gaining appropriate advice, concerns over post-retrofit performance, combined with poor quality workmanship have undermined trust with the wider public [37].

2. Uncertain benefits and quality

Predicted energy and cost savings from retrofits are based on modelled energy performance. There is consistently a 'performance gap' between these models and actual energy performance outcomes [1]. This is characteristic of an industry with a reputation for low quality and with few contractual penalties for under-performance [34]. Equally, retrofit interventions may alter a building's existing features, affecting a household's routines and practices in ways that may make them reticent to change – such as different heating timing and controls [32]. By only focusing on financial savings, policies have also failed to recognise that retrofits could be framed and promoted in terms of aesthetics, comfort and wellbeing [28]. Much evidence now suggests that those who undertake energy retrofits do so because of these non-economic sources of value, such as environmental concerns, desire for improved comfort and living standards, property longevity and aesthetics [18,38].

3. Complexity, disruption and timing

Whole house retrofits involve multiple activities carried out by multiple contractors and consultants. Management of this process is complex and time consuming for the household [37]. Alongside the significant disruption of extensive works, this can be a major deterrent to uptake [39]. Thus, households may prefer to retrofit gradually, when it is less disruptive to do so, despite the higher costs and longer duration [40]. Consequently, energy retrofit may only be considered during wider renovations [32]. Identifying such 'trigger points' could therefore promote retrofit in certain circumstances, such as moving into a new home [36].

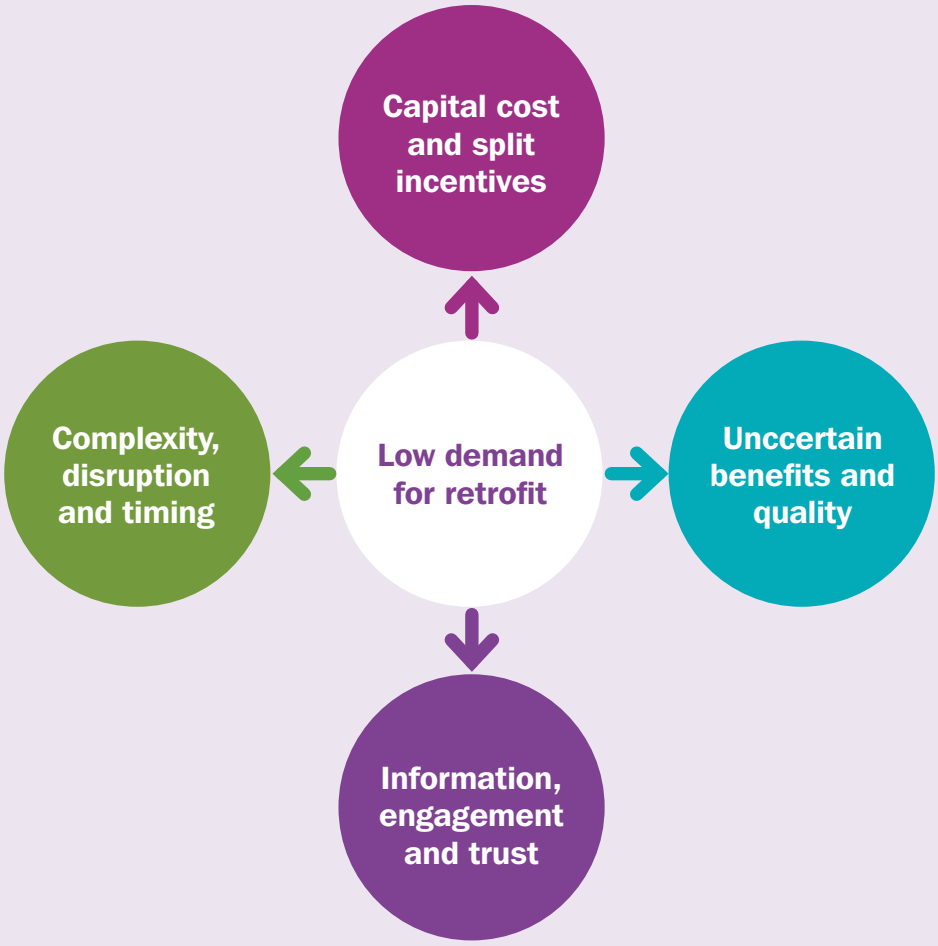
4. Capital cost and split incentives

Whilst retrofits result in long term energy savings, whole house retrofits typically require long periods before the capital cost can be recovered in energy savings [41]. Thus, many households lack access to up-front capital, with the benefits of the investment not being realised when moving house or in a landlord-tenant situation – termed 'split incentives' [30]. Whilst the up-front cost barrier has largely been the focus of recent policy initiatives in the UK, the economics of long term financing is extremely sensitive to interest rates [41], particularly if energy bill neutrality[5] is required [28]. Further, whilst households may value funding for wider non-energy measures, such as general repairs, the majority of policies fund EE measures alone [17].

These four related challenges are shown in Figure 3.

[5] Bill neutrality may include requirements that modelled savings are 'cash-flow positive' meaning that finance repayments are equal to, or result in, net energy cost savings [17].

FIGURE 3 KEY SYSTEMIC CHALLENGES FOR DRIVING RETROFIT DEMAND



Typically, policy interventions in this area have targeted one or at most two of these issues. However, to overcome these multiple challenges and deliver on the promise of residential retrofit, a systemic approach across multiple sectors and involving multiple government departments will be necessary (see Section 6). We now draw on three key concepts to achieving a retrofit: the business model; financing and the role of intermediaries. Building on these insights we then propose policy solutions to overcome the challenges for the widespread diffusion of whole house residential retrofit.

