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Accelerating Energy Efficiency Retrofits in Owner-occupied Homes

An International Review of Good Practice Policies

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Background

Residential buildings contribute around a quarter of the UK's energy consumption, with space and hot water heating contributing the most to emissions from UK buildings. Improving the thermal energy efficiency of homes will be an important part of reducing these emissions. Most of the UK's 28 million homes will require low carbon heating, including the use of heat pumps and heat networks, and/or energy efficiency upgrades to achieve net zero by 2050. In 2022, around 70% of homes with cavity walls in England were insulated, while 10% of homes with solid walls had insulation. Around 1.5% of homes have a heat pump in the UK, one of the lowest proportions in Europe.

Building energy efficiency improvements have been significantly underfunded in the UK over the last decade, leading to a sharp fall in installation numbers of loft and cavity wall insulation since 2013. This followed the success of earlier UK energy supplier obligations in deploying several million such insulation measures from 2008 to 2012. The inconsistent and stop-start nature of government incentives, such as the Green Deal and Green Homes Grant, have not been helpful for developing the supply chain and promoting market confidence. In 2021, Government schemes such as the Energy Company Obligation (ECO) supported energy efficiency improvements in around 150,000 homes, a modest rate compared to the scale of the retrofit challenge.

Most households (63%) are owner-occupied in Great Britain, representing around 17 million homes. This tenure is amongst the least thermally efficient, comprising many older and larger properties, and improving their energy efficiency remains a significant policy gap. Prior to the cost of living crisis, most of the UK's owner-occupier households were categorised as 'able to pay' for energy efficiency improvements to their properties (1). There is not a clear or agreed definition of 'able to pay' in literature on home energy renovation, or an up-to-date analysis of how medium to high-income homeowners' ability to pay may have changed as a result of recent inflationary pressures or higher mortgage repayments. Being 'able to pay' does not necessarily mean that homeowners are able or motivated to renovate (2), which itself may require more targeted policy support, including clearer messaging, improved information framing, access to trusted advice and finance, and support in managing disruption.

There is currently no widespread financial incentive for supporting energy efficiency measures in owner-occupied, 'able to pay' households. However, policy has rarely addressed the fact that energy efficiency measures (particularly higher cost and more complex interventions) often lead to mess and disruption for residents. Where households have energy efficiency measures installed, unexpected delays and complications resulting from a lack of experienced installers have led to dissatisfaction and could negatively impact future uptake.

Purpose and Research Questions

To date, various building energy efficiency retrofit policies have been implemented across the OECD. This working paper reviews policy design and implementation internationally for increasing uptake of energy efficiency retrofitting in medium to high-income, 'able to pay' owner-occupied households. It identifies examples of good practice which could be most effectively employed in the UK context.

Drawing on Saffari and Beagon (3), we use the term 'home energy retrofit' (HER) to refer to energy efficient renovations in residential buildings which help to reduce energy consumption and greenhouse gas emissions and improve thermal comfort. These can include renovations to improve the energy performance of the building envelope for heating, hot water, ventilation and cooling, for example through upgrades to windows, doors, cavity, loft and solid wall insulation. They can also include energy efficiency measures which help to decarbonise heating or electricity such as heat pumps or solar PV microgeneration.

The review takes into account that there are different sub-categories of building energy renovations, particularly the distinction between 'shallow' retrofit involving one or two measures or piecemeal approaches, and 'deep' retrofit involving multiple interventions - aimed at achieving primary energy use savings of at least 60% - including comprehensive, pre-planned and complementary 'whole house' renovations.

This briefing paper addresses the following overall research question:

Which internationally applied, good practice policies have the most potential to accelerate quality, energy efficiency retrofits of owner-occupied, 'able to pay' households in the UK?

Based on a review of international evidence focusing on policies targeting medium to high-income or 'able to pay', owner-occupied homes, we also consider the following sub-research questions:

- Is there an optimal combination of policies and/or sequence for their implementation to achieve a step change in quality, energy efficiency retrofits in 'able to pay', owner-occupied homes?
- What should be the role of national government across different areas of policy, to deliver this?
    - Policy areas may include e.g., financial incentivisation (public/private sector), information policies, building energy efficiency standards, skills and supply chain development.
- What are good practice examples of national policy coordination with regional and local retrofit policy and delivery?

Review Approach

The review comprised three stages:

1. A (non-systematic) scoping review of academic and grey literature through which key reviews and other relevant publications were collated on HER policies in owner-occupied households internationally.
2. Relevant national retrofit programmes and international datasets were identified to compare progress on HER in different countries, and (subject to data availability) broad, owner-occupier characteristics and typical features of their housing stock.
3. A Rapid Evidence Assessment (REA): a short but systematic review on a constrained topic (4–6), implemented here to evaluate good practice polices and strategies for energy retrofit in mid-to-high income owner-occupier homes internationally. Searches were carried out in two databases: Web of Science (for academic literature) and Overton (for grey literature and policy documents).

The scoping review identified several relatively recent reviews on the topic. Therefore, the REA searches were restricted to the last five years (2019-2024) in order to consider the newest evidence. The findings presented in this report are based on an analysis of 70 of the most relevant documents, drawn from a wider body of over 700 documents identified through the search strategy.

We do not apply a strict definition of 'able to pay' or medium to high-income households, as such definitions vary in terms of how they are applied in the literature. In general, documents exclusively considering low-income owner-occupied households were rated of lower relevance and excluded from the analysis.

Findings

UK and international progress: home energy retrofit

In the UK, successive energy efficiency policies have been implemented since the 1970s (7). These policies have included mandatory requirements for domestic energy suppliers to meet CO_2 reduction targets through the installation of various energy efficiency measures, funded through energy bills. In particular, the Carbon Emissions Reduction Target (CERT) and Community Energy Saving Programme (CESP), active from 2008 to 2012, were effective in deploying lower cost and easier to treat insulation measures, and (excluding energy efficient light bulbs) led to a higher volume of installations in four years than successor ECO schemes have since 2013. Although 4.1 million measures were installed in 2.5 million households under ECO from 2013 to 2024, loft and cavity wall insulation experienced a sharp drop in installations coinciding with the replacement of CERT and CESP with ECO and the Green Deal in 2013, and a government decision in 2014 to reduce the target for ECO suppliers on the basis of lowering energy bills.

Retrofit policy delivery also varies across UK regions and devolved administrations. For example, Scotland and Northern Ireland have separate information and advice services for householders (Home Energy Scotland and Northern Ireland Energy Advice Service, respectively), which offer signposting to grants and/or loans for energy retrofit, administered by the Energy Saving Trust, with evidence of some moderate

impact in terms of enquiries responded to and subsidy uptake. A clear policy gap appears to be a lack of a similar advice/signposting service for England and Wales.

Our international review highlights that residential energy renovations in OECD countries are mostly shallow single measures, with a small portion comprising multiple measures or deeper renovations. Although some countries such as France, Germany, the UK and the US have retrofitted millions of single measures to homes, this review has not identified any countries which have delivered deep home energy retrofit at a widespread scale.

Through our review, we highlight examples of national investment subsidies and 'one stop shop' schemes, aiming to support the customer retrofit journey and promote use of accredited suppliers and/or products, which have led to a scaling up of interventions. In several cases, these have led to 100,000s of single measure installations, although they mostly represent examples of shallow retrofit rather than deeper or whole house energy renovation.

The extent to which national energy retrofit schemes have supported thermal energy efficiency upgrades or low carbon heat supply varies. Approaches in France, Germany and Canada have been dominated by low carbon heating installations rather than building fabric improvements. These examples contrast with the US, where in 2023 the Energy Efficient Home Improvement Credit (EEHIC) had 2.3 million claimants, and subsidised modifications mostly related to home insulation, windows and skylights, and energy efficient air conditioning. There were approximately 450,000 claims for heat pump installations under the EEHIC or the Residential Clean Energy Credit (RCEC) (8–10). In Ireland, less than 14,000 of 419,500 measures installed over the last decade under the National Home Retrofit Programmes have been for heat pumps (11).

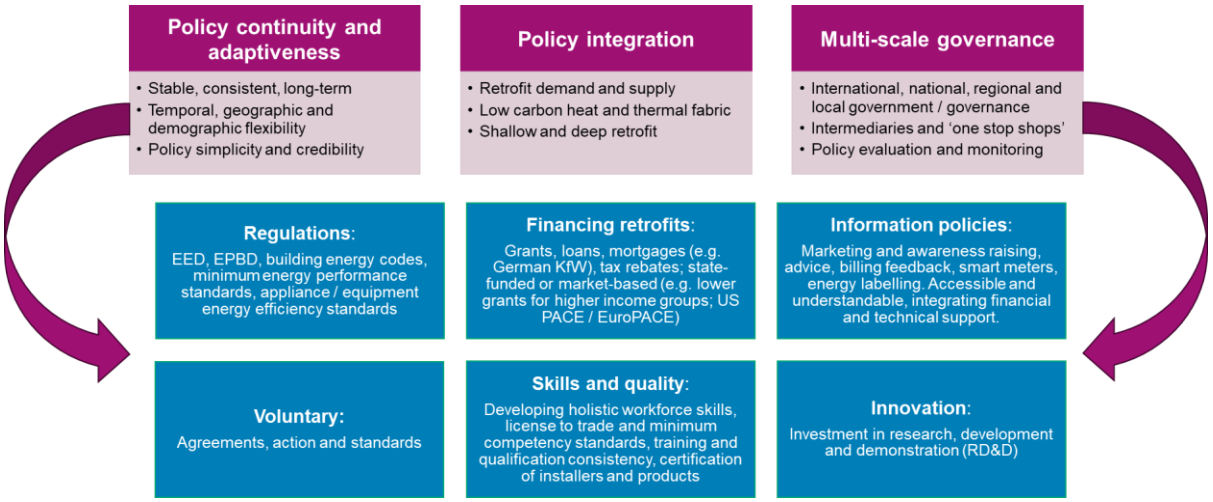
International findings on policy instruments

We identified various review studies on policy instruments which have been applied in different countries and are considered important for implementing residential energy renovation. Policy instruments most commonly emphasised are regulations, financial support and information provision. Most reviews also include policies to develop workforce skills and competencies, supply chains and quality assurance. Research, development and demonstration (RD&D) or innovation, and voluntary agreements and actions, are also mentioned in some of the reviews, however, there is less detail on what effective policy approaches have been or should be in these areas.

We review international evidence on six individual policy instruments, and key examples and features of these are synthesised in Figure E1. Additionally, there is a consensus, particularly in existing reviews on HER policies, that the application of single policies alone will not be enough to achieve a transformational increase in energy renovation rates. Indeed, the latter remain low despite the application of various policies internationally. In countries where higher volumes of HER have been achieved, such as Canada, France, Germany and Ireland, we have identified several cross-cutting success factors which include long-term policy reliability and flexibility,

effective policy mixes, policy integration and multi-scale governance, including the use of intermediaries such as ‘one stop shops'. These success factors are summarised in Figure E1.

Figure E1: Policy approaches and success factors identified in the review



Cross-cutting policy success factors

Key to effective home energy retrofit policies internationally is stable, long-term policy support, helping to increase certainty for household and supply chain investment decisions. Policies should be credible to policymakers and capable of receiving consistent political commitment over a long period of time, helping to achieve policy targets. Policies should be flexible so that they can be adapted over time to account for changing circumstances (12).

HER policies can be applied together to achieve more impact, for example information measures and standards can help to increase the success of other policies (13). Relevant policies should also be adaptive enough to account for the risk that individual policy instruments might interfere with each other and reduce their efficacy (12,14). These points relate to the concept of a ’policy mix’, referring to sets of government policies, including policy objectives, strategies and instruments which have innovation impacts, and may evolve incrementally over many years (15,16).

Policymakers in the EU have generally applied a wide range of policy instruments for building energy renovation, rather than single instruments or specific sequences of policies. Voluntary standards can be increased upon the introduction of compulsory standards to stimulate further innovation. Regulations may increase technical standards, but may also create a need for extra training and accreditation in supply chains, and therefore appropriate skills development policies should also be in place (12,17).

Intermediaries could help to bridge the gap between national government and millions of private homes. They may include installers, craftspeople, construction firms, architects and energy advisers, but there may be issues with consumer trust. Intermediaries are often involved in consumer decisions on whether or not to retrofit

in ways which may have positive or negative outcomes on technological diffusion. To effectively support HER, intermediaries such as craftspeople need to be convinced that energy efficient renovation measures are useful (161).

A prominent example of an intermediary is a 'one stop shop', an innovative service model which can fulfil or integrate various functions, including providing homeowners with access to finance, quality assurance and training of contractors, performance monitoring and maintenance. A 'one stop shop' can operate at local, regional and/or national scales, and be funded by different sources, including government, industry, or a combination of public and private sector organisations. Bertoldi, Boza-Kiss, *et al.* (18) estimate that there are around 100,000 'one stop shop' projects per year in the EU. There is a role for national and local government to promote effective intermediaries, which is achievable if government and intermediary goals are reasonably aligned.

In several European countries, there are examples of national retrofit strategies or 'one stop shops' which include training, certification and/or quality assurance of retrofit tradespeople. In Germany, the KfW (Kreditanstalt fuer Wiederaufbau) bank scheme requires households to access advice from building energy specialists registered on quality-assured lists. The Canadian Greener Homes Initiative offers grants and an interest-free loan for home energy evaluations and retrofits. Access to grants and loans requires pre- and post-retrofit EnerGuide evaluation by an energy adviser.

A feature of several of the national 'one stop shop' schemes identified in our review is the integration of policy support for different types of technologies and interventions, including thermal fabric improvements, low carbon heating (including heat pumps) and microgeneration (solar PV in particular). Despite this, the uptake of such interventions via national 'one stop shops' have tended to be dominated by single measures or shallow renovations. However, in some cases these schemes offer extra incentives for deeper renovations, including low interest loan support particularly targeted at 'able to pay' owner-occupiers, in addition to investment grants typically offered to a wider range of household types and incomes.

Local authorities can be well placed to identify the least efficient building stock in their areas and respond to the needs, preferences and concerns of local residents, but may generally lack their own resources for financial incentivisation. Instead, local authority financing can be funded from a national (e.g. the Netherlands, US) or international governance level, e.g. through EU cohesion policy including the Cohesion Fund and the European Regional Development Fund. Another option is for local authorities to partner with banks in offering local financing products (19).

We identify international examples of funding and resources distributed to local government for HER. Over the next few years, the Dutch National Insulation Programme includes funding for local authorities to insulate 750,000 homes in districts due to transition to natural gas-free heating (20). This decentralised funding arrangement bears similarity to the US Better Buildings Neighborhood Program (BBNP), which was active from 2010 to 2014, in which the US Department of Energy (DOE) distributed a total of $508 million to state and local governments via 41 grantee organisations to finance building energy retrofits. Grantees reported that around

120,000 energy efficient upgrade measures were installed across 34 states and one territory, in mostly residential buildings.

In the process of carrying out our review, we have observed the following on monitoring and evaluation. There is poor availability of regularly updated data to track progress in HER in different countries and compare relative progress internationally for specific measures and more comprehensive renovations alike. But there is also a paucity and inconsistency of monitoring data and metrics within countries, linking progress tracking at local, regional and national levels.