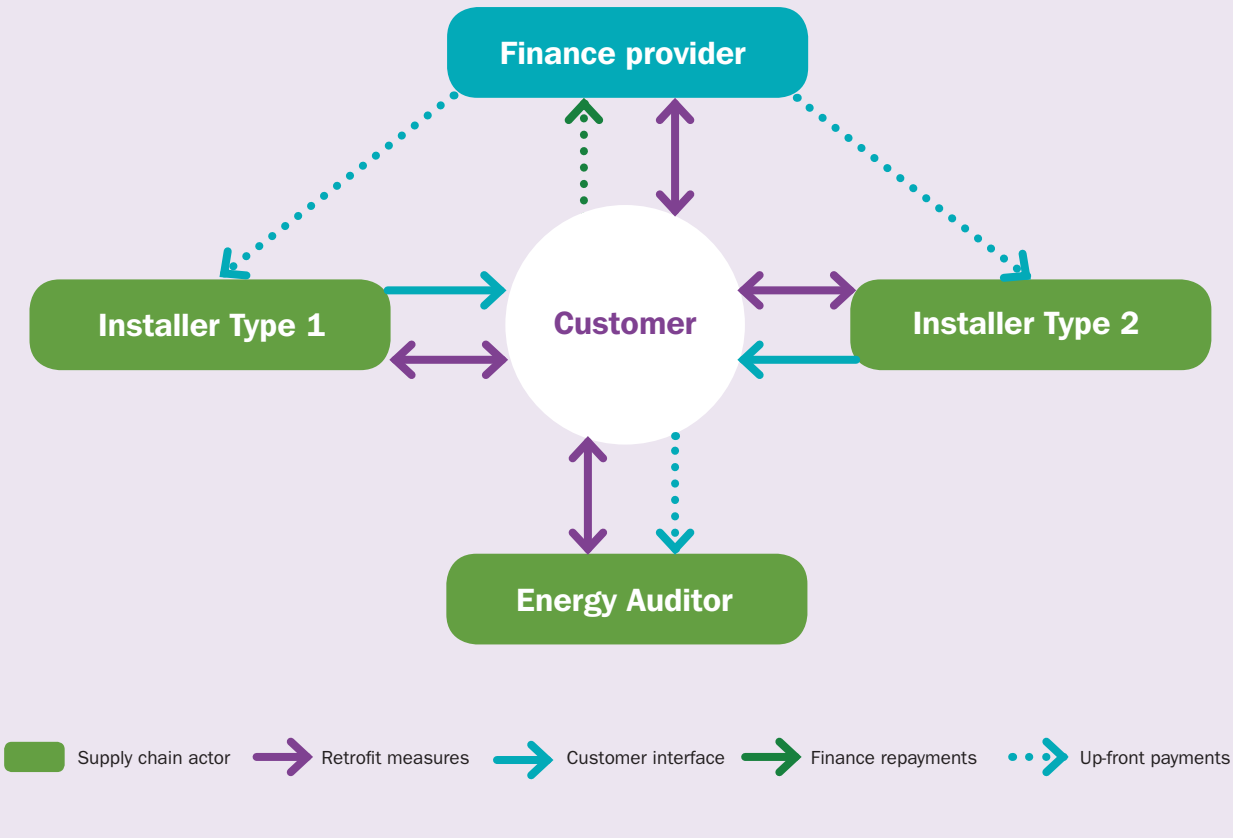
5. Overcoming the challenges for residential retrofit

5.1. Retrofit business model

A business model is defined as the nature of the value delivered to customers; the activities involved in delivering that value; and the means of capturing revenue from these activities [42]. Drawing on recent CIED research [8], we argue that despite significant policy action in this area, a major reason for the lack of uptake of whole house retrofit is the limitations of the traditional business model.

The dominant business model for residential retrofit (Figure 4) is characterised by a piecemeal offering; with a fragmented supply chain, a focus on single (rather than multiple, complementary) measures, and no guarantees on performance. This is typically marketed on estimated energy cost and carbon savings and involves measures and technologies installed by separate contractors. Customers procure the individual measures, energy audits and finance separately, with the result that multiple interfaces are required for a comprehensive residential retrofit. The offer of energy savings is based on modelled impacts of measures, and no performance guarantees are provided. Therefore, any finance package is based on estimated rather than guaranteed savings. Such an approach has typified the delivery of the EE through UK policies such as ECO and the Green Deal.

FIGURE 4 THE INCUMBENT 'ATOMIZED MARKET MODEL' FOR RESIDENTIAL RETROFIT [8]



This approach introduces significant *complexity* for customers in managing multiple interfaces with sub-contractors, auditors and finance providers, also tending to result in major disruption for a whole house retrofit. Equally, the narrow emphasis on estimated cost savings, without performance or ongoing maintenance guarantees, means uncertain benefits for the customer and provides limited trust on installation quality. Unsurprisingly, this approach has resulted in low demand for comprehensive residential retrofits.

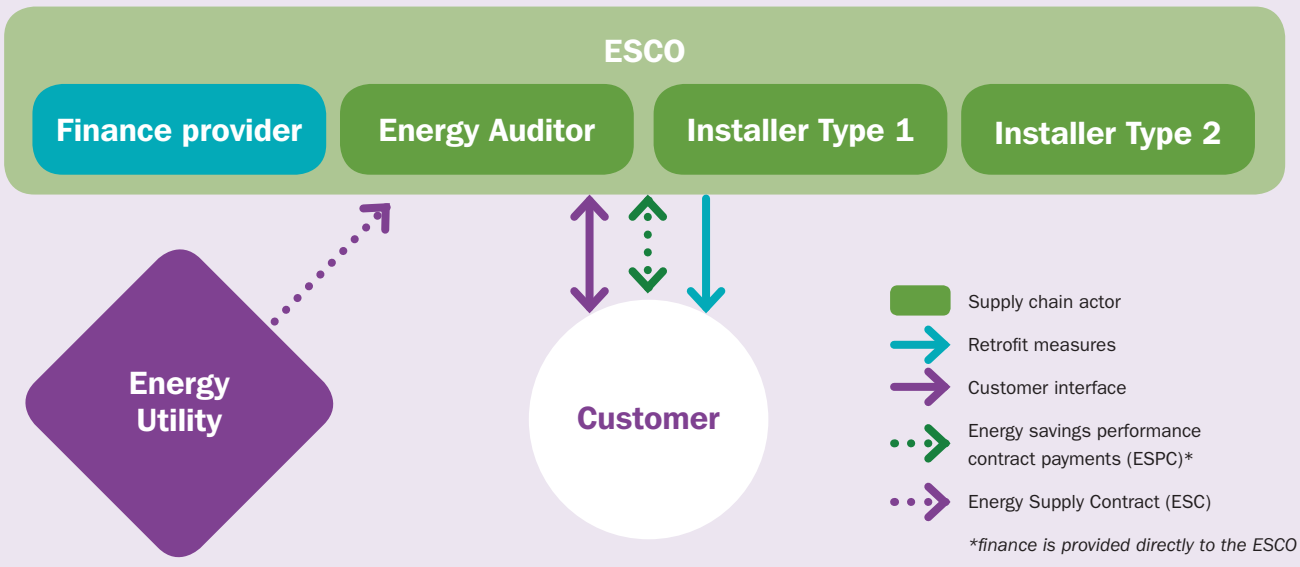
Emerging 'service-based' business models provide the useful end service (e.g. hot water volume, room temperature) rather than the technology or commodities themselves (e.g. natural gas, insulation), shifting incentives for resource efficiency onto suppliers [43]. Consequently, energy service (or ESCO) business models are promoted as a means of reducing energy demand [44]. Innovations such as distributed energy[6] and whole house retrofit may thus require novel, complementary business models before they are viable on a large scale [45].

Recently, integrated business models for residential retrofit have begun to emerge. These approaches emphasise a broader source of value for a whole house retrofit; focussed upon final energy services, aesthetics, increased property value, comfort, health and wellbeing alongside energy and carbon savings. Such approaches involve integrated and increasingly industrialised supply chains providing comprehensive whole-house retrofits, through a single contractor or well integrated network of sub-contractors. These approaches are characterised by a simplified customer interface with a single expert point of contact to co-ordinate entire project. Some examples also offer integrated financing packages, and in some cases energy performance guarantees (see Box 1.)

Box 1. The Energiesprong Managed Energy Service Agreement (MESA)

The Energiesprong (Energy leap) initiative originated in the Netherlands and has expanded into the UK, with a full trial now underway in Nottingham [73]. Customers are offered a comprehensive residential retrofit, based upon net-zero energy consumption. Typically, an Energiesprong retrofit involves the rapid delivery and installation of off-site manufactured, insulated wall facades, integrated with renewable heat systems and photovoltaic panels as well as ventilation and controls. The provider offers a 30-year energy performance guarantee (based on set internal temperature) for annual net-zero energy consumption, with specified energy usage limits, alongside an upstream financing package. An energy service contractor (ESCO) also takes on responsibility for the payment of the energy bill of the customer to provide 'total energy management'. This represents a holistic energy services offering to the household, commonly termed a Managed Energy Services Agreement (MESA) [56] shown in Figure 3. This approach is currently largely being trialled in multi-family buildings and across large social housing estates.

FIGURE 5 THE ENERGIESPRONG MANAGED ENERGY SERVICES AGREEMENT (MESA) [8]



[6] Defined as electricity generation feeding into the local distribution network (operating from 132kV down to 230V), as opposed to the regional or national transmission grid (which operates from 400kV and 275kV).

Integrated business models have significant potential to drive demand for residential retrofit. By providing energy services and broader sources of value including additional renovation measures as part of the offering, suppliers can attract customers by appealing to the wider benefits of improved aesthetics, increased property value, comfort, health and wellbeing alongside energy and carbon savings. Creating a simplified customer journey through an integrated supply chain, project co-ordination and a financing offer reduces *complexity* and minimises *disruption* for households. Further, the offer of energy performance guarantees provides *certainty* surrounding the ongoing performance benefits of the retrofit and the quality of the installation.

While this may be the optimal solution, these integrated business models also face barriers, due to lack of demand from consumers and capacity in the supply chain and their uptake has been slow in the residential sector [46]. Therefore, adopting integrated energy service business models remains a challenge for an industry dominated by small scale SMEs. Section 5.3 therefore discusses how market-facing intermediaries can play a role in co-ordinating these fragmented supply chains towards an integrated business model.