Applying international experience to the UK

In reviewing policy experiences in OECD countries, questions arise as to the extent to which the building stock for (medium to high-income) owner-occupiers varies between the UK and other countries, and how translatable separate national experiences might be in cases where building archetypes are significantly different.

63% of households are owner-occupied in England, Wales and Scotland, compared to 69% in the EU (21), 70% in Canada and 65% in the US (22). The age profile of residential buildings in the UK creates additional challenges for future proofing low carbon retrofit and mitigating adverse health outcomes (23). A fifth of the UK housing stock is over 100 years old, with 38% of dwellings built before 1946, compared to an average of 18% for the EU (24,25).

Effective HER policy design requires accounting for the multiple factors which may influence homeowners to carry out energy renovations, relating to saving on energy bills and carbon emissions, comfort, utility, aesthetics, social aspirations, health and heritage. Homeowners may be more likely to make decisions to install retrofit measures during certain ‘trigger points’ such as moving home, changes in family structures, members and relationships, or other events resulting in unexpected changes to household practices and prioritisation of concerns within the home (26,27).

In addition, recent analyses of households in the UK propose that energy retrofit policies need to account for the role of social relations (23,28). This informs a recommended set of alternative policies, grounded in a social relations perspective and drawing on case studies of the ‘retrofit journey’ of 30 UK households which self-funded energy renovations. Such alternative policies should avoid ‘one size fits all’ solutions and utilise community and social ties to target key entry points in the consumer retrofit journey, including moving home and decisions to carry out general renovation work (that may not initially include energy retrofit measures) (23).

The construction sector in the UK and EU has been characterised as a ‘low skills equilibrium’, where salaries are low and job security is poor, in turn leading to a poor reputation for construction work which is not typically promoted as an ambitious career in schools (29,30). Buildings decarbonisation therefore requires a larger, more diverse and competent workforce (31).

The UK labour market for construction and energy efficiency retrofit is largely unregulated, in other words, there are no minimum or ongoing licensing requirements

for workers or businesses with respect to training and qualifications (30). For home energy renovation this applies particularly to insulation and other thermal fabric improvements, increasing the risk of low quality renovations (32). For heat pumps and solar PV, the Microgeneration Certification Scheme has been in existence for around a decade to quality assure installers and products. Even so, this scheme is focused on specific technology requirements, rather than quality assurance for multiple-skill sets and competencies that can help ensure that any single measures are appropriate, and minimise risks of adverse impacts elsewhere in the home.

There are significant challenges in ensuring local and regional planning is integrated with national programmes to ensure policies are in place, enabling plans to actually get delivered. In England there is no requirement for local authorities to conduct comprehensive heat or whole system energy planning, and there could be value in following a similar approach to Scotland with centralised guidance and technical resources set up to support the development of Local Heat and Energy Efficiency Strategies (33).

A key policy gap in England is the absence of a comprehensive, national advice and/or 'one stop shop' programme. National advice services already exist in Scotland and Northern Ireland, administered by the Energy Saving Trust (94). Maby (187) recommends that the UK government should set up a national information and advice resource for low carbon renovation, supported by a network of local and regional 'one stop shop' hubs, clearly linked to the national resource. Advice could be tailored to support homeowners and households of different tenures to make appropriate home energy upgrades, including at key trigger points such as moving home or carrying out general renovation work.

Conclusions and Policy Recommendations

Drawing upon our review of international and UK evidence, we make a series of policy recommendations for an effective home energy retrofit policy framework in the UK, with a focus on medium to high-income owner-occupier households. These recommendations address the review research questions, and are grouped accordingly below.

Combination and sequence of policies

- Key success factors are the design and implementation of policy instruments which are credible, stable, long-term and flexible.
- Policy packages or combinations of complementary policies are more effective than applying individual policy instruments alone.
- Effective policy mixes should include policies to stimulate both homeowner demand and a competent supply chain for retrofit.
- Policy targets should set a clear direction of travel and be measurable, including use of quantitative metrics comparable across countries and localities, to allow continuous monitoring of progress.

Role of national government and good practice policies

- Regulatory measures can be effective for shallow retrofit. To achieve deeper retrofit impact, UK regulations could be aligned more closely with EU directives on building energy renovation, particularly in relation to requirements for EU member states to develop Building Renovation Plans for building stock decarbonisation by 2050.
- Energy efficiency obligations have been effective in deploying millions of lower cost and easier to treat measures. ECO focuses on low-income households but could be extended to part-fund renovations in higher-income households to encourage wider uptake of measures.
- The review highlights several retrofit financing mechanisms that can be targeted specifically at mid-to-high income owner-occupied households. Given pressures on government spending, a blended financing approach combining direct, publicly funded financial incentives with innovative measures to stimulate private financing, is likely to be required.
- For England and Wales, we recommend that a national retrofit programme with financial incentives for 'able to pay' homeowners and a 'one stop shop' and advice service linked to local and regional hubs could help to support the customer retrofit journey and develop supply chains.
- In taking measures to grow the required workforce and ensure quality outcomes, the UK building energy retrofit industry should develop a regularly updated licence to trade, minimum competency and training standards and more standardised and comparable qualifications.

Policy co-ordination of national, regional and local retrofit initiatives

- National and local government retrofit policy should be better coordinated, including through dissemination of financing to support uptake of measures at a local level.
- National policy programmes for home energy renovation should be integrated with mandatory local area planning to ensure plans actually get delivered.
- There is a role for national and local government to facilitate effective intermediaries, which can be achieved if government and intermediary goals are reasonably aligned.
- Establish regular collaboration between UK and devolved governments, to foster mutual learning and greater consistency in policy design and implementation across the UK.

1. Introduction

1.1 Background

Residential buildings consume 70% of global final energy demand from buildings, with the building sector consuming equivalent to 31% of global final energy demand, leading to 31% of CO_2 emissions, according to the IPCC (34). Mitigation of emissions resulting from this primarily includes energy efficiency retrofit interventions to the fabric and heating, or cooling. Countries in Europe where 85-95% of existing buildings will still be standing by 2050 (35), have a particular focus on retrofit, or renovation, interventions. Despite some progress with deployment of individual measures, overall building energy retrofit rates remain low (36), leading to a Renovation Wave Strategy designed to increase these rates across the EU (37).

It has previously been suggested that policies for building energy renovation should support not only the least cost and easiest to implement measures, such as loft insulation, energy efficient appliances and lighting, but also deeper, more complex and expensive whole-house retrofits (38). Making such a shift to a more comprehensive uptake of multiple energy efficiency measures will require a well-targeted and holistic combination of policies (38,39). To date, various energy efficiency retrofit policies have been implemented across the OECD. This working paper reviews policy design and implementation internationally for increasing uptake of energy efficiency retrofitting in owner-occupied households, and deriving examples of good practice which could be most effectively employed in the UK context. Most households (63%) are owner-occupied in Great Britain, representing around 17 million homes (40,41). This tenure is amongst the least thermally efficient, comprising many older and larger properties, and improving their energy efficiency remains a significant policy gap (42).

1.2 UK Policy Context

Residential buildings contribute around a quarter (26%) of the UK's energy consumption and a fifth (20%) of its greenhouse gas emissions (43,44). Space and hot water heating contribute the most to emissions from UK buildings (42), and improving the thermal energy efficiency of homes will be an important part of reducing these emissions. Achieving the UK's 2050 Net Zero Target will require home heating to be decarbonised by replacing gas and other fossil fuel heating with low carbon alternatives such as heat pumps and heat networks (45).

Reducing energy demand of the UK's housing stock could help to alleviate the energy price and cost of living crises over the medium to long term. Moreover, a number of interventions such as draught proofing, hot water tank insulation, loft and cavity wall insulation (in easy-to-treat homes) are relatively affordable compared to more expensive measures such as solid wall insulation (46). Under the Climate Change Committee's Balanced Net Zero Pathway set out for the Sixth Carbon Budget, 15 million households would need to receive loft, wall or floor insulation by 2050, and an additional 8 million would require upgrading with draft-proofing (47). Analysis for the

latest Seventh Carbon Budget indicates that low carbon heating (particularly heat pumps) could contribute two-thirds of carbon emissions reduction by 2040 in the Balanced Pathway, with insulation and draught proofing contributing an additional 10% of emissions reduction in 2040 (188). In 2022, around 70% of homes with cavity walls in England were insulated, while 10% of homes with solid walls had insulation (48), however, data on the quality of installation and materials used is harder to find. Around 1.5% of homes have a heat pump in the UK, one of the lowest proportions in Europe (49).

In 2021, Government schemes such as the Energy Company Obligation (ECO) supported energy efficiency improvements in around 150,000 homes, a modest rate compared to the scale of the retrofit challenge (42,50). Most of the UK's 28 million homes will require low carbon heating and/or energy efficiency upgrades to achieve net zero by 2050 (51).

Building energy efficiency improvements have been significantly underfunded in the UK over the last decade, and this has been linked to a sharp fall in installation numbers of loft and cavity wall insulation since 2013 (52). This followed the success of earlier UK energy supplier obligations, such as the Carbon Emissions Reduction Target (CERT) and Community Energy Saving Programme (CESP), in deploying several million such insulation measures from 2008 to 2012 (53,54). A lower CO_2 reduction target for suppliers under the subsequent ECO scheme (54), and the inconsistent and stop-start nature of government incentives such as the Green Deal and Green Homes Grant, have not been helpful for developing the supply chain and promoting market confidence (55). The UK Government's aspiration is for as many homes as possible to be at least Energy Performance Certificates (EPC) band C by 2035 (54). In England and Scotland, over half of homes were rated EPC band C or higher in 2023, with lower rates indicated in Wales and Northern Ireland according to the latest available data (ibid.). However, it is well established that EPCs have confusing and opaque metrics, and EPC ratings are difficult to compare with real-world energy use (56).

Prior to the current cost of living crisis, most of the UK's owner-occupier households were categorised as 'able to pay' for energy efficiency improvements to their properties (1,57). There is not a clear or agreed definition of 'able to pay' in the literature on home energy renovation, or an up-to-date analysis of how medium to high-income homeowners' ability to pay may have changed as a result of recent inflationary pressures or higher mortgage repayments. Being 'able to pay' does not necessarily mean that homeowners are able or motivated to renovate (2), which itself may require more targeted policy support, including clearer messaging, improved information framing, access to trusted advice and finance, and support in managing disruption. There is an extensive literature on barriers to owner-occupiers retrofitting their homes, including high upfront costs, low awareness and knowledge, uncertainties about possible benefits and long payback times, perceptions of likely disruption to home life and complexities, low trust in government and low confidence in being able to find skilled and reliable installers (2,12,58–61).

Despite recent high gas prices in the UK, where around 85% of homes use gas heating, one key barrier to the uptake of low-cost energy efficient renovations is the

tendency of householders to undervalue future bill savings set against immediate installation costs (1). This is set against longer payback times for more expensive measures such as solid wall insulation, solar PV and heat pumps (62,63), while the latter would also benefit from market reform to lower electricity prices. A survey of 3,000 UK homeowners conducted in 2023 found that respondents tended to overestimate the cost and installation time of energy efficient modifications such as loft and roof insulation and double or triple glazed windows (64).

In the UK, current relevant policies to address owner-occupied homes include some limited funding coverage in the Great British Insulation Scheme, the Boiler Upgrade Scheme which provides investment grants for heat pumps (but not thermal fabric upgrades), and householder advice services in Scotland and Northern Ireland which provide signposting to grants and/or loans for home energy renovation (see Table 2 below).

There is currently no widespread financial incentive in the UK for supporting energy efficiency measures in owner-occupied, 'able to pay' households. However, policy has rarely addressed the fact that energy efficiency measures (particularly higher cost and more complex interventions) often lead to mess and disruption for the resident, and Curtis, Grilli and Lynch (65) cite this as an overlooked challenge, with only 1 in 4 households actively receptive to retrofit policy supports. Where households have energy efficiency measures installed, unexpected delays and complications resulting from a lack of experienced installers have led to dissatisfaction and could negatively impact future uptake (66).

Importantly, effective policies should be directed not just at homeowners, but also at the retrofit industry, through mechanisms to develop workforce competencies and the retrofit supply chain. This is particularly applicable to private households, given that installations are fitted by multiple independent tradespeople, and the effectiveness of existing installation and maintenance standards has been contested (32,50,61,67).

1.3 Research Questions and Scope

This Briefing Paper addresses the following overall research question:

Which internationally applied, good practice policies have the most potential to accelerate quality, energy efficiency retrofits of owner-occupied, 'able to pay' households in the UK?

Based on a review of international evidence focusing on policies targeting medium to high-income or 'able to pay', owner-occupied homes, we also consider the following sub-research questions:

- Is there an optimal combination of policies and/or sequence for their implementation to achieve a step change in quality, energy efficiency retrofits in 'able to pay', owner-occupied homes?
- What should be the role of national government across different areas of policy, to deliver this?

- Policy areas may include e.g., financial incentivisation (public/private sector), information policies, building energy efficiency standards, skills and supply chain development.

- What are good practice examples of national policy coordination with regional and local retrofit policy and delivery?

1.4 Definitions of Home Energy Retrofit Included in the Review

There are various definitions in the literature of what constitutes energy efficient retrofit, and a general tendency to use the terms retrofit and renovation interchangeably in this context (27). Drawing on Saffari and Beagon (3), we use the term 'home energy retrofit' (HER) in this paper to refer to energy efficient renovations in residential buildings which help to reduce energy consumption and greenhouse gas emissions, and improve thermal comfort. These can include renovations to improve the energy performance of the building envelope for heating, hot water, ventilation and cooling, for example, through upgrades to windows, doors, cavity, loft and solid wall insulation. They can also include energy efficiency measures which help to decarbonise heating or electricity such as heat pumps or solar PV microgeneration (3,27,68,69).

The review takes into account that there are different sub-categories of building energy renovations, particularly the distinction between 'shallow' retrofit involving one or two measures or piecemeal approaches, and 'deep' retrofit involving multiple interventions - aimed at achieving primary energy use savings of at least 60% - including comprehensive, pre-planned and complementary 'whole house' renovations (2,3,70–72). For the purposes of this report, Table 1 presents a classification of different types of residential energy retrofit measures identified in the review, which are differentiated by shallow, deep, whole-house renovations and broad installation cost ranges for the UK.

Table 1 Taxonomy of home energy retrofit (HER)[1]

Retrofit category	Sub-category	Example measures or approaches	Typical UK capital cost range
Shallow retrofit or single measures	Low-cost insulation	Hot water tank insulation Draught proofing Loft insulation Cavity wall insulation (easy to treat)	£100 - £1000

[1] Table 1 sources: (3,46,73–76).