5.2. Retrofit finance

The up-front *capital cost* of retrofit measures and the *split incentives* faced by tenants and landlords, remain a key challenge for the scaling up of comprehensive residential retrofits. Many UK households are also still in *fuel poverty* and are therefore struggling to afford to sufficiently heat their homes. The following section sets out three key policy approaches to overcome these financial issues.

5.2.1. Retrofit grants for the 'fuel poor'

The UK's market-based SOs have provided 'free' loft and cavity wall insulation, low energy lightbulbs and other low cost measures [47]. ECO, the latest evolution of the SO policies, was initially designed to fund more expensive retrofit measures, such as solid wall insulation. It has since been criticized for its piecemeal nature with a focus on single measures [8], dis-incentivizing comprehensive installations, with no funding for complementary work such as ventilation and damp prevention [9]. SO policies require a levy on all households' energy bills, and thus increase the energy bills of households that do not benefit from programmes such as ECO [48]. The ECO has now been redesigned to focus on the 'fuel poor'. Although, having added approximately £50 a year to average household bills - a total of £1.3Bn annually [49], policies like ECO are arguably a poorly targeted means of addressing fuel poverty [48].

Meeting the UK's residential retrofit targets will require an estimated £85.2bn of net investment to 2035 [6]. Achieving this level of investment through an SO like ECO could introduce politically unacceptable bill rises [20] and be particularly regressive for people living in fuel poverty who do not adopt retrofit measures [48]. Previous fuel poverty policies such as Warm Front – funded by general taxation – had a no such impact on energy bills, and are thus more progressive than a flat rate SO [13]. A fuel poverty policy funded by general taxation is also more consistent with targeting the co-benefits of social welfare [48] and improved health and well-being [4]. Therefore, new polices could target these fuel poor households and be delivered through a grant offering holistic deeper retrofits for free, or with a sliding scale of free and 'financed' elements– more in line with the approach taken in the UK's devolved administrations.

5.2.2. Financing for the 'able-to-pay'

Alongside fuel poverty grants, there is a likely need for repayable financing for the 'able-to-pay' segment [50]. The UK's Green deal policy involved a novel *finance mechanisms*, intended to deliver approximately 2 million retrofit installations per year and leverage billions of pounds of private sector investment. The scheme was based on private sector lending to households, paid back through energy bills–known as on-bill-repayment. However, the scheme achieved a fraction of its targets, and resulted in a significant loss to the UK taxpayer before its premature scrappage in 2015 [28].

A range of other retrofit finance mechanisms have been developed, in the UK, wider EU and USA, including several that have been markedly more successful than the Green Deal [51,52]. Table 1 describes the key types of finance mechanisms currently in operation and their key features, including some prominent examples. Whilst some examples such as green mortgages are likely to be more market led, all will likely to require some form of policy support and intuitional change if they are to provide significant funding for residential retrofit. It is also likely that different approaches will need to be utilised for different segments of the market [51].

Type of finance mechanism	Description
Public loan / credit enhancement	Public retrofit finance usually involves low interest loans provided by government, and credit enhancements - where public money is mixed with private sources of capital in a single fund [51]. Germany's KfW state bank CO_2 Building Rehabilitation Programme (CBRP) – is perhaps the most well-known example. Long term, low interest loans are provided through retail banks, providing financing for a range of retrofit and renovation measures. The scheme has driven the majority of Germany's 24% emissions reduction in homes between 1990 - 2006, achieving an average reduction of 59% per property with €5bn in loans in 2007 alone [53]. Credit enhancements use public money to reduce the risk for private sector capital providers. These schemes are able to leverage significant ratios of public to private finance. An example in the UK is the London & Mayors EE Funds (LEEF & MEEF) [54], having leveraged significant sums for EE with LEEF and MEEF raising £100m and £1bn respectively [54].
On-bill finance	On-bill finance (OBF) mechanisms involve the repayment of retrofit financing through the energy bill. Loans are often secured through the option to cut-off energy supply, if unpaid [55]. This theoretically makes them suitable for a landlord-tenant situation by removing split incentives. The UK's Green Deal was a prominent example of OBF, although other schemes in North America have been more successful. In the USA, UK and Canada over 20 OBF schemes have financed over $1.05Bn of household retrofit measures.
Property assessed clean energy (PACE)	PACE financing has been adopted in the USA since 2007, and allows municipalities to fund household 'clean energy' investments through special debt instruments that are linked to the property and repaid through a charge on the property tax bill [56]. This approach has been used in the USA since the 17th century to fund municipal infrastructure works. Originally PACE involved the use of municipal bonds, although the majority of residential PACE now uses private capital, whist still adopting the property tax collection channels of local governments [56]. PACE has grown significantly in recent years reaching $3.8 billion in residential lending [57], with providers RENEW Financial achieving an average 28-27% reduction energy demand [52].
Green mortgage	Mortgage eligibility assessments are based on the applicant's ability to afford re-payments. Yet these eligibility assessments currently use arbitrary estimates for household energy expenditure. Green or EE mortgages instead utilise actual Energy Performance Certificate data in these estimates. Therefore, mortgage providers may increase lending for more efficient homes at lower interest rates–as the lower bills and higher disposable income reduces the risk of default [58]. This may also become reflected in increasing property prices for the more efficient homes [58], whilst also enabling additional borrowing for retrofits. The EU green mortgage market is currently very small scale; with a few niche providers such as the UK's Ecology Building Society offering additional borrowing for EE and interest rate discounts of 0.25% for each EPC improvement level [59]. Whilst the Fannie Mae mortgage company lending reached $3.6 billion (2016) in the USA under its Green financing for multi-family buildings scheme [57].
Energy services agreement (ESA)	An ESA involves a form of energy performance contract, where building occupants are provided with an energy performance guarantee for specific energy services, usually derived from a baseline of past consumption [56]. Instead of paying for units of heating fuel, occupants are guaranteed a level of performance. Measures are financed directly by the ESCO or through a third-party financier. This shifts the financing upstream from the household to integrate finance and measures through an energy service charge [8]. Loans can be aggregated and sold into secondary markets, allowing ESCOs to move the projects off balance sheet and take on additional retrofit work [52]. PosiGen offer an ESA for residential retrofit with 8,400 completed projects in the USA [57]. In the European multi-family sector RENESCO offer ESAs for the deep retrofit and renovation of Latvian housing blocks, while Servizi Energia Ambiente (SEA) provide ESAs to the Italian multi-family market. Large institutional investor funds such as the UK's Green Investment Group [60] are increasingly becoming involved in ESA financing.
Community financing	Community-based financing has been used extensively in the delivery of funding for distributed energy systems such as solar PV, in countries such as Germany. This model is now beginning to be utilised for funding energy efficiency measures, often within a small geographical area, adopting 'co-operative type' legal structures. A retrofit co-operative will issue shares for the project, which are often bought by members of the local community, who may value the social and environmental benefits of these investments [61]. One example of this mechanism is BHESCo based in Brighton, UK who issue loans to households for efficiency measures under a hire purchase agreement. As these are repaid the proceeds are distributed to shareholders in the form of dividends.

Three key outcomes affect the success of these finance mechanisms [52]. Firstly, a low *cost of capital* is key to the current economic viability of deeper retrofits with long term payback periods, such as those involving solid wall insulation (Figure 6).

Secondly, and perhaps more significantly, mechanisms that reduce complexity by simplifying the *customer journey* are likely to achieve much higher levels of uptake. This includes linking the loan repayment to the property not the individual, removing split incentives, but also making finance available alongside the retrofit measures as outlined in Section 5.1.

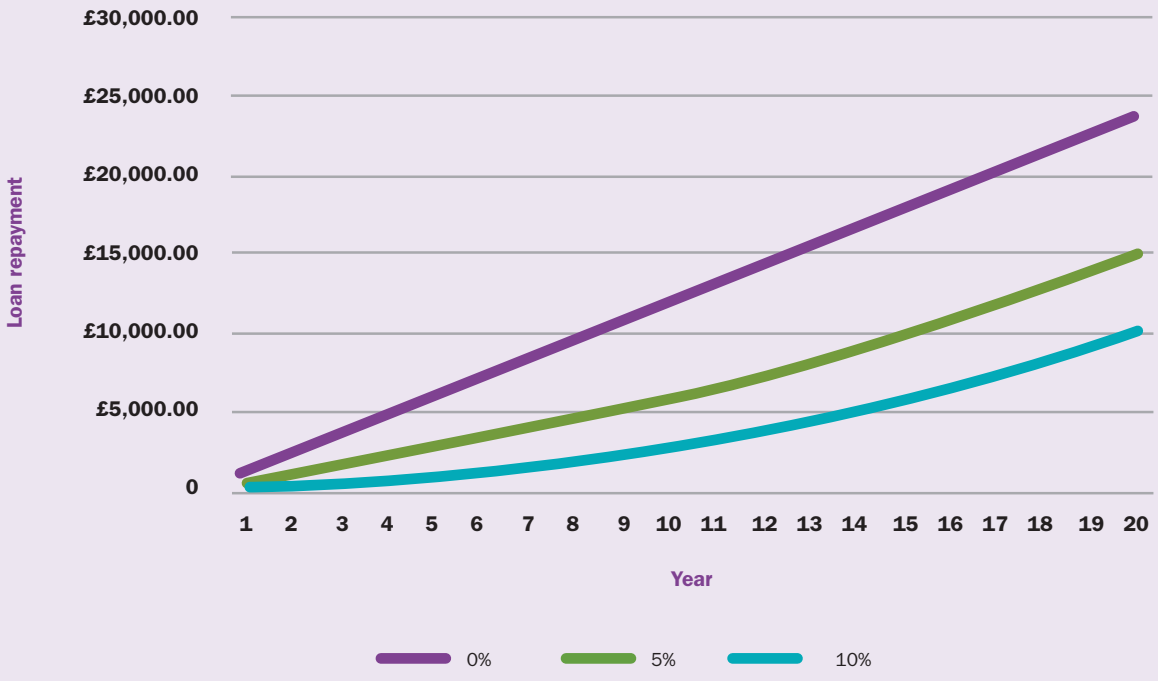
Thirdly, by enabling non-energy measures such as general improvement works, schemes can appeal to broader *sources of value* that are more highly valued by households, often 'addressing a problem', such as a broken boiler or low levels of comfort.

The importance of the cost of capital is illustrated in Figure 6. The figure shows the total amount that can be borrowed with a fixed £100/month repayment and a loan length of 20 years, at 0%, 5% and 10% interest rates respectively. With a 0% interest rate the household could borrow £24,000 (the principal) whereas with an interest of 5% only £14,954.65 could be borrowed, and only £10,216.27 at 10%. Thus, assuming fixed affordability and loan maturity, the cost of capital has a significant impact on the amount that can be borrowed and the subsequent depth of the retrofit funded.