	Higher-cost insulation	Cavity wall insulation (hard to treat) Floor insulation (suspended timber) Double glazing Solid wall insulation (internal) Solid wall insulation (external)	£3000 - £10,000 +
	Heating efficiency improvement or microgeneration	Air-to-water heat pump (ASHP) Ground source heat pump (GSHP) Solar PV (3.5kWp)	£7,000 (solar PV) - £25,000 (GSHP)
Deep retrofit	Multiple measures aimed at achieving 60% primary energy savings	Combinations of above single measures	£10,000s - depends on measures included
	Whole house renovations	Comprehensive and pre-planned, simultaneous	£10,000s - £100,000
		Carried out in stages, can include use of home energy passports	As above, but allows up-front costs to be spread out over time

2. Approach and Evidence Review

As a first step, we conducted a (non-systematic) scoping review of preliminary evidence on the topic, drawing upon several academic and grey literature databases (Science Direct, Web of Science, Overton and Google). Through the scoping review, key reviews were collated on HER policies in owner-occupied households internationally and other highly relevant publications. Secondly, relevant national retrofit programmes and international datasets were identified to compare country progress on HER, and (subject to data availability) broad owner-occupier characteristics and typical features of their housing stock. The scoping review informed the selection of keywords, search strategies and databases used in the Rapid Evidence Assessment (REA), the third and substantive step of the research. A REA is a short but systematic review on a constrained topic (4–6), implemented here to evaluate good practice policies and strategies for owner-occupier energy retrofit internationally. The search terms were combined in search strings and applied to two databases: Web of Science (for academic literature) and Overton (for grey literature and policy documents). The keywords or phrases searched for are listed in the Appendix and relate to the following topic categories: building energy efficiency; building sector, household and occupancy type; a range of relevant policies identified in the scoping review; governance at different geographic scales; and retrofit delivery mechanisms (including public, private and business models).

The scoping review identified several relatively recent reviews on the topic which are discussed in Section 3.2 and summarised in Table 4. Therefore, the REA searches were restricted to the last five years (2019 to 2024) in order to consider the newest evidence. The returned results were filtered manually for their relevance to the research questions based on reading their title and abstract, or further inspection of the main text if necessary (see Appendix for relevance ratings, inclusion and exclusion criteria used). The findings presented in this report are based on an analysis of 70 of the most relevant documents, drawn from a wider body of over 700 documents identified through the search strategy, after duplicates were removed. The analysed documents: include material on (mid-to-high income) owner-occupied households specifically; the focus is on retrofit polices or strategies; and are based mainly on empirical, country-based evidence rather than forward looking material (e.g., modelling studies or policy strategy documents). We do not apply a strict definition of 'able to pay' or medium to high income households, as such definitions vary in terms of how they are applied in the literature. In general, documents exclusively considering low-income owner-occupied households were rated of lower relevance. The geographical coverage of the review is international, but dependent on those countries and continental regions for which relevant evidence was identified in the databases used. The review was restricted to evidence available in English.

The research was informed by a small group of expert advisers, who met twice through the course of the project to comment on the scope, proposed approach, advise and assist in the selection of relevant evidence sources, and review provisional results. The expert advisers are listed in the Appendix.

3. Review Findings

3.1 UK and International Progress: Home Energy Retrofit

Tables 2 and 3 present recent and ongoing examples of HER policy initiatives both in the UK, and in the OECD, including Europe, North America and New Zealand. We discuss these first in this section, and then with respect to specific policy instruments in the sections which follow.

In the UK, a succession of energy efficiency policies have been implemented since the 1970s, as described by Mallaburn and Eyre (7). These have included mandatory requirements for domestic gas and electricity suppliers to meet CO_2 reduction targets through the installation of various energy efficiency measures, funded through energy bills (ibid.). In particular, the Carbon Emissions Reduction Target (CERT) and Community Energy Saving Programme (CESP), active from 2008 to 2012, were effective in deploying lower cost and easier to treat insulation measures, and (excluding energy efficient light bulbs) led to a higher volume of installations in four years than successor ECO schemes have since 2013 (Table 2). The CERT scheme was available to all households in Great Britain, whereas CESP was targeted at low-

income neighbourhoods (77). Six CERT energy companies together achieved the overall CERT target of 293 million tonnes (Mt) of CO_2 savings by the end of 2012 (ibid.). Through CERT, 3.9 million households received professionally installed loft insulation and 2.6 million professional cavity wall insulation, with approximately 70% of these in private households (53). Due to over 300 million compact fluorescent light (CFL) bulbs being supplied to households during the first two years of the scheme, CERT was amended in 2010 to make CFL and halogen light bulbs ineligible. The majority of CO_2 savings were required to be from professional or DIY insulation (ibid.). Although 4.1 million measures were installed in 2.5 million households under ECO from 2013 to 2024, loft and cavity wall insulation experienced a sharp drop in installations coinciding with the replacement of CERT and CESP with ECO and the Green Deal in 2013, and a government decision in 2014 to reduce the target for ECO suppliers on the basis of lowering energy bills (54).

Figure 1 Millions of insulation measures installed under Government schemes in Great Britain, 2009 - 2024

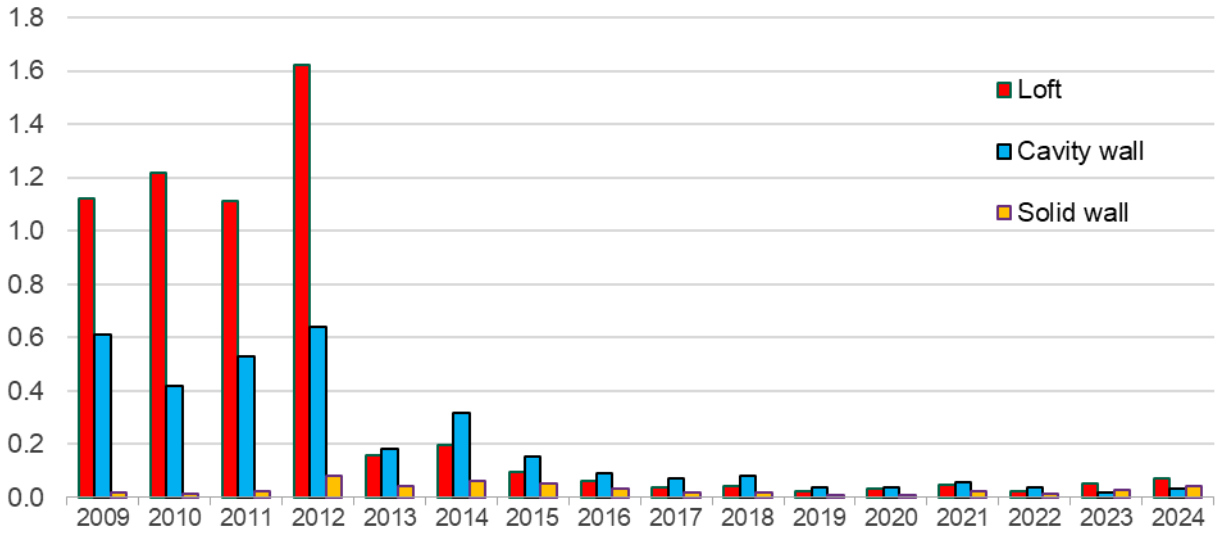


Figure 1 source: Bolton (54)*, based on data from DESNZ* (78).

In the UK, current building retrofit subsidies most relevant to medium-to-high income owner-occupiers are the Great British Insulation Scheme (GBIS, formerly ECO+ and also an energy supplier obligation) for thermal fabric measures and the Boiler Upgrade Scheme (BUS, a direct grant available to homeowners with a valid EPC certificate to subsidise heat pump installation costs) which have resulted in the uptake of around 100,000 building energy efficiency measures (including at least 40,000 heat pumps) over the last two to three years (Table 2). This is a modest deployment rate compared to CEST and ECO, although the BUS supports heat pumps which have higher up-front costs than easier-to-treat thermal fabric measures such as loft and cavity wall insulation. As part of its Warm Homes Plan, the UK government increased funding for the BUS to £295 million for 2025/26, which could support the equivalent of up to 39,000

heat pump installations (79). This is still well below the government target to reach 600,000 annual heat pump installations by 2028.

Retrofit policy delivery also varies across UK regions and devolved administrations, with ECO schemes being applicable to Great Britain, the BUS to England and Wales, and separate initiatives in Scotland, Wales and Northern Ireland (Table 2). The Optimised Retrofit Programme in Wales promotes whole-house retrofit, but is not shown in Table 2 as it is targeted at social housing (80). The Northern Ireland Sustainable Energy Programme (NISEP) is a public service obligation collected via a levy on residential and commercial electricity consumer bills throughout Northern Ireland. Homeowners, private tenants and housing association properties are eligible to receive energy efficiency measures. Low-income households are typically fully-funded; higher-income households can be part-funded. Scotland and Northern Ireland have separate information and advice services for householders (Home Energy Scotland and Northern Ireland Energy Advice Service, respectively), which offer signposting to grants and/or loans for energy retrofit, administered by the Energy Saving Trust, with evidence of some moderate impact in terms of enquiries responded to and subsidy uptake (Table 2). A clear policy gap appears to be a lack of a similar advice/signposting service for England and Wales.

Table 2: Recent and ongoing national retrofit policy programmes and impact on owner-occupied households in the UK

Geographical coverage	Policy name, sources and timescale	Policy description	Outcomes
United Kingdom (UK)	Clean Heat Market Mechanism (CHMM) (81) April 2025 – (scheduled until at least 2029)	The scheme applies an obligatory low carbon heat target to any given company or group of companies which supply at least 20,000 gas boilers or 1,000 oil boilers annually. For the first year of the scheme, 6% of sales above these thresholds require CHMM credits, where: installing one standalone heat pump earns *one* credit, and a hybrid heat pump installation receives *half* a credit.	From 1 April, scheme participants are required to begin monitoring boiler sales for the current scheme year. Scheme participants which do not have enough certificates to meet their low carbon heat target must pay the scheme administrator (Environment Agency) £500 for each unit of the target not met, after the end of each scheme year.

Great Britain (GB)	Carbon Emissions Reduction Target (CERT) (53,77,82,83) 2008 - 2012	Energy efficiency obligation with mandatory requirements for electricity and gas suppliers to meet CO_2 reduction targets through the installation of various energy efficiency measures, available to all households in GB.	Insulation comprised two-thirds of measures installed by CERT companies, with other measures including lighting, heating, microgeneration and household appliances. Almost a fifth (19%) of all GB households received a CERT measure.
	Energy Company Obligation (ECO) (54,83–86) 2013 – (ongoing) Currently in its 4th phase (ECO4) and due to end in 2026.	Obligation on medium to large energy suppliers to provide energy efficiency measures in low-income or fuel poor households.	4.1 million measures were installed in 2.5 million residences from 2013 to 2024. 1.7 million households or 70% of ECO recipients were owner-occupied. The most commonly installed measures have been cavity wall insulation, boiler replacements, heating controls and loft insulation.
	Great British Insulation Scheme (GBIS)-(87,88) 2023 – 2026 (scheduled end)	Formerly ECO+, the GBIS places an obligation on medium and large energy companies to deliver energy saving improvements to the least energy efficient homes, with a focus on single measures. Available to homes with an EPC rating of D-G, Council Tax bands A-D in England and A-E in Scotland and Wales.	From May 2023 to November 2024, 53,387 measures were installed in 42,554 households. Of these, 22,536 were for cavity wall insulation, 14,764 for loft insulation and 10,839 for heating controls. Up until September 2024, 82% of households receiving GBIS measures were owner-occupied.
England and Wales	Boiler Upgrade Scheme (BUS) (74,89) 2022 – (ongoing)	Grants available to homeowners (or small business premise owners) covering £7,500 off the installation cost of an ASHP or GSHP, and £5,000 off the installation of a	From May 2022 to November 2024, there were over 60,000 applications, with 53,000 vouchers issued (confirming eligibility). Payment was redeemed for almost 40,000

		biomass boiler (the latter in rural off gas-grid locations). Eligible recipients must have a valid EPC certificate and be replacing fossil fuel or non-heat pump electric heating.	vouchers, the vast majority (97%) being for ASHPs.
Northern Ireland (NI)	Northern Ireland Energy Advice Service (NIEAS) (90–93) 2022 – (ongoing)	'One stop shop' and free energy efficiency, heating and renewables advice service, including signposting to energy grants, available to all NI households.	NIEAS has responded to 25,500 unique queries since 2020.
	Northern Ireland Sustainable Energy Programme (NISEP) (90–93) Previously the Energy Efficiency Levy, known as NISEP since 2022 and has been extended until 2027.	Public service obligation: £8 million fund collected from a levy on residential and commercial electricity consumer bills throughout NI. Homeowners, private tenants and housing association properties are eligible to receive energy efficiency measures.	The funding has been used for schemes installing measures such as boiler upgrades, LED lights, heating controls, draught proofing and insulation. 80% of the funding is allocated for vulnerable households.
Scotland	Home Energy Scotland (94–96) 2008 – (ongoing)	Advice service for householders; grants and interest free loan scheme for owner-occupiers installing low carbon heat and/or energy efficiency measures.	From 2020/21 to 2022/23, there were 12,430 successful applications for Home Energy Scotland grants and/or loans. > air source heat pump and solar PV installations per 100,000 homes in Scotland vs England.

Table 3 illustrates that in most cases residential energy renovations in OECD countries are shallow single measures, with a small portion comprising multiple measures or deeper renovations. Although some countries such as France, Germany, the UK and the US have retrofitted millions of single measures to homes, this review has not

identified any countries which have delivered deep energy retrofit at a widespread-scale. The most recent data on energy renovation rates in the EU28 (2012-2016) shows that on average each year, 0.2% of the floor area of residential buildings received deep renovation, defined as retrofit measures resulting in greater than 60% primary energy savings (36). The corresponding proportions for shallower energy renovations (measures achieving either 3-30% or 31-60% primary energy savings) were 4% and 1% respectively (ibid.).

Through our review we highlight examples of national investment subsidy and 'one stop shop' schemes, aiming to support the customer retrofit journey and promote the use of accredited suppliers and/or products, which have led to a scaling up of interventions. In several cases these have led to 100,000s of single measure installations, although they mostly represent examples of shallow retrofit rather than deeper or whole house energy renovation. In France, the MaPrimeRénov' national 'one stop shop' scheme provided grants for at least one million homes from 2020-2023, mostly to low-income households. Only around 10% of dwellings which received funding under MaPrimeRénov' carried out multiple measure installations or deeper renovations (97). In the US there were 3.4 million claims for the Energy Efficient Home Improvement Credit (EEHIC) and/or the Residential Clean Energy Credit (RCEC) in 2023. Of these, 163,000 owner-occupiers claimed both tax credits, indicating instances where two of more measures were installed. The latter group were more likely to be high-income taxpayers earning $500,000 or more (8,9).

The extent to which national energy retrofit schemes have supported thermal energy efficiency upgrades or low carbon heat supply varies. Approaches in France, Germany and Canada have been dominated by low carbon heating installations rather than building fabric improvements. Of the 670,000 home energy renovations supported by MaPrimeRénov' in 2022 almost half were for air source heat pumps or biomass pellet stoves. In Germany, the Kreditanstalt fuer Wiederaufbau (KfW) bank loan/grant scheme from 2005-2017 led to measures being retrofitted in 2,870,000 dwellings. Of the 275,000 homes renovated in 2017, 35% were for thermal insulation measures, and 69% heating replacement. The Canadian Greener Homes Grant funded energy renovations in 338,900 households over the last five years, with 60% of these being for heat pumps. Other retrofits supported included window and door interventions, insulation, air sealing and solar PV. These examples contrast with the US, where in 2023 the EEHIC subsidised modifications mostly related to home insulation, windows and skylights, and energy efficient air conditioning. Nevertheless, there were approximately 450,000 claims for heat pump installations under the EEHIC or RCEC (8–10). In Ireland, less than 14,000 of 419,500 measures installed over the last decade under the National Home Retrofit Programmes have been for heat pumps (11).