By contrast the Green Deal involved a complex vetting and application process, that required a separate interface with a third-party provider, with no funding available for wider improvements. This introduced significant complexity for households that was likely to be offputting for most [8]. The Green Deal also had relatively high interest rates of 7-11% [33]. Indeed, the total cost of capital amounted to at least 49% of total Green Deal Plan costs over 15 years [62].

Programmes such as the KfW scheme offer finance at extremely low or zero interest rates (<2%) [53]. Such offers are likely to be more appealing to households [33] and drastically improve the economics of whole house retrofits with longer payback periods [62].

FIGURE 6 THE IMPACT OF THE INTEREST RATE ON BORROWING POTENTIAL, ASSUMING A FIXED REPAYMENT AND TERM



5.2.3. Financial incentives

There are limits to what financing alone can achieve. In most cases financing is likely to be an *enabler* of retrofit projects rather than a *driver* of demand [63]. Consequently, a range of incentives can increase demand for retrofit. These include fiscal or energy supplier incentives, such as variable property taxes (for example Stamp Duty or Council Tax), income tax rebates, a Landlord's Energy Savings Allowance (LESA), VAT reductions or EE feed in tariffs (FiT) [64,65]. Some can be made fiscally neutral through penalizing properties that do not meet a certain performance level [65].

Incentives are likely to be particularly effective when they are available at key junctures when broader renovation decisions are being made. Thus, approaches that target key *trigger points* such as when properties change hands, during extensive renovations or heating replacements, are likely to be most successful [36].

Analysis undertaken by the ACE [66] and modelling by the UKGBC [65] in Table 2 shows the impact and costs of three of these alternative incentive approaches - Variable Stamp Duty Land Tax, Variable Council Tax and an EE FiT. Each approach would have its own challenges and policy reach, therefore further research is needed to determine which policy should be adopted.whole house retrofits with longer payback periods [62].

Comparative impacts of Variable Stamp Duty Land Tax, Variable Council Tax and an EE FiT (Source UKGBC [65])

	Variable Stamp Duty Land Tax	Variable Council Tax	EE FiT
Annual increase in number of retrofits	135,195– 270,402	517,739– 1,480,935	64,598 – 169,464
Annual net effect on GDP	£404m-£807m	£1,520m-£4,421m	£193m - £506m
Annual direct cost of subsidy*	Near zero**	Near zero**	£52m - £273m
Annual carbon saving (tCO2)	208,538– 417,088	812,192– 2,231,594	96,961 - 254,364

* In the case of Government funding, this excludes any resulting increases in tax revenue.

** For these incentives, the model was built specifically to be revenue neutral. In each case, this was achieved to within a relatively small margin (less than £300k).

5.3. Policy implementation and project delivery – the role of intermediaries

A key remaining challenge for the widespread uptake of comprehensive retrofit is the paucity of information, engagement and trust with the wider public, as well as the complexity and disruption of whole house retrofits. Support is therefore needed both at project level (e.g. specific retrofits) and the broader market level.

Intermediaries – that can be individuals, organisations or platforms – facilitate retrofits by educating, collecting and allocating financial and human resources, assessing new technologies and practices, creating partnerships, and influencing changes in regulations and rules [67]. These actors may also act as a single point of contact between households and retrofit contractors. Such initiatives are often co-ordinated by local authorities, while drawing on the local skills base that often includes a mix of not-for profit/NGOs and local businesses. Policy solutions should seek to build on these existing networks rather than replace them.

Therefore, intermediation can (1) stimulate, guide and manage different whole house retrofit projects, and (2) aid the creation of a market for new 'one-stop-shops' to integrate supply chain business models and financing solutions [68]. Yet, these institutions and actor networks which can effectively stimulate the market for owner occupiers and private landlords, are still largely lacking in the UK at the community level.

An often cited example of a successful area-based approach to retrofit implementation is the Kirklees Warm Zone programme [69], with web platforms such as Retrofitworks connecting contractors with households for retrofit projects [70]. Box 3 outlines the findings of a recent CIED project, outlining seven key intermediation actives that can support the market for residential retrofit [71].

Box 2. Seven key intermediation activities for successful retrofit projects [71]

1. Providing impartial, trusted knowledge and advice that is tailored to the local context.
2. Connecting different actors through events and networks.
3. Promoting and facilitating the uptake of government programmes.
4. Developing robust project plans: choosing technically appropriate solutions and finding suitably skilled builders and installers.
5. Coordinating between different elements of a fragmented supply chain and providing a single point of contact for consumers.
6. Ensuring smooth delivery of the project.
7. Raising the profile and representing the sector among the policy community.

At the project level, support is thus needed to stimulate interest in whole house retrofits, share experiences among home owners, and provide necessary expertise during planning and implementation. Platforms, such as Eco Open Houses in the City of Brighton and Hove, organised in 2008 and between 2010-2015, enabled people to see and visit sustainable homes [72]. These cases demonstrate that such events have been extremely useful in providing information, stimulating engagement and sharing knowledge on whole house retrofits, as well as providing details of trusted local tradesmen and installers.

More support is, however, needed to establish these institutions in every community, to provide 'one-stop-shops' for households, looking to undertake a retrofit [8]. Through these one-stop-shops, households could access trustworthy advice on technological and financing options, as well as tradespeople, contractors and installers. Thus, their role is being key providers of *information* for households on the options and benefits of undertaking comprehensive retrofits; as well as *engaging* communities and supply chains to promote retrofit at a local level. Furthermore, they are likely to be more trusted than actors with a financial stake in promoting certain services or products.

Another important determinant in market formation is the positioning between ambitious sustainability aims and connections to business. Innovative supply chain business models, such as the Energiesprong approach, often owe their existence to market facing intermediaries, initiated by government policy. Energiesprong was brought into being through a €50m grant from the Dutch government, and the setting up of a *market development team* [73]. These market development teams brought together stakeholders including; the construction industry, housing providers, policy makers and financiers to radically re-think the business model through which EE retrofit is delivered. Whilst these approaches still face challenges, they could represent a template for how the UK could deliver on its ambitious retrofit targets.

6. Policy recommendations

The previous sections outline how achieving widespread residential retrofit will need to overcome four key challenges that constrain household uptake: a widespread **lack of information, engagement and trust** with households on the options for, and advantages of, EE retrofit; a perception that retrofit has **uncertain benefits** and low quality workmanship, without guarantees on performance; involves significant **complexity**, **disruption** and poor integration with the **timing** of wider renovation decisions; and issues with the up-front **capital cost** of measures and **split incentives**, between landlords and tenants, or those looking to move.

Addressing these challenges will require a sophisticated and multifaceted policy approach to promote business model innovation, delivering a range of financing options and incentives along with the establishment of strategic intermediaries at both a local community and national level. Achieving these goals requires the recognition that government has a role to play in shaping this market. This will require a wide reaching and systemic strategy, and a broad range of policy instruments and initiatives [74]. This strategy should incorporate:

- political leadership and regulations to create confidence for the direction of travel and market signals for new business models to emerge
- policies to overcome issues with finance; both in terms of access to capital and split incentives, but also up-front incentives to stimulate demand
- intermediary actors to ensure effective delivery of retrofit and promote integrated business models - in both consumer and market facing roles. This requires policy action to ensure that the appropriate institutions are in place in local communities as well as at a national level.
- different solutions will be required for socially rented, privately rented and owner occupier sectors.

This will require joined-up action across multiple government departments including but not limited to: Business Energy and Industrial Strategy (BEIS), Housing, Communities and Local Government (MHCLG), the Treasury (HMT), Education (DfE) and Health (DH), the Department for Work and Pensions (DWP), Her Majesty's Revenue and Customs (HMRC) and the National Infrastructure Commission (NIC). The following section provides an outline of the range of policies (summarised in Table 3), which could contribute to achieving the enormous opportunities for the comprehensive retrofit of residential buildings.

6.1. Political leadership

There exists huge outstanding potential and multiple social, economic and environmental benefits to be gained from the energy efficiency retrofit of the UK's housing stock [6]. Whilst recent announcements in the government's Clean Growth Plan set out ambitious targets for the sector [2], these ambitions need to be matched by political leadership and policy action.

The principle of 'Efficiency First' is gaining traction at the European Union (EU) level and is now informing policy design in Germany. Put simply, Efficiency First *'prioritises investments in efficiency resources whenever they would cost less, or deliver more value, than investing in energy infrastructure, fuels, and supply'* [64]. We recommend that the **UK should adopt 'Efficiency First' as a guiding principle in the design of its energy policies**, to champion EE's vital importance in meeting climate and social policy objectives.

EE retrofits create economic benefits that are often several multiples of the initial investment [7]. Cost effective investments in residential EE to 2035 have a current net present value of £7.5 bn. With wider benefits such as GDP effects and health improvements that could be up to £47 bn [6]. Thus, EE investments share the characteristics of other forms of infrastructure as identified in HM Treasury's valuation guidance [75]. Therefore, we argue that **EE should be considered as an infrastructure priority** by the UK government and given the level of strategic support and status as other forms of infrastructure; such as road, rail and supply side energy infrastructure and be included within the remit of the NIC [64].

6.2. Regulations

The UK Clean Growth Plan set an aspirational goal for all domestic buildings to achieve an EPC level C or higher by 2035. We support these aims, but argue the government could go further, mandating minimum EE standards (MEES) for landlords and the owner occupier sector in the 2020s. This could take the form of a gradual step change through to a **minimum EPC level of C by 2035** at the point of sale, with potential for ever tightening standards moving into the 2040s and beyond [76].

There remain concerns surrounding the standard and quality of many installations currently funded under ECO, particularly solid wall insulation, which is to be a key part of the UK's climate targets [9]. Therefore, we support the findings of the recent Each Home Counts –'The Bonfield Review' for the establishment of a **new quality assurance standard** such as the **Home Quality Mark** [34]. This should also be accompanied by a nationwide training program for retrofit installation and project management to address the widely recognised 'skills gap' that currently exists in the UK [34]. Such a policy should be designed to minimise the regulatory and cost burden on SMEs, and could build on existing standards of good practice along the lines of the Investor Confidence Project in the commercial sector [77].

Taken together these high-level framing and regulatory policies would set the strategic direction for UK residential retrofit and would send market signals for the development of integrated business models, novel financing solutions and market intermediaries. However, on their own, top down regulations are unlikely to build a sufficient market for whole house retrofit.

6.3. Financial measures

Overcoming the up-front capital cost of EE retrofit remains a challenge for many households. Current fuel poverty schemes such as ECO are limited in size and have inherent design flaws [48]. For those in fuel poverty we instead propose that these costs should largely be met through government grants in the form of a **fuel poverty obligation paid for by general taxation**. This would allow the government to better spread the costs of such a scheme, and if properly designed could reduce spending in areas such as health, social care and welfare [6]. Such an approach could adopt a sliding scale of grant support and financing.