The Netherlands introduced a National Insulation Programme in 2022, initially committed €4 billion and set a target to insulate 2.5 million homes, focusing on the least energy efficient 1.5 million dwellings. This programme is still in the process of being rolled out, and includes the distribution of substantial funding to municipalities (20).

In New Zealand, successive Warm Up New Zealand (WUNZ) programmes have made grants and loans available to homeowners and landlords to install insulation and low carbon heating. As of 2021, at least 365,000 insulation upgrades and 60,000 heating retrofits had been installed through the various programmes since 2009. After 2013, installations were targeted at low-income households. However, WUNZ: Heat Smart provided specific support for general income owner-occupiers from 2009 to 2013 – the government funded 33% of their total insulation costs (up to a $1,300 cap), compared to 60% for low-income homeowners and landlords.

Table 3: Recent and ongoing national retrofit policy programmes and impact on owner-occupied households: international examples from the OECD

Country and sources	Policy name(s) and timescale	Policy description	Outcomes
France (97,98)	MaPrimeRénov' 2020 – (ongoing)	National 'one stop shop' supporting the customer retrofit journey and offering grants to private homeowners varying by four household income levels (very low to high income). The 'one stop shop' provides a directory for customers to search for local certified installers.	One million (mostly low-income) households received funding 2020 – February 2023 (70% heating, 21% insulation).
Germany (99–102)	Federal Promotional Support for Energy Efficiency in Buildings 2005 – (ongoing)	National energy efficient refurbishment programme providing grants or loans from the government-owned KfW bank for renovations which meet 'KfW efficiency house' standards for primary energy demand and transmission heat loss.	At least 6 million homes were subsidised through the scheme up to 2022. 2005-2017: 2,870,000 dwellings refurbished in total.
Ireland (103,104)	National Home Retrofit Programmes[2] 2015 - (ongoing)	National 'one stop shop' service, energy upgrade grants and loans for	419,500 energy upgrade measures installed[2]; 265,800 properties upgraded.

[2] Includes: Better Energy Homes Scheme, Community Energy Grants Scheme, National Home Energy Upgrade Scheme, Solar PV Scheme and Warmer Homes Scheme. Numbers shown for measures installed do not include the Warmer Homes Scheme (103).

		homeowners, private landlords and approved housing bodies.	
Italy (105)	Superbonus 2020 – (ongoing)	Tax credit scheme which covered 110% (reduced to 50% in 2025) of expenses for homeowners to undertake renovations for energy efficiency, housing quality and comfort, and seismic safety.	Renovation works completed in at least 470,000 buildings from Q3 2021 to Q1 2024[3]
Netherlands (20,106)	National Insulation Programme (NIP) 2022 – (ongoing)	National funding programme with a target to insulate 2.5 million of the least energy efficient homes by 2030.	In 2023 and 2024, the national government made €1 billion available for municipalities to renovate the least energy efficient homes (energy labels E, F and G).
Canada (97,107,108)	Greener Homes Initiative Greener Homes Grant (2020-2024) Greener Homes Loan (2022 - ongoing)	Grants and loans for homeowners via a federal programme (Greener Homes Initiative) supporting the retrofit customer journey and supply chain development.	338,900 households received a grant and completed retrofits. 6 in 10 homeowners installed a heat pump. 53,000 Greener Homes Loans ($24,000 on average) approved from June 2022 to January 2024.
US (8–10,109–112)	Better Buildings Neighborhood Program 2010 - 2014	U.S. Department of Energy (DOE) administered programme for whole building energy upgrades. which distributed $508 million in total to state and local governments via 41 grantee organisations.	Grantees reported 99,000 energy efficient upgrades in residential and commercial buildings from 2010-2013 (119,400 to 2014 unverified by USDOE, 2015). Around 95% of these were in residential buildings (including multifamily).
	Inflation Reduction Act: Energy Efficient Home Improvement	EEHIC: Tax credit for owner-occupiers up to $3,200 per year for	2023 uptake: EEHIC had 2.3 million claimants, almost 1.4

[3] Includes only Eco-Superbonus, and therefore is estimated to represent only 65% of all related schemes (105).

	Credit (EEHIC); Residential Clean Energy Credit (RCEC) EEHIC: 2023 – 2025 RCEC: 2022 - 2025 (Both tax credits to be discontinued from 2026 following provisions in the One Big Beautiful Bill Act)	home energy efficiency and low carbon heating installations. RCEC: Tax credit for owner-occupiers to install renewable energy or battery storage, covering 30% of expenses.	million for home insulation, windows and skylights; and 488,000 for efficient air conditioners. RCEC claimed by 1.2 million taxpayers, 752,000 for rooftop solar PV.
New Zealand (83,113)	Warm Up New Zealand (WUNZ) WUNZ: Heat Smart: 2009 – 2013 (general income). WUNZ Healthy Homes: 2013 - 2018 (low-income). Warmer Kiwi Homes: 2018-ongoing) (low-income).	Grants and soft loans for insulation and low carbon heating available to homeowners and landlords.	At least 365,000 insulation upgrades and 60,000 heating retrofits have been installed through the various programmes since 2009 (as of 2021).

3.2 Building Energy Retrofit Policy Frameworks: Policy Instruments and Packages

Our review identified various assessments of policy instruments which have been applied internationally and/or are considered important for implementing residential energy renovation. These are summarised in Table 4, including the international coverage of each source. One caveat to note is that there is overlap between different instrument categories and they are not mutually exclusive. Policy instruments most commonly emphasised are regulations, financial support and information provision, and these are the foundation of the International Energy Agency's energy efficiency policy toolkit (39). Most reviews also include policies to develop required workforce skills and competencies, supply chains and quality assurance. Research, development and demonstration (RD&D) and innovation is also widely included in these reviews, however, there is less detail on what effective policy approaches have been or should be in this area. Voluntary agreements and actions are mentioned in several reviews, although there is some uncertainty over what the role of these should be compared to, for example, regulations or mandatory instruments.

Table 4: Policy categories considered in identified reviews on building energy renovation policies

Author(s)	Geographical coverage and/or countries included	Regulations	Financing and subsidies	Information policies and advice	Voluntary agreements and action	Skills, supply chains and quality assurance	RD&D and innovation
Bertoldi et al. (114)[4]	EU		X				
Björklund, von Malmborg and Nordensvärd (115)	EU	X	X	X	X	X	X
Brocklehurst et al. (61)	Europe, Australia, Canada, US	X	X	X		X	X
CCC (83)	Europe, Canada, US, New Zealand, Japan	X	X	X		X	
Economidou et al.(116)	EU	X	X	X	X	X	X
Camarasa (117); IEA (39,118)	International	X	X	X		X	X
Kerr and Winskel (12)	Europe and North America, including Denmark, France, Italy, US	X	X	X	X	X	X
Rosenow, Kern and Rogge (38)	14 EU Member States	X	X	X	X	X	
Sebi et al. (119)	France, Germany and US	X	X	X		X	X
Zhang et al. (120)	US, Canada, Germany, France, UK, Spain, China, Singapore, Japan, Australia, and New Zealand	X	X	X			X

3.2.1 The role of regulation

Relevant regulatory approaches relevant to HER include: building energy efficiency targets (e.g. renovation rates) to support long-term market growth and investment, building energy codes that should be updated frequently for new and existing

[4] Bertoldi, Economidou, et al. (114) review exclusively financial instruments.

buildings, minimum energy performance standards (MEPs) for existing buildings, and energy efficiency and labelling regulations for appliances and lighting (39,83).

Energy efficiency standards and labels for appliances and equipment have been effective in reducing energy consumption in countries with longstanding programmes, such as in the US and in EU (121). EU Ecodesign and Energy Labelling Directives have led to considerable energy and carbon savings, and other co-benefits (122). The UK's Market Transformation Programme implementing MEPs and energy labelling in products such as TVs and lighting, and 2005 regulations requiring the introduction of condensing boilers, have previously been highlighted as good practice examples of product energy efficiency regulation supported by policy certainty and industry buy-in (83).

Building energy codes have been implemented in around 80 countries, including the UK (117). In Germany, for example, the Energy Efficiency Ordinance (EnEV) was launched in 2001 to set regulatory maximum limits on primary energy use from new and existing buildings. The UK's Energy Performance Certificates (EPCs) were developed in response to the EU Energy Performance of Buildings Directive (EPBD), which first came into force in 2003 (7). Building codes offer a comparative policy tool, and if audited, potential inaccuracies can be understood and ideally addressed. UK homeowners or landlords are required to show EPCs displaying modelled energy performance at the point of property sale or rental (7), but the metrics used have been described as opaque and bearing poor relation with actual energy consumption (NRH, 2024). For example, Hardy and Glew (123) found that approximately 27% of EPCs in the open record exhibited at least one flag indicating potential inaccuracies with discrepancies often stemming from assessors differing in their evaluations of building parameters. Glew et al. (124) observed that replacing default values used in EPCs with measured values for airtightness, thermal conductivity and heat loss can help to reduce such inaccuracies. A Domestic Operational Rating (DOR) based on actual energy data could complement the Standard Assessment Procedure (SAP) generating EPCs (125).

In the EU, the Energy Performance of Buildings Directive (EPBD, recently revised) sets out that member countries should establish national targets to reduce energy consumption in residential buildings. EU countries are also required to develop Building Renovation Plans for achieving a zero emission building stock by 2050 (126).

EU regulations also support quality assurance initiatives and 'one stop shops' respectively, relevant to sections below. Under the EU Energy Efficiency Directive (EED), Member States should develop certification schemes and/or equivalent qualifications for energy efficiency workers (127). The EPBD also requires the creation of at least one 'one stop shop' for every 80,000 inhabitants, for each region, or in areas where the building stock age is above the national average (126) (and the latter is more likely to be a characteristic of private owner-occupier households).

Following Brexit, the UK is not required to update equivalent legislation in line with EU regulations, but doing so could help to avoid adverse consequences, such as the dumping of less energy-efficient products in the UK (122). The Product Regulation and Metrology Act 2025 includes powers for the UK government to implement similar or

corresponding regulations as the EU to ensure the efficient operation of products and reduce or limit the environmental impact of product use and marketing (128).

3.2.2 Financial instruments and subsidies

A cost comparison of modelled building energy renovations across six European countries suggests that retrofits are most cost-effective for buildings which have yet to be renovated, and more cost-effective for shallow retrofit where the aim is to achieve less than 60% heat savings compared to deep renovations targeting higher savings (129). Given that building energy retrofits may not always pay for themselves but can bring societal and environmental benefits, several policy interventions can be utilised to increase uptake of energy efficiency measures (130). Previous international reviews of retrofit policies highlight some key features of successful financial incentives. Kerr and Winskel (12) emphasise the importance of simple application processes for homeowners to access subsidies.

Bertoldi, Economidou, et al. (114) review various financial instruments for residential building energy retrofit across the EU (see also Table 5). These span well-established instruments such as grants, loans and tax incentives, 'tested and growing' instruments including energy efficiency obligations through to more innovative tools such as crowdfunding, energy efficient mortgages and property assessed clean energy (PACE) financing, and we discuss the latter further below in relation to the US and Europe. Which financial support is appropriate varies geographically and by occupancy type – energy efficiency mortgages and preferential loans (offering favourable interest rates and long repayment periods) may be more suitable for homeowners with good credit; grants and subsidies may be better suited for lower income households or rented homes (ibid.). Bertoldi, Economidou, et al. (114) conclude that there is "*no silver bullet*" for financing building energy efficiency due to the complex nature of the sector and supply chain. In commenting on their review, Galvin (130) observes that for all financial instruments considered, "*it is assumed that the upgrade will pay back on its own merit within a relatively short time so that, after the investor has got their return, the homeowner can then enjoy the financial benefits of the upgrade for the remaining years (or decades) of its technical lifetime."* In practice however, various financial incentives have been unsuccessful due to anticipated energy savings being overestimated, and now face additional challenges in their implementation including higher construction costs, interest rates and energy prices (114,130).

Financial instruments can also be linked effectively with other policy instruments, such as quality assurance (115). Since 2005, the Kreditanstalt fuer Wiederaufbau (KfW) state investment bank in Germany has financed grants and low interest loans for building owners to carry out refurbishment or construction which meets KfW energy efficiency standard criteria. This criteria effectively assumes that more expensive, high energy efficiency renovations which exceed the EH140 standard (approximately 70 kWh/m^2/year) do not pay back and therefore require subsidies (130).

Energy efficiency obligations place targets on energy suppliers to deliver energy or carbon saving improvements to buildings. They have been used in various European

countries (114) and have tended to promote cheaper energy efficiency measures, since energy suppliers are incentivised to install the lowest cost upgrades that can help to achieve relevant targets (83). The UK was the first country in Europe to introduce an energy efficiency obligation on suppliers in 1994, and has implemented a series of successive obligations, leading to CERT, CESP and ECO. While ECO has focused on more low-income or fuel-poor households, energy efficiency obligations may be more regressive for these households since they recover costs via energy bills. Alternatively, therefore, such obligations may be better targeted at part-funding higher-income households which can contribute to the up-front costs of energy renovation measures (ibid.).

Along similar lines to energy supplier obligations, the UK government introduced the clean heat market mechanism in April 2025, which requires gas and oil boiler manufacturers to meet minimum quotas for selling heat pumps as a rising proportion of all their boiler sales, set initially at 6% for 2025/2026 (81).

Table 5: Types and market maturity of financial instruments supporting building energy renovation in the EU[5]

	Traditional and well established	Tested and growing	New and innovative
Non-repayable rewards	Grants and subsidies Tax incentives	Energy efficiency obligations	Energy efficiency feed-in tariffs
Debt financing	Soft loans Leasing	Energy performance contracts Energy service agreements Revolving funds Commercial loans	Energy-efficient mortgages Crowdfunding Property Assessed Clean Energy On-bill finance
Equity financing	N/A	Energy performance contracts Energy service agreements	Crowdfunding

In the US, PACE (Property Assessed Clean Energy, 2007-, mainly California, also Florida, Missouri) is a financial incentive scheme where local authorities fund energy

[5] Table 5 source: Bertoldi, Economidou, et al. (114), as modified by Björklund, von Malmborg and Nordensvärd (115).

renovations, homeowners repay over 10-20 years via secured debts paid as property tax additions (131). Data from PACENation (132) indicates that 371,000 homes were upgraded through US PACE from 2015 to 2023, reflecting over $9 billion of investment across mainly energy efficiency, renewable energy, and resilience related renovations. EuroPACE was modelled on US PACE and was implemented from 2018 to 2021. The scheme was piloted in Olot, Spain and adopted in the Basque Country. A successor project was developed in the Balearic Islands and has inspired various EU 'replicator' projects (133).

Brown, Sorrell and Kivimaa (131) analyse retrofit financing mechanisms in the EU and US. They observe that access to low-cost finance is key for deeper, whole-house retrofit (e.g., solid wall insulation). Financing mechanisms can be effective where they also support general property improvement works or wider sources of value, e.g., thermal comfort. It is suggested that UK homeowners could benefit from financial incentives which provide access to low-cost institutional capital such as PACE, or public co-financing schemes in the US which reduce risk for and achieve higher private investment (ibid.). National retrofit schemes can differentiate financial support based on the assumed ability to pay:

- France: MaPrimeRénov' provides investment grant funding for owner-occupiers to carry out energy efficiency renovations, with bonuses for whole building interventions (multiple measures). Financial support varies by income, building type and ownership categories. There are four groups based on household income; for multiple measures, high income groups are eligible for less public finance / higher private finance (97).

- Canada: the Greener Homes Grant, now closed, was equally available to homeowners regardless of income (97,107). The Greener Homes Loan offers $5,000-$40,000 interest free/unsecured, with an up to 10-year repayment – designed for homeowners and deeper retrofit. 53,000 Greener Homes Loans, averaging $24,000 each, were approved from June 2022 to January 2024 (108).

- Ireland: in April 2024, the Irish government launched a €500 million scheme offering unsecured, low-interest loans (from approved finance providers) ranging from €5,000 to €75,000 for homeowners to carry out deep retrofits involving one, two or several upgrades which must have received a Sustainable Energy Authority of Ireland (SEAI) grant and 'be projected to achieve a minimum 20% improvement in the energy performance (BER) of the building' (104).

Analysis carried out for the Connected Places Catapult supports the potential effectiveness of combining a blended (private/public) finance, place-based and neighbourhood (or street by street) approach to decarbonising buildings, although evidence on real world implementation would help determine whether such an approach can accelerate the pace of HER at a substantive scale (134). Given the high up-front cost of deep retrofit involving multiple interventions such as demand reduction, insulation, low carbon heat, and microgeneration, a blended finance approach could make significant use of long-term private investment (or patient

capital) and potentially reduce the government subsidy component of up-front costs from 70-80% to 35%. This involves two private investment vehicles, one to raise finance and the other to support delivery in neighbourhoods in partnership with local authorities. Long-term patient capital would be utilised to value energy savings over 30-50 years across multiple dwellings, which could help widen uptake by removing the need for individual homeowners to fund up-front costs and allowing them to benefit from lower energy bills, while institutional investors could receive an income stream from long-term service contracts linked to property utility bills (ibid.).

3.2.3 Information policies, advice and support services

Information policies can include information on building performance such as energy performance certificates and labels, public awareness campaigns, billing, metering and smart technologies showing real-time energy use (39,83). They can support or be integrated with other policies such as regulations and financial incentives, and be aimed at householders (e.g., through advice and support services) or the building workforce (e.g., via training and education). The latter is discussed in section 3.2.4.

Energy performance certificates (EPCs) are mandatory for buildings in the EU and are widely used (12,83). In their international review of policies for private household investment in energy efficiency retrofit, Kerr and Winskel (12) refer to examples of EPCs in Denmark which can be too 'general and superficial', and this suggests that EPCs may be insufficient on their own to influence consumer decisions. Kerr and Winskel contrast EPCs with energy assessments, involving face-to-face meetings between advisers and householders, but find that the use of such assessments is not clear in countries such as the Netherlands and Germany, and can lead to positive, negative or uncertain outcomes with respect to household retrofit decisions (ibid.).

There is a need for the conventional 'atomised' market model, whereby homeowners still make all major renovation decisions, to be reconsidered; navigating complexity is a fundamental barrier to retrofit uptake (135). Intermediary agencies such as 'one stop shops', local government and energy advisers can play roles in assisting homeowners through the renovation journey, and this is addressed further in Section 3.3.3 below on multi-scale governance.

Comparative case studies of retrofit policies in the UK, France, Netherlands, Germany, Italy and Sweden suggest that "*easy access to personalised consultations and advice*" can facilitate increased homeowner uptake of energy renovations (136).

With respect to owner-occupied households in the Netherlands, Ebrahimigharehbaghi et al. (137,138) find that policymakers can encourage homeowners to retrofit based on improved quality of life, cost savings and integrating energy retrofit as part of general home maintenance. Access to easier to find, reliable information and experts should be improved, and there is a need to integrate financial, information and technical support available to homeowners (ibid.). A separate study for owner-occupiers in multiple apartment buildings in China highlights the importance of providing understandable technology information to homeowners, and that

homeowners perceive expert knowledge and published materials to be relatively credible, so these should be prioritised (139).

In the US, it has been found that moderate-income, first-time buyers were more willing to participate in a weatherization programme in response to 'gain-framed' messages (energy savings) vs 'loss-framed' messages (avoiding financial losses) Chen (140). Alternatively, in the German context Galvin (130) contends that since many more substantial retrofit measures may not pay back through savings on energy costs over their lifetimes, an idea that government could promote amongst owner-occupiers is saving up a fund for building maintenance, modernisation and energy efficiency. Bertoldi, Economidou, et al. (114) observe that dedicated renovation savings accounts are compulsory for multi-apartment buildings in several central and eastern European countries, and Italy. Although typically used for maintenance in general, these accounts can also be used to fund energy efficiency improvements (ibid.).

Once products are installed, it is crucial to ensure new technologies and systems work for the householders. Evidence from multiple reviewed sources, mainly from the UK and US, found that general heating controls and programmable thermostats are difficult to use and this can have a significant impact on energy demand (141). Quality assurance is critical for all aspects of energy efficiency upgrade, and is considered in the next section.

3.2.4 Skills, supply chains and quality assurance

In Europe, North America and Australia, the housing retrofit industry remains immature and fragmented compared to the dominant repair, maintenance and improvement (RMI) industry, according to an international review of retrofit supply chains (61). Many RMI firms and customers deliver projects with little regard to climate mitigation, / low carbon energy policy or high-level targets linked to these policies (ibid.) In the EU, supply chains for building energy renovation are typically comprised of small businesses with an insufficient supply of workers who have the competencies needed to deliver high quality work (31). In the UK, over two-thirds of practitioners working in repair, maintenance and improvement are micro-enterprise businesses, with many making sufficient income using trusted products and processes without entering the energy efficiency market (142).

In order to carry out competent whole house energy retrofits, workers in relevant trades should ideally possess manual or technical skills, theoretical and interdisciplinary knowledge and the ability to apply it, and ethical conduct (29,143,144). Building trades in the UK and the EU tend to be characterised by low skills and a low demand for, and supply of, good quality training across multiple skill sets, increasing the risk of sub-optimal renovations that do not account for whole house implications (29,69,145). Given the variability of vocational education and training (VET) content across Europe, the EU Skills Registry (146) was developed to support international comparison of qualification and training schemes, as well as skills and competency profiles for different construction and building energy efficiency jobs.

Retrofit installer certification schemes are already established in various European countries, however these could be strengthened by incorporating a license to trade linked to regularly updated, minimum qualification standards (147). Existing examples of licensing to trade and minimum training requirements include those required for contractors to provide services via 'one stop shops' (69).

In several European countries, there are examples of national retrofit strategies or 'one stop shops' which include training, certification and/or quality assurance of retrofit tradespeople (97). In Germany, the KfW bank scheme provides access to householder advice via building energy specialists on a registered list. It is mandatory to consult an independent expert on this quality-assured list. Spot checks of documents, energy calculations, and on-site inspections of completed work, are carried out randomly under the scheme, to monitor compliance with minimum technical requirements and/or the KfW Efficiency House Standard (99).

The French MaPrimeRénov' scheme includes streamlined requirements for accreditation, whereby installers can use the same accreditation as for the French ECO equivalent (White Certificate), helping to reduce White Certificate and firms' administrative costs and burden (97). In Ireland, the One Stop Shop Service in the National Retrofit Plan requires retrofits to be delivered by registered private companies. Early observations described the registration process as slow and onerous, with the One Stop Shop Service launched only recently in 2022 (ibid.).

Similar policy instruments can be found in North America, where the Canadian Greener Homes Initiative offers grants and an interest-free loan for home energy evaluations and retrofits. Access to grants and loans requires pre- and post- retrofit EnerGuide evaluation by an energy adviser, and $10 million funding has been allocated to recruit and train 2,000 new energy advisers (97). In the US, retrofit advice to consumers and training and certification of retrofit contractors tends to be locally provided by some utilities, states or cities (119).

3.2.5 Voluntary agreements and action

Public policy instruments such as regulation, subsidies and information campaigns are often supported by private or voluntary initiatives in an approach referred to as 'new governance' by Bjorklund et al. (115) in their review of building energy efficiency and decarbonisation policies in the EU. In reality, various companies and other organisations have been experimenting with such voluntary approaches for several decades. These include buildings certification and classification instruments, such as BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design), which issue certificates classifying the relative performance of buildings against different sustainability criteria. This certification and classification approach has been most successful in office buildings located in city centres, and less effective in residential buildings (ibid.).

Voluntary agreements can involve an industry sector or actors within it making commitments to public authorities to reduce their energy consumption over time, develop and deliver an energy efficiency plan, or install and use particular energy

efficient appliances (38). Zhang et al. (120) observe that many countries have voluntary policy instruments for retrofitting residential buildings, and these can be more flexibly implemented, both over time and in response to stakeholder interests, compared to mandatory instruments. In Germany, the KfW Efficiency House Standard is a key component of the KfW bank scheme quality assurance, as noted in the previous section (see also Table 3). Voluntary standards for minimum energy performance in Japan include a Flat 35 mortgage scheme to encourage homebuyers to buy homes which exceed these standards (83).

Innovative financing can involve voluntary action, e.g. crowdfunding and energy efficiency mortgages (114). Voluntary action can also be manifested through grassroot initiatives such as community-led retrofit, which in the UK has facilitated household engagement and access to finance, while supporting the development of local supply chains (148). However, since this is locally or community-focused, it is unlikely in itself to lead to widespread renovation of homes without a coherent national policy programme of regulatory and financial policy support (115).

3.2.6 RD&D and innovation

Public funding for research and development (R&D) can include industry partnerships and, according to the International Energy Agency, 'is fundamental to technological innovation in energy efficiency' (118). Various governments have invested in R&D programmes for building energy retrofit, including Australia, Canada, France, Germany and the US (119,120). For example, the Better Buildings Neighbourhood Program in the US included a focus on innovative R&D to improve building energy efficiency (120).

Bjorklund et al. (115) note that there are several EU funds which can be used to finance research and innovation related to energy efficient building renovation. These include the European Regional Development Fund (ERDF) and the EU Structural Funds (ESIF), which have been used for insulation and energy performance improvements in multi-apartment buildings in Latvia, for example (115,149).

In addition to technological innovation, good-quality outcomes in HER will require a reorganisation of innovations of practice and business models across the retrofit industry (61). The fragmented nature of the housing retrofit and construction sectors in countries considered in this review, where small or micro-enterprises tend to dominate in temporary and informal networks, leads to a culture of conservatism with respect to innovation: installer companies aim typically for only modest profits, choosing known, reliable and accessible products and materials over more innovative, higher risk or low carbon options (12,61,147). There is a risk aversion in the RMI sector to new ways of deploying new, low carbon technologies and materials, with the risks that this would carry, and therefore cultural change across the industry and innovative and disruptive business models, such as Energiesprong, have been recommended to overcome this at a sufficient scale (61).

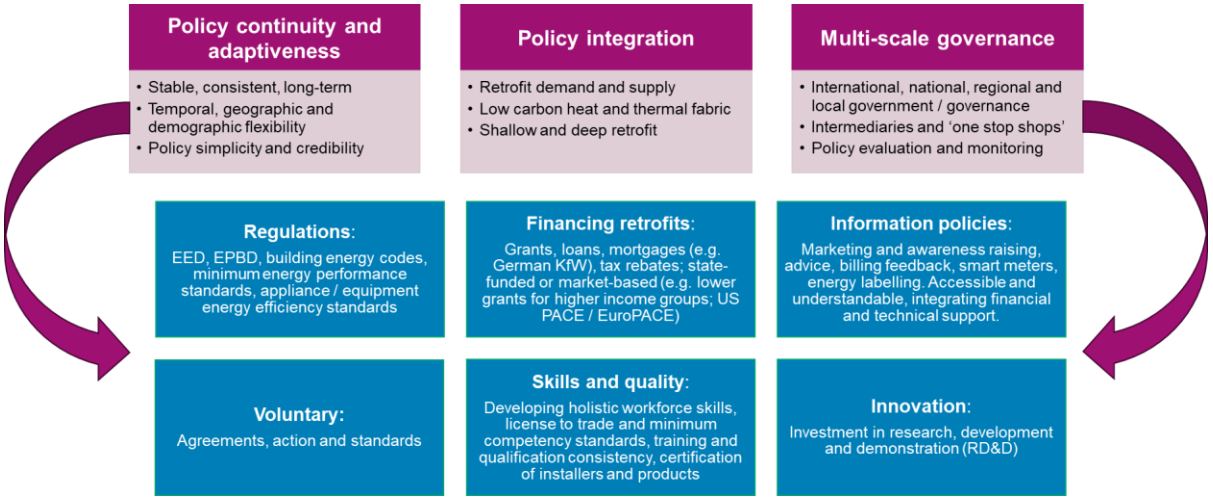
The Energiesprong business model was established by the Dutch government in 2013, and has been exported elsewhere, e.g. UK, France, Germany and North

America (135). Elements include a net zero energy performance contract, whole-life financing, an industrialised supply chain and a single customer interface. While Energiesprong promotes deeper, whole house retrofit; it may be more immediately suited to social housing in UK, given high initial costs (150).

3.3 Cross-cutting Policy Success Factors

The preceding sections have reviewed international evidence on individual policy instruments, and key features of these are synthesised in Figure 2. Additionally, there is a consensus particularly in existing reviews on HER policies, that the application of single policies alone will not be enough to achieve a transformational increase in energy renovation rates (12,14,38). Indeed the latter remain low despite the application of various policies internationally. In countries where higher volumes of HER have been achieved, such as Canada, France, Germany and Ireland, we have identified several cross-cutting success factors which include long-term policy reliability and flexibility, effective policy mixes, policy integration of different forms and multi-scale governance, including the use of intermediaries such as 'one stop shops'. These success factors are summarised in Figure 2 and discussed in the following sections.

Figure 2: Policy approaches and success factors identified in the review



3.3.1 Policy continuity and adaptiveness

Key to effective home energy retrofit policies internationally is stable, long-term policy support, helping to increase certainty for household and supply chain investment decisions (12,83). Policies should be flexible so that they can be adapted over time to account for changing circumstances, and differentiated according to different household and regional characteristics (12). For example, particular households may be more likely to respond positively to different types of support at different times, underscoring the need for comprehensive and flexible policy packages (38).

In Germany, since the early to late 2000s consistent support has been provided from a combination of measures including the Energy Saving Ordinance (EnEV), Renewable Heat Law (EEWarmeG), Market Incentive Programme for renewable heat, and KfW grants and loans (151). The federal Government published a Long-Term Renovation Strategy in 2020, alongside many other European countries as required under the EU Energy Performance of Buildings Directive (152).

The French MaPrimeRénov' has no formal end date, and is expected to continue for 10 years according to EST and Green Alliance (97), with its budget is renewed annually. In 2025 the scheme has been paused over the summer until September, to address tens of thousands of suspect fraudulent claims and backlogs (153). Around one million households were funded by the scheme from 2020 to 2023 (70% heating systems; 21% insulation; 4% ventilation) (97).

HER policies should be adaptive enough to account for the risk that individual policy instruments might interfere with each other and reduce their efficacy (12). Conversely, there are opportunities for policies to be applied together to achieve more impact, for example information measures and standards can help to increase the success of other policies (13). These last points also relate to policy mixes, discussed in the next section.

3.3.2 Policy mix and integration

The concept of a 'policy mix' has various definitions and can refer to sets of government policies which have innovation impacts, and can be characterised by a complex policy landscape with multiple policy objectives, evolving incrementally over many years (16). A body of academic literature underlines the importance of policy mixes for energy system decarbonisation, which can relate to how different policy instruments interact in specific energy sectors such as energy efficiency (13) or renewable electricity (154), as well as more widely across different energy sectors (38). Rogge & Reichardt (15) recommend that an effective policy mix for sustainability transitions should include policy objectives, strategies and instruments which have the following characteristics: consistency, credibility, coherence and comprehensiveness. Consistency can refer to how well different policy instruments are aligned so as to avoid interference between them and help to achieve policy objectives. Coherency can be characterised by the extent to which policy making is synergistic across different policy areas, governance levels and public sector organisations, while also being systematic in assembling diverse sources of information from multiple, relevant stakeholders. In practice it may not be possible to achieve perfect consistency and coherency for a variety of reasons, but maximising these characteristics can help to increase the effectiveness and efficiency of a policy mix.

Policies should also be credible, or in other words believable and reliable, which can be supported by political commitment to an instrument mix which is consistent over time, helping to achieve policy targets. Furthermore, a policy mix should be comprehensive in comprising an overall strategy, objectives and policy instruments which put these into action. As such, instruments within the mix should

comprehensively address technology-push, demand-pull and more systemic level purposes (ibid.).

Measuring the real-world implementation of such concepts is not straightforward; Wade et al. (16) set out to do so for policies related to local energy systems in England, Scotland and Wales. Their findings are considered in section 4.5. To evaluate policy credibility, the authors analyse the duration of policy instruments, long-term policy target-setting, delivery organisations and available budget information. For comprehensiveness, they assess the balance of a policy mix by quantifying how policy instruments are dispersed across different policy types. Their study further evaluates the extent to which policies have 'technology specificity' or not, i.e., do they focus on specific technologies, or are they aimed at a wider energy sector or the broader economy. Higher technology specificity may help to encourage diffusion of novel technologies, in comparison to more widely directed policies which may be more suitable for supporting innovation in mature technologies (ibid.).

For energy efficiency specifically, Rosenow et al. (38) contend that effective policy mixes should support both "*low-cost and simple energy efficiency measures as well as high-cost and complex options*". The authors analysed policy instruments used to comply with the Energy Efficiency Directive across 14 EU countries, finding that the most commonly used were, in order of frequency: grants, regulations, loans and energy efficiency obligations. Notably, policymakers in these countries applied a wide range of policy instruments, rather than single instruments or specific sequences of policies (ibid.). This contrasts with earlier literature which identifies that financial incentives followed by voluntary and then mandatory standards was an effective sequence supporting the deployment of condensing boilers in the UK (17). Such an approach is common for new technologies, but may be more challenging with respect to building fabric. Voluntary standards can be increased upon the introduction of compulsory standards to stimulate further innovation. Regulations may increase technical standards, but may also create a need for extra training and accreditation in supply chains, and therefore appropriate skills development policies should also be in place (12,17).

An econometric analysis of 23 OECD countries from 1990-2010 suggests that a comprehensive mix of policy instruments, well balanced between demand-pull and technology-push purposes, can enhance energy efficiency innovation activities in the residential sector, subject to a threshold above which increasing the number of instruments may indiscriminately lead to conflicts between them and reduce overall policy mix effectiveness (14).

Effective home energy renovation policy requires a holistic approach integrated across consumer demand and retrofit supply side (12).This is a key point reinforced through our review, since demand-side polices focused only on encouraging owner-occupiers to retrofit will not be sufficient without quality-assurance initiatives which help to expand the competent workforce and raise consumer trust. Kerr & Winskel (12) also highlighted that there has been insufficient policy attention on the workforce and supply-side in building energy retrofit policy, although this has been considered in more detail by Brocklehurst et al. (61) in their review of international supply chains,

and by Camacho McCluskey et al. (32) as a case study on UK building retrofit jobs and skills needs for net zero.

International evidence underlines the importance of accessible and integrated policy support. For example, in France, the Sobriété Énergétique is a policy package including MaPrimeRénov' and a communications campaign to encourage individuals to reduce energy demand and bills (97). In Germany, the Funding for Efficient Buildings Scheme packages together separate investment funding into one customer offering to increase user friendliness, including the CO_2 Building Modernisation Programme and Market Incentive Programme (136).

A feature of several of the national 'one stop shop' schemes identified in our review, and as reflected in section 3.1, is the integration of policy support for different types of technologies and interventions, including thermal fabric improvements, low carbon heating (including heat pumps) and microgeneration (solar PV in particular). The uptake of such interventions via national 'one stop shops' have tended to be dominated by single measures or shallow renovations. However, in some cases these schemes offer extra incentives for deeper renovations, including low interest loan support particularly targeted at 'able to pay' owner-occupiers, in addition to investment grants typically offered to a wider range of household types and incomes.

In deciding which mix of policy instruments to develop in a given country, policymakers should consider the purpose, strengths and weaknesses of instruments already in place and policy gaps, i.e., are particularly types of instruments under-utilised? For example, it may be more time efficient to strengthen existing regulation rather than create entirely new legislation (39). Particular types and combinations of policies may be required to achieve deeper, more extensive renovation in contrast to shallow retrofit. For deep retrofit of detached houses in Denmark and Sweden, Mainali et al. (155) suggest that various options could help to address financial barriers experienced by consumers: soft loans from banks; 'one stop shops' offering financial support; mortgage refinancing; property taxes related to building energy performance; and promoting renovation carried out in stages to spread costs over time. In addition to demand-side polices, supplier focused instruments such as skills and training development, quality standards and installer certification are key to managing risks of poor quality, deep renovation (ibid.).

3.3.3 Multi-scale governance: international, national, and local

In Section 3.2.1., we discussed EU-level governance of member states with respect to regulations, specifically the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED), and the changing relationship of the UK with respect to these. This section considers what Rogge & Reichardt (15) refer to as the vertical governance dimension in their analysis of policy mixes. Vertical governance distinguishes between international (e.g. OECD or the EU), national, regional (federal) and local levels.

At least 40 international institutions have been identified as active in the area of building energy efficiency, however there is no formal international agreement on global buildings decarbonisation or efficiency targets, or a dedicated institution coordinating relevant knowledge and activity. The International Energy Agency (IEA) is the main reference point for relevant data, analysis and policy recommendations (156). Despite the localised nature of the buildings energy sector in terms of geography, climate and supply chains, more coherent international governance could help to strengthen national building renovation strategies and policies, particularly where country-level political commitment is low and policies unambitious (ibid.).

The IEA (39,118) recommend that effective energy efficiency policy making requires the development of clear targets and strategies, building capacity and resources to implement policies, and continuous monitoring and evaluation of progress, including relevant and appropriate data collection (e.g., on energy consumption) to support this.

In the process of carrying out our review, we have observed the following on monitoring and evaluation. There is poor availability of data to track progress in HER in different countries and compare relative progress internationally for specific measures and more comprehensive renovations alike (e.g., the latest renovation rates data for the EU which is cited frequently is 2012-2016 (36)). But there is also a paucity and inconsistency of monitoring data and metrics within countries, linking progress tracking at local, regional and national levels.

Given variable definitions of building energy retrofit and renovation, and that buildings decarbonisation is likely to require at least some degree of deeper retrofit (see Section 4.1 below), there is a need for international consensus across policy, academic and practitioner communities on what policy success looks like and how it should be monitored. This points to a possible role for a dedicated international monitoring observatory specialised in buildings energy efficiency and decarbonisation, with wider international coverage than currently provided by the IEA or Buildings Performance Institute Europe. It is equally important to develop capacity to monitor HER progress nationally, regionally and locally, as well as through tools to compare policy effectiveness internationally. But a key challenge is how to ensure comparability and compatibility of monitoring data produced in different countries and contexts.

We have discussed individual policy instruments in Section 3.2, particularly at national scale. The remainder of the present section considers examples of coordination between national and local-level governance in different countries. Sebi et al. (119) note that most building energy retrofit policies in the US have taken place at state and local levels, providing a contrast with the national government-led approach of countries such as France and Germany. The Home Performance with Energy Star programme is led by states, utilities and cities in collaboration with the US Department of Energy and US Environmental Protection Agency (119,157). It includes around 40 local programmes and a network of 1,500 home improvement contractors. The first recommended step for interested householders is a ‘home performance assessment’ with an Energy Star ‘home energy expert’ as part of a stated whole house approach. Participating contractors sign a participation agreement with a local programme sponsor, are required to follow their protocols and report and track activity (158).

Therefore local requirements can vary, although most programmes include training and certification for contractors and quality inspections. At least 600,000 homes were retrofitted through the scheme from 2002-2017, with average project savings reported as around 20%-30% of total household energy consumption (119).

Local government can provide access to information, technical assistance and national or local financial support for energy retrofit. The level of such support can vary widely depending on each local authority's capacity, as has been observed in the Netherlands (138). In Great Britain, local authorities can play a central role in identifying low-income or fuel-poor households for retrofit which would otherwise not be eligible for standard support under the ECO scheme, through the ECO4 Flex mechanism (159).

Over the next few years, the Dutch National Insulation Programme will include funding for municipalities to insulate 750,000 homes in districts due to a transition to natural gas-free heating (20). This decentralised funding arrangement bears similarity to the US Better Buildings Neighborhood Program (BBNP), which was active from 2010 to 2014, in which the US Department of Energy (DOE) distributed a total of $508 million to state and local governments via 41 grantee organisations to finance building energy retrofits. Grantees reported that around 120,000 energy efficient upgrade measures were installed across 34 states and one territory, in mostly residential buildings. The most commonly installed measures were heating and/or cooling systems, insulation, and air sealing (111). As part of the Better Buildings Neighborhood Program, a coalition of partners in Michigan offering low interest loans ($1000 -$20,000 for 10 years) found that more expensive packages of measures including air and duct sealing attracted higher participation rates from eligible homes, compared to a basic package comprising a diagnostic energy assessment and cheap, direct install items (160). However, participation varied by neighbourhood, depending on household income levels and community cohesion, as well being mediated by the variations in outreach strategies employed by programme staff (ibid.).

Intermediaries could help to bridge the gap between national government and millions of private homes, since third parties are often involved in consumer decisions to retrofit (161). These third parties may include installers, craftspeople, construction firms, architects, energy advisers but there may be issues with consumer trust (161,162). Moreover, to effectively support HER, intermediaries such as craftspeople need to be convinced that renovation measures are useful, and there is some evidence that where personal opinions of intermediaries are opposed to specific low carbon heating or energy efficient interventions, this may serve to constrain their diffusion (161).

A prominent example of an intermediary is a 'one stop shop', an innovative service model to guide customers through the renovation journey, integrate retrofit demand and supply, and overcome market fragmentation. In general, a 'one stop shop' has been defined as *'a physical or virtual place where customers obtain multiple products and services at one single point'* (163). 'One stop shops' can fulfil or integrate various functions, including providing homeowners with access to finance, quality-assurance and training of contractors, performance monitoring and maintenance. Bertoldi, Boza-Kiss, et al. (18) evaluate 63 'one stop shops' in 22 EU countries and their role in

homeowner energy retrofit decisions. These include 24 national, 19 regional, 13 city and 6 city/regional scale 'one stop shops', some targeting owners in individual houses, others homeowner associations for multi-apartment buildings. They can be funded by different sources, including government, industry, or a combination of public and private sector organisations. Locally, they have in some cases been set up and operated directly by municipalities. Bertoldi, Boza-Kiss, et al. (18) estimate that there are around 100,000 'one stop shop' projects per year in the EU.

Pardalis et al. (164) contrast publicly and privately led 'one stop shop' business models for residential building renovation, based on an analysis of ten 'one stop shops' which operate in one of six countries: France, the Netherlands, Ireland, Spain, Sweden or the UK. Their findings, although based on a limited sample, suggest that public 'one stop shops' tend to be supported by trusted organisations, can provide access to various forms of financing and be proactive in raising householder awareness of energy efficiency benefits and communicating advice, although since they rely on public funding, their business model could be at risk where state funding is discontinued. Private sector led 'one stop shops' typically need to be more proactive in attracting and developing a trust relationship with households, and are more dependent on income from a sufficient number of customers to make profit. While they do not provide access to public financing, there could be some potential in private 'one stop shops' partnering with banks to offer low interest loans for HER; this would require securing enough customers who would be willing and eligible to take up such loans.

Three specific 'one stop shop' archetype business models are defined by Bagaini et al. (163): Facilitation, Coordination and Development. This draws upon the authors' categorisation of 29 'one stop shops' in the EU. Facilitation 'one stop shops' offer homeowners and other market participants a single point of advice and information (e.g., technical and financial) for HER. This archetype offers the lightest form of support of the three and tends to be led by public organisations, and its main focus is addressing information barriers to retrofit. Coordination 'one stop shops' are public-private partnerships which provide support across the renovation journey for both homeowners and the retrofit industry, which can include contractors, suppliers, banks and certification bodies. The Coordination model evidences the most integration of different types of stakeholders, and could be helpful for addressing market fragmentation, a persistent challenge with HER. The third Development business model archetype is private company-led and was identified for the lowest number of 'one stop shops' (6 of 29). However, it is described as providing the fullest support for homeowners at any point of their HER journey, since the 'one stop shop' "*acts as a general contractor, guaranteeing quality of work execution and achievement of estimated energy savings even when sub-contractors are involved*". Through this business model, a 'one stop shop' can directly finance the up-front cost of renovations, paid back by consumers through mechanisms such as a service fee, energy performance contracting, on bill finance or loan interest. According to the authors, Development 'one stop shops' are best placed among the three archetypes to support deep renovation tailored to consumer needs (ibid.).

A very recent comparison of 37 'one stop shop' business models for HER operating in the EU contends that the success of 'one stop shops', which is a requirement in EU

renovation policies underpinned by the EPBD, requires enhanced customer-focused communication strategies and more rigorous competitor analysis to distinguish their individual value propositions to consumers (165).

There is a role for national and local government to promote effective intermediaries, which is achievable if government and intermediary goals are reasonably aligned. In Norway, a government programme for whole-house retrofit in private dwellings (2012-2016) was not effective in part due to conflicting objectives between government and craftspeople acting as intermediaries (162).

The French MaPrimeRénov' national 'one-stop shop' scheme supports the customer journey through: upfront quotes, energy audits, local certified installer directory, free consultation with advisors, access to a renovation guide and an online customer account (97).

4. Applying International Experience and Good Practices to the UK

4.1 Balance Between Shallow and Deep Energy Renovation

Recent analyses advocate moving beyond a 'fabric first' approach where building fabric improvements such as insulation are prioritised over low carbon heating and renewable energy systems installed in buildings (45). Instead, Eyre et al. (166) and Nesta (167) argue that insulating every home to a high standard would not be cost effective or feasible for rapid decarbonisation of the housing stock. In this new approach, it is contended that in many homes, heat pumps or other zero carbon heating will be enough to decarbonise heating without needing to improve their thermal fabric. Building fabric improvements still have an important role but may only be typically needed in 30%-50% of national building stocks (166). They should be prioritised in new buildings, in retrofits where low-cost measures are possible, and where they can bring other co-benefits such as better comfort and health, reducing heat pump running costs and lessening electricity demand from the grid (ibid.).

Similarly, Galvin (168) presents a cost-benefit analysis of 44 deep renovation scenarios for the German building stock based on current construction, finance and energy costs, finding that no scenario is economically viable, with an average 25-year payback of 22%. The cost of decarbonisation through deep renovation of buildings was also found to be significantly higher than transitioning to a low carbon electricity grid using wind power or solar photovoltaics. Galvin therefore emphasises that policymakers should be more receptive to evidence demonstrating that deep building energy retrofit may not pay back within reasonable timescales. This may mean focusing on heat decarbonisation, e.g., through a shift to heat pumps, and redirecting

subsidies towards more basic rather than very highly energy-efficient renovations (130,168).

In the UK, Glew et al. (124) monitored 41 fabric retrofits installed in 14 solid walled homes as part of the Demonstration of Energy Efficiency Potential (DEEP) project, finding that combining draught proofing, different types of insulation (loft, ground floor and solid wall), and new windows and doors could lower whole-house heat losses by as much as 60%. Solid wall insulation could contribute to much of this reduction, but at an up-front cost ranging from £4,000 to £44,000, is the most expensive retrofit measure. It would take many decades for most of the retrofit measures to pay back, while additional costs arose due to the need to prepare for renovation work or make building repairs. More thorough surveys prior to installation, including air tightness testing, identifying the condition and risks of previous retrofits, could help to mitigate some challenges experienced in delivering whole house renovations (ibid.).

4.2 UK and International Owner-occupier Housing Stocks

In reviewing policy experiences in OECD countries, questions arise as to the extent to which the building stock for (medium- to high-income) owner-occupiers varies between the UK and other countries, and how translatable separate national experiences might be in cases where building archetypes are significantly different. It is challenging to address these questions due to a lack of sufficiently granular data, however, we have extracted available information from formal statistics and other relevant documents to make the following observations.

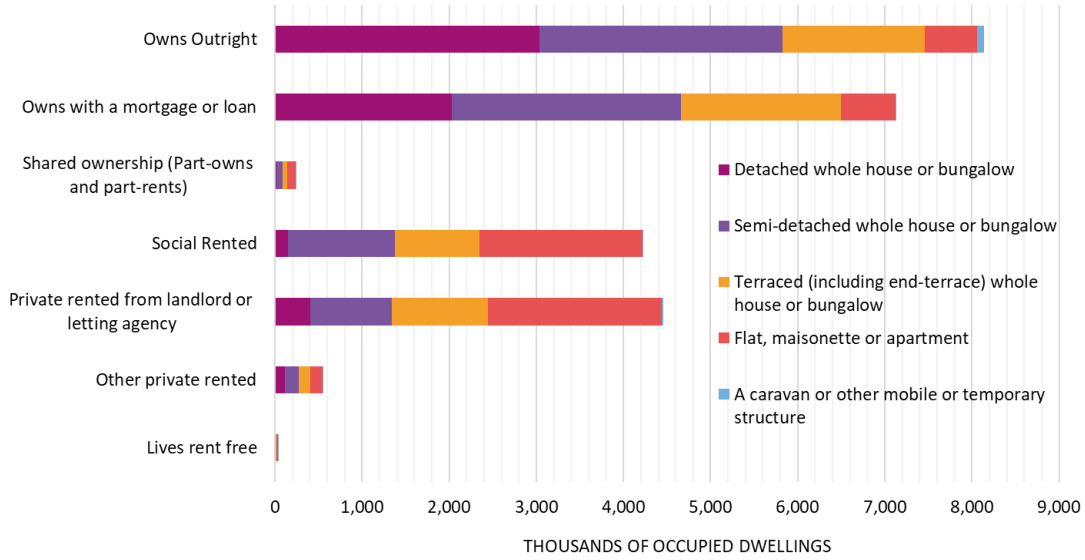
63% of households are owner-occupied in England, Wales and Scotland in 2021/2 according to the most recent Census data (see Figures 2 and 3). This equates to 15.5 million homes in England and Wales and 1.6 million in Scotland, with slightly over half owned outright and around 45% owned with a mortgage or loan. Most owner-occupied homes (10.5 million homes) in England and Wales are detached or semi-detached properties, with a further 3.5 million being terraced housing. Scotland has almost 1.2 million detached or semi-detached homes, but the dominant accommodation type is actually tenements or blocks of flats (800,000), particularly in urban areas (25). By comparison, 69% of residents living in households owned their homes in the EU in 2023 (21), which is similar to the share of homeowner households in Canada (70%) and the US (65%), according to recent data from the OECD (22). Within Europe, Germany is notable for having the lowest rate of home ownership at 48% of residents which is exceeded by the share of tenants at 52% (21).

In some European countries, such as Germany and Spain, most residents live in flats rather than houses (61% and 66% of their respective national populations in 2023), however houses are more common than flats in two-thirds of EU member states: 52% of the EU population lived in a house compared to 48% living in flats in 2023 (21). The share of population residing in a house is notably high in Ireland (90%), the Netherlands (79%), and almost two-thirds in France (ibid.). These countries are similar

in this respect to England and Wales, where 78% of households lived in a house or bungalow in 2021, compared to 22% that lived in a flat, maisonette or apartment (40).

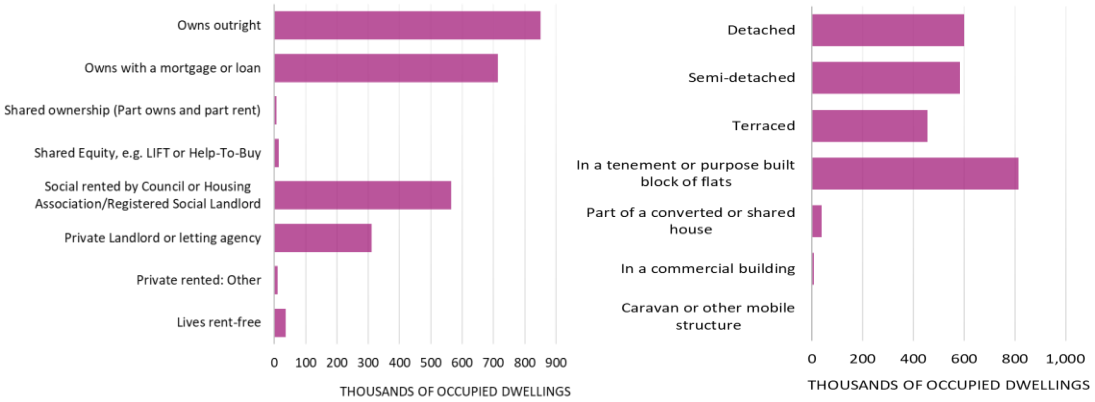
The age profile of residential buildings in the UK creates additional challenges for future-proofing low carbon retrofit and mitigating adverse health outcomes (23,25). A fifth of the UK housing stock is over 100 years old, with 38% of dwellings built before 1946, compared to an average of 18% for the EU (24,25). Across the EU27, the final energy consumption of residential buildings decreased from 2000 to 2019, but with a slowing trend since 2014, which was also mirrored in the UK (169). Part of the overall decrease over this 20-year period can be attributed to improvements in energy efficiency, mediated by other factors such as energy prices, occupancy rates and household practices. In 2019, the UK was around the EU average for total residential energy consumption at approximately 1.3 tonnes of oil equivalent (toe)/dwelling. In the same year, space heating accounted for 65% of household energy consumption in the EU, by far the most dominant end use, followed by water heating (14%), appliances (13%) and cooking (6%). The UK was also very close to the EU average for household space heating at just above 100 kilowatt-hour (kWh) per m^2 in 2019 (declining from 170 kWh per m^2 in 2000), although UK progress on space heating reduction stagnated from 2014 to 2019. Across the EU, a decreasing trend of 2.1% per year from 2000 to 2014 was followed by a slower decline of 0.6% per year until 2019 (ibid.).

Figure 3: Household tenure by types of occupied homes in England and Wales[6]



[6] Figure 3 data source: Census 2021 in England and Wales (40)

Figure 4: Household tenure and types of occupied homes in Scotland[7]



4.3 Owner-occupier Barriers and Motivations

Section 3.1 described the effectiveness of the Carbon Emissions Reduction Target (CERT) and Community Energy Saving Programme (CESP), in supporting the uptake of lower cost and more straightforward thermal fabric measures such as cavity wall and loft insulation in the UK from 2008 to 2012. By contrast, the UK's Green Deal (2013-2015) focused narrowly on addressing financial barriers, with a flawed assumption that owner-occupier decisions to renovate are economically rational and calculated and can be triggered once appropriate financial incentives are in place (27,58). The Green Deal has been widely criticised for its limited economic framing, and a failure to promote the social and environmental co-benefits of HER to owner-occupiers (27,60,148). These drawbacks contributed to its modest installation volume (20,000 measures installed compared to an annual target of 2 million) and early closure of the scheme after only two and a half years (58).

Effective HER policy design requires accounting for the multiple factors which may influence homeowner decisions on whether or not to carry out energy renovations. In addition to anticipated savings on energy bills and carbon emissions, these factors may include values and considerations related to comfort, utility, aesthetics, social aspirations, health and heritage (2,170–173). Homeowners may be more likely to make decisions to install retrofit measures during certain 'trigger points' such as moving home, changes in family structures, members and relationships, or other events resulting in unexpected changes to household practices and prioritisation of concerns within the home (26,27).

In section 3.2.3, we discussed information and advice polices which aim to address homeowner barriers to retrofit, however as Simpson et al. (174) note, *"Renovation involves millions of decisions and actions. Owner-occupied households are a key group of decision-makers, but with conflicting demands on their time and finances. Householders collect information from multiple sources."* Based on an assessment of

[7] Figure 4 data source: Scotland's Census 2022 (41). LIFT refers to 'Low-cost Initiative for First Time Buyers' shared equity schemes in Scotland.

Nottinghamshire and Suffolk owner-occupier uncertainties and information needs with respect to early energy renovation decisions, the authors propose the use of digital apps to connect households with suitable retrofit measures and local, trusted advisers and practitioners for in-person home visits (ibid.).

Recent analyses of households in the UK propose that energy retrofit policies need to account for the role of social relations. Owen et al. (175) found that low-income owner-occupier households with Asian origin, residing in terraces with low energy efficiency, were disproportionately more likely to apply for ECO subsidies, relative to anticipated levels, and even more so in the north of England. Since these households share common demographic and dwelling characteristics, the authors suggest tentatively that uptake has been facilitated through networks of social relations in the community, although further research is required to fully support this claim. Brown et al. (23) develop this 'relational' framing as an alternative to conventional understandings of householders as rational decision makers acting in their best economic interests, which, they argue, has tended to guide and constrain the effectiveness of residential energy efficiency policy both in the UK and internationally. This informs a recommended set of alternative policies, grounded in a social relations perspective and drawing on case studies of the 'retrofit journey' of 30 UK households which self-funded energy renovations. Such alternative policies should avoid 'one size fits all' solutions and utilise community and social ties to target key entry points in the consumer retrofit journey, including moving home and decisions to carry out general renovation work (that may not initially include energy retrofit measures). Brown et al. (23) recommend for example that a combination of "*place based fuel poverty and able to pay retrofit programmes by adopting a blended finance offer, may be more visible in communities and create solidarity between households with different incomes*" (ibid.).

4.4 Workforce and Supply Chain Challenges

In the UK and Europe, buildings decarbonisation requires a larger, more diverse and competent workforce (31). The revised EPBD includes provisions around more holistic skills development and training (126). Formal training in the UK construction sector, such as further education and apprenticeships, focuses more on fossil fuel technologies and new builds rather than building energy renovation (176). Some new training for retrofit jobs is emerging, including heat pump installer courses (177), but such offerings typically aim to develop technical skills for single technologies, as opposed to more comprehensive training around whole house renovation and the interaction of energy consuming appliances and the thermal envelope of the home (32).

The construction sector in the UK has been characterised as a 'low skills equilibrium', where salaries are low and job security is poor, in turn leading to a poor reputation for construction work which is not typically promoted as an ambitious career in schools (29,30). The UK labour market for construction and energy efficiency retrofit is largely unregulated; in other words there are no minimum or ongoing licensing requirements for workers or businesses with respect to training and qualifications (30). For home

energy renovation, this applies particularly to insulation and other thermal fabric improvements, increasing the risk of low quality renovations (32). For heat pumps and solar PV, the Microgeneration Certification Scheme has been in existence for around a decade to quality assure installers and products (67). Even so, this scheme is focused on specific technology requirements, rather than quality assuring for multiple-skill sets and competencies that can help ensure that any single measures are appropriate, and minimise risks of adverse impacts elsewhere in the home.

The construction and retrofitting workforce in the UK and Europe is acutely lacking in diversity, comprising predominantly older, white males (69,178), with only 10% of EU construction workers categorised as female (179). In the UK, only 6% of construction labourers are classed as Black or minority ethnic (BAME) and 6% are people with disabilities (180). Masculine construction cultures, concerns about job security, health and safety and difficult working conditions can be key barriers to attracting more diverse employees, as well as younger generations, into the building energy retrofit sector (69).

Technical standards do not necessarily guarantee quality installations, particularly for more expensive and complex measures such as solid wall insulation which can have significant unintended consequences when fitted inappropriately, i.e., without proper consideration of the risks of damp, insufficient ventilation and overheating (124). New quality assurance standards for retrofit installers were introduced in 2021, upgrading to PAS (Publicly Available Specification) 2035 from the previous PAS 2030, in an attempt to more clearly define how installers should follow a whole house approach and manage different levels of risk including where only single measures are being retrofitted. PAS2035 also introduced a new Retrofit Coordinator role to ensure retrofit projects comply with quality standards, in addition to technical monitoring (50,124). Focus groups with installers of internal wall insulation (IWI) in the north of England revealed that these practitioners may view IWI installation as a low-skilled job which does not require training or reference to standards (50). Moreover, installers of various building energy retrofit measures (not just IWI) may lack awareness of, or otherwise ignore, technical standards such as PAS 2030 and PAS 2035. They may not see such standards as credible enough to justify additional bureaucratic and cost burdens that may be placed on SMEs and subcontractors typical of the UK construction sector. This also means that retrofit tradespeople may not follow relevant standards and install measures inappropriately, leading to unintended adverse consequences. Policies are needed to address these workforce challenges that could include new approaches to installer licensing and training, and interventions to develop stronger professional identity, behaviours and holistic competencies (ibid.).

4.5 National, Regional and Local Policy Coordination

Retrofit policy support varies according to the governance structure in a given country. A survey of 170 local and regional financial schemes for building energy renovation in the EU27 found that most (90 schemes) took the form of grants and subsidies, while 35 mixed schemes combined grants and loans (19). 13 EU Member States were

identified as having both local and regional financial schemes, while some Northern and Eastern European countries do not have schemes at these governance levels and may only use national financial instruments. In several cases, local financial schemes are integrated with schemes at regional and/or national scale. These combined schemes may facilitate deeper renovation and higher energy savings, but are constrained frequently by limited budgets, tending to result in lower impact compared to national schemes. Local authorities in the EU can be well placed to identify the least efficient building stock in their areas and respond to the needs, preferences and concerns of local residents, but may generally lack their own resources for financial incentivisation. Instead, local authority financing can be funded from a national (e.g., the Netherlands, US) or international governance level, e.g., through EU cohesion policy including the Cohesion Fund and the European Regional Development Fund. Another option is for local authorities to partner with banks in offering local financing products (ibid.).

The Netherlands has developed a local government-led approach to heat decarbonisation which may be particularly instructive for translating international experiences to the UK, given its similar high gas dependency for heating and where the role of local government in HER is not well defined (20). The Dutch government created a strategy to phase out natural gas heating in residential buildings by 2050, as part of its Climate Agreement in 2019 and following a succession of earthquakes around the Groningen gas field. The Climate Agreement set out that municipalities or local authorities should take the lead role in developing heat decarbonisation visions and plans to create gas-free neighbourhoods across the country. From 2018, 64 Dutch municipalities were funded €400 million to set up gas-free district trials, which have tested the use of low carbon heat technologies, opportunities to reduce costs, effective citizen engagement and appropriateness of the relevant laws and regulations. While some local experiences may be context-specific, the trials have helped to promote learning by doing whereby challenges and potential solutions are suggested to the national government, which can then consider whether changes to policies or regulations might be required (ibid.).

Devenish & Lockwood (20) highlight that this locally led governance approach has experienced some challenges, including tensions between local authority planning and national government instruments typified by market incentives and regulations. The authors suggest that there is more coherence in the design of the National Insulation Programme compared to tensions in balancing the deployment of heat pumps for individual homes versus expanding heat networks. While the National Insulation Programme devolves funding to municipalities for home insulation upgrades as noted in Section 3.3.3, a further concern is that Dutch local authorities lack or vary in their financial resources and appropriate powers to enact a gas free district heat decarbonisation vision (ibid.).

There are significant challenges in ensuring local and regional planning are integrated with national programmes to ensure policies are in place, enabling plans to actually get delivered. Drawing upon the Dutch experience in the UK could help enhance locally customised and participatory approaches to community engagement on low carbon heat technologies and HER (20,181). Two funding mechanisms already exist

in England, the Local Authority Delivery Scheme and Home Upgrade Grant which devolve funding for local authorities to target low-income and least energy efficient (based on EPC ratings) homes in their areas. The latter scheme focuses on low-income homes off the gas grid (86), but has been criticised in relation to short-term funding windows disincentivising longer-term development of a skilled supply chain and therefore quality retrofit outcomes (182).

Local Area Energy Planning (LAEP) in England and Wales takes a whole system approach to achieving net zero in a locality, and can integrate granular local data on building stock energy performance, tenure and socio-economic factors with analysis of grid capacity to provide a better understanding of priority areas for building fabric improvements and heat electrification - amongst other decarbonisation initiatives (33,183). Local Heat and Energy Efficiency Strategies (LHEES) in Scotland follow a similar area-based approach, focusing on the analysis of building options for heat decarbonisation and energy efficiency (33,184). In Scotland, all local authorities have been required by a statutory obligation to publish LHEES, and many have five-year delivery plans in place. This has been facilitated by a common methodology developed by Arup, Zero Waste Scotland and several local councils and mandated in Scottish national planning policy (185). In England there is no requirement for local authorities to conduct comprehensive heat or whole system energy planning, and there could be value in following a similar approach to Scotland with centralised guidance and technical resources set up to support the development of local energy plans. While various local or regional authorities have commissioned LAEPs in England, there is no consistent framework or methodological protocol for how these should be designed and implemented (33,182). Nevertheless, the Energy Systems Catapult has received public funding to develop a tool helping local authorities produce LAEPs (182). In Wales, the devolved government has funded the production of LAEPs for all local council areas, helping to inform the development of a National Energy Plan for Wales (33,186).

Policy mixes for local energy systems relating to energy efficiency, low carbon heat and distributed energy generation have been compared for England, Wales and Scotland in a study by Wade et al. (16). Analysing 105 policy instruments across the three nations from 2010 to 2021, the authors found relevant policies in England were the most variable, short-term and subject to cancellation, indicating lower levels of policy credibility than in Scotland and Wales, which had clearer policy ambitions and a continual increase in the number of policy instruments over time. It was also observed that the policy mixes in Scotland and Wales were less balanced or comprehensive than in England due to limits in devolved powers (ibid.).

Section 3.3.3 discussed in detail international evidence on ‘one stop shops’ for HER. A key policy gap in England is the absence of a comprehensive, national advice and/or ‘one stop shop’ programme. As noted earlier in our report, France and Ireland have already set up national ‘one stop shop’ schemes which help to guide and support householders through their energy renovation journeys, as well as connecting them to sources of finance and lists of accredited installers. National advice services already exist in Scotland and Northern Ireland, administered by the Energy Saving Trust (94). Maby (187) recommends that the UK government should collaborate with the energy

advice sector to set up a 'national information resource' for low carbon renovation with comprehensive coverage of relevant technologies and aspects of user behaviour. This would be supported by a network of local and regional 'one stop shop' hubs, clearly linked to the national resource, and characterised by consistency of advice and contact points across the UK. Advice could be tailored to support homeowners and households of all different tenure types to make appropriate home energy upgrades, including at key trigger points such as moving home or carrying out general renovation work. It is proposed that this service should be publicly funded and commercially independent to minimise bias (ibid.).

5. Conclusions and Policy Recommendations

To date, various energy efficiency retrofit policies have been implemented across OECD countries. Despite some progress in deploying individual measures with modest energy and carbon savings, energy efficiency retrofit rates remain low for deeper, more complex renovations with higher carbon abatement potential. This working paper has presented findings from an international review of good practice policy design and implementation to increase uptake of energy efficiency retrofitting in owner-occupied households. Our review of international evidence focuses on policies targeting medium- to high-income or 'able to pay', owner-occupied homes. We highlight examples of good practice policies which could be effectively employed in the UK context, and help to accelerate quality, energy efficiency retrofits. Around two-thirds of households in Great Britain, the EU and North America are owner-occupied, however the UK faces additional challenges associated with retrofitting an older housing stock compared to the EU.

In most cases residential energy renovations in OECD countries are shallow single measures, with a small portion comprising multiple measures or deeper renovations. Although some countries such as France, Germany, the UK and the US have retrofitted millions of single measures to homes, this review has not identified any countries which have delivered deep energy retrofit at a widespread scale. Through our review we highlight examples of national investment subsidies and 'one stop shop' schemes, aiming to support the customer retrofit journey and promote use of accredited suppliers and/or products, which have led to a scaling up of interventions. In several cases these have led to 100,000s of single measure installations, although they mostly represent examples of shallow retrofit rather than deeper or whole-house energy renovation.

We identify various policy instruments which have been applied internationally and/or are considered important for implementing residential energy renovation. Policy instruments most commonly emphasised in relevant review studies are regulations, financial support and information provision, and these are the foundation of the

International Energy Agency's energy efficiency policy toolkit (39). Most reviews of required HER policies in OECD countries also include measures to develop required workforce skills and competencies, supply chains and quality assurance. In countries where higher volumes of HER have been achieved, such as Canada, France, Germany and Ireland, we have identified several cross-cutting success factors which include long-term policy reliability and flexibility, effective policy mixes, policy integration (e.g., between low carbon heat and thermal fabric measures) and coordination between national and local government, including the use of intermediaries such as 'one stop shops'.

In developing policy recommendations from the international analysis, we note that effective policies need to account for various reasons why homeowners may decide whether or not to carry out energy retrofits, which begins with an awareness of the potential to install relevant measures. Decisions whether or not to retrofit can relate to values and considerations around anticipated energy bills and carbon savings, comfort, utility, aesthetics, social aspirations, health and heritage (2). Trigger points such as moving home, changes in family composition and plans to carry out more general (non-energy) renovations can also motivate decisions to install energy efficient measures (23,26,27). Recent work highlights that social and community relations can be utilised to target these key entry points in the consumer retrofit journey, to help raise awareness and uptake of HER interventions (23,175).

Drawing upon the discussion of international and UK evidence in previous sections, we make a series of policy recommendations for an effective home energy retrofit policy framework in the UK, with a focus on medium to high-income owner-occupier households. These recommendations address the review research questions (Section 1.3) and are grouped accordingly below.

5.1 Combination and Sequence of Policies

Key success factors are the design and implementation of policy instruments which are credible, stable, long-term and flexible.

- Wider deployment of HER requires stable, long-term and flexible policies which can be adapted as needed over time. Consistent, predictable and long-term policy support can help to increase certainty which may positively influence household and supply chain decisions to invest in energy renovations.
- Policies should be credible to policymakers and capable of receiving consistent political commitment over a long period of time, helping to achieve policy targets. Policies should be designed to be flexible so that they can be adapted over time to account for changing circumstances, progress in achieving intended outcomes, or the risk of interference between individual policies that could reduce their effectiveness.
- In Germany, the Federal Promotional Support for Energy Efficiency in Buildings has run since 2005, enabling confidence to be developed in the sector. The EU Energy Performance of Buildings Directive requires member states to develop long-term strategies to achieve zero emission building stocks by 2050.

Policy packages or combinations of complementary policies are more effective than applying individual policy instruments alone.

- Policy instruments applied together in a complementary way, such as standards and information measures, can help to raise the success of other policies. Financial instruments can be linked effectively with other policy instruments such as quality assurance.
- Specific sequences of policies may be effective in certain circumstances. For instance, expanding voluntary standards after compulsory standards have been introduced can help to stimulate ongoing innovation. Regulations can increase technical standards, but this in turn may create a need for additional skills development policies to expand training and accreditation of supply chains.

Effective policy mixes should include policies to stimulate both homeowner demand and a competent supply chain for retrofit.

- International evidence underlines that making a shift to a more comprehensive uptake of various energy efficiency upgrades will require a well-targeted and holistic combination of policies. Polices focused only on encouraging owner-occupiers to retrofit will not be sufficient without quality-assurance initiatives, which help to expand the competent workforce and raise consumer confidence and trust in the retrofit supply chain. This is particularly applicable to private households given that installations are fitted by multiple independent tradespeople.
- In deciding which mix of policy instruments to develop in a given country, policymakers should consider the purpose, strengths and weaknesses of instruments already in place and policy gaps, i.e., are particular types of instruments under-utilised? For example, it may be more time efficient to strengthen existing regulation rather than create entirely new legislation (39).

Policy targets should set a clear direction of travel and be measurable, including use of quantitative metrics comparable across countries and localities, to allow continuous monitoring of progress.

- Internationally, quality of monitoring data on progress (renovation rates), impact (carbon reduction) and benefits/drawbacks (indoor air quality, comfort, health, etc.) of home energy retrofitting is particularly poor.
- There is low availability of up-to-date metrics and data to track progress in HER in different countries for specific measures and more comprehensive energy-efficiency renovations alike. There is also a lack and inconsistency of monitoring data and metrics within countries, linking progress tracking at local, regional and national levels.
- This is only beginning to be addressed in Europe by the Renovation Wave Strategy. While the International Energy Agency (IEA) tracks progress on buildings and energy efficiency for OECD countries, this is not used to officially monitor compliance with regulation.
- The IEA (39,118) recommend that effective, energy efficiency policies require clear targets and strategies, the development of capacity and resources to

implement policies, and continuous progress monitoring and evaluation assisted by appropriate data collection (e.g. on energy consumption).

5.2 Role of National Government and Good Practice Policies

Regulatory measures can be effective for shallow retrofit. To achieve deeper retrofit impact, UK regulations could be aligned more closely with EU directives on building energy renovation, particularly in relation to requirements for EU member states to develop Building Renovation Plans for building stock decarbonisation by 2050.

- Energy efficiency standards and labels for appliances and equipment have been effective in reducing energy consumption in countries with long running programmes, such as in the US, EU and the UK. Building codes offer a comparative policy tool, and if audited, potential inaccuracies can be understood and ideally addressed. UK homeowners or landlords are required to show Energy Performance Certificates (EPCs) displaying modelled energy performance at point of property sale or rental, but the metrics used require improvement as they remain opaque and bear poor relation with actual energy consumption (56).
- The EU Energy Performance of Buildings Directive (EPBD) sets out that member states should set national targets to reduce energy consumption in residential buildings. EU countries are required to develop Building Renovation Plans to achieve a zero-emission building stock by 2050.
- Under the EU Energy Efficiency Directive (EED), Member States should develop certification schemes and/or equivalent qualifications for energy efficiency workers. Following Brexit, the UK is not required to update equivalent legislation in line with EU regulations.
- The Product Regulation and Metrology Act 2025 includes powers for the UK government to adopt similar or corresponding provisions as the EU to increase the energy efficiency and reduce the environmental impact of product use.

Energy efficiency obligations have been effective in deploying millions of lower-cost and easier-to-treat measures. ECO focuses on low-income households but could be extended to part-fund renovations in higher-income households to encourage wider uptake of measures.

- Energy efficiency obligations place targets on energy suppliers to deliver energy or carbon saving improvements to buildings, and can be effective in deploying high volumes of shallow energy retrofit measures.
- In the UK, the Carbon Emissions Reduction Target and Community Energy Saving Programme (2008 to 2012) were successful in deploying several million lower-cost and easier to treat insulation measures (e.g., loft and cavity wall insulation), and (excluding energy efficient light bulbs) led to a higher volume of installations in four years than successor ECO schemes have since 2013.

Energy efficiency obligations could alternatively be targeted at part-funding higher-income households which can contribute to the up-front costs of energy renovation measures. ECO has focused on more low-income or fuel poor households, but it may be more regressive for these households since costs are recovered via energy bills.

The review highlights several retrofit financing mechanisms that can be targeted specifically at mid-to-high income owner-occupied households. Given pressures on government spending, a blended financing approach combining direct, publicly funded financial incentives with innovative measures to stimulate private financing is likely to be required.

- Public funding is limited, and therefore directly funded financial incentives will likely need to be combined with innovative financing products, such as green mortgages, blended finance and energy service contracting, to enable the rate and scale