For the 'able to pay' segment, a range of market led financing mechanisms may eventually emerge, including mortgage-based approaches and other private sector offerings. Yet we argue that the government should learn the lessons of the failed Green Deal and create a **new low-cost financing mechanism tied to the property**, perhaps retaining the on-bill repayment channel from the Green Deal. Successful financing schemes such as Germany's KfW program have used government funds to provide a *low cost of capital*, involved a simplified *customer journey* and funded *broader sources of value* such as wider renovation works, which are likely to be perceived as higher value to households [53].

Although providing sources of lending for EE measures is key to *enabling* retrofit projects, it is unlikely that low cost financing alone will *drive* demand for retrofit [63]. Therefore, government should introduce a range of **fiscal incentives at key trigger points** to promote uptake. These might include; variable VAT, Stamp Duty Land Tax, Council tax, Income Tax rebates, a Landlord's Energy Savings Allowance (LESA) or an EE feed in tariff for households who have undertaken measures –with increasing benefits for deeper retrofits [65]. Such approaches will be most effective when they are targeted at key trigger points such as moving home, replacing a boiler or when undertaking major renovations [36].

6.4. Policy implementation and new institutions

A key challenge for residential retrofit remains the paucity of information, engagement and trust within communities. Recent work at CIED [68] and the UK Green Building Council [4] has highlighted a role for **new consumer-facing intermediaries to catalyse retrofit and regeneration activity in local areas**. These actors would act as a 'one-stop-shop' [8] to engage local communities on the benefits of retrofit and re-generation. Thus providing a single point of contact for: information, marketing, financing and project delivery through dedicated project managers/coordinators – drawing on the pre-existing networks of diffuse intermediaries already operating in many communities [72]. These intermediaries could be based on Community Social Enterprise or Local Authority Arm's Length Management Organization (ALMO) delivery models, and funded through a combination of local authority budgets, central government grants and community shares [4].

These new institutions can also play a role in developing supply chains and promoting business model innovation. Examples such as the Dutch Energiesprong scheme [70] and the RE:FIT program in London [78] demonstrate how public bodies can promote supply chain integration and business model innovation, through the **creation of new market-facing intermediaries and standardised procurement frameworks**. These initiatives help reduce transaction costs and bring together stakeholders to foster learning, new funding approaches and supply chain integration. Such approaches would also help deliver on the skills agenda through training initiatives and job creation in local areas [4], especially when linked to consumer engagement activities.

Achieving the promise of residential retrofit and tackling the multiple challenges that stand in the way, will require a joined up and co-ordinated strategy – as outlined in this report. To deliver this vision, we argue that the UK government should set up a **National Retrofit Taskforce**. This body would be responsible for the planning and delivery of the MEES targets through an overarching strategy, monitoring and verification process that brings together key stakeholders, including, Government, Third sector, Industry and Consumer groups [64]. This new high level agency would also be responsible for the management of the central **Information Hub** (to act as a collection point for best practice advice and guidance) and a **Data Warehouse** (to act as a store for property-level data and information) as both outlined in the Each Home Counts review [34]. Advising multiple government departments, this body could monitor progress towards the UK's targets for the sector and propose polices to keep this progress on track.

Climate change is perhaps the biggest challenge facing humanity in the 21st century. Buildings are the biggest single contributor, with the existing residential buildings by far the largest component [5]. Such a herculean challenge will require an equally herculean effort and the proposals presented here could go a long way towards achieving this.

Policy type	Policy	Challenge addressed	Government department
Political leadership	**'Efficiency First' as a guiding principle** [64] in the design of energy policies, to champion EE's vital importance in meeting climate and social policy objectives	**All**	All
	EE as an Infrastructure Priority [75] and given the level of strategic support and status as other forms of infrastructure	**All**	HMT, NIC
Regulation	**Minimum EE Standards (MEES)** moving to EPC C in 2035 [76]	**All**	MHCLG
	New retrofit **quality assurance standard** such as home Quality Mark [34]	**Uncertain energy savings and quality**	BEIS, MHCLG
Financial	**Financial Incentives** at trigger points [65], options could include: • Variable Stamp Duty • Variable Council Tax • 0% VAT on renovation work that includes retrofit • Income tax rebates & Landlord's Energy Savings Allowance (LESA) • EE Feed in Tariff	**Capital cost and split incentives** **Complexity, disruption and timing**	BEIS, HMT, HMRC
	Government backed low interest **financing mechanism** secured to property and available at point of sale of retrofit [17], whose features should include: • A Low cost of capital • Simplified customer journey through integration with installer business model • Funding for wider renovation and repair works included • Repayment through either energy bills or tax regime removing split incentives	**Capital cost and split incentives** **Complexity, disruption and timing**	BEIS, HMT, NIC
	Fuel poverty obligation funded by general taxation [48]	**Capital cost and split incentives**	BEIS, HMT, DH, DWP
Policy implementation and new institutions	**National Retrofit Taskforce/Agency** [6] with central Information Hub and a Data Warehouse	**All**	BEIS, MHCLG, HMT, DfE, DH, NIC
	Area based intermediaries based on Community Social Enterprise or Local Authority Arm's Length Management Organization (ALMO) delivery models [4]	**Information, engagement and trust**	BEIS, MHCLG, HMT, DfE, DH, NIC
	Market facing intermediaries and standardised procurement frameworks to promote supply chain innovation, new business models and skills [78]	**Complexity, disruption and timing**	

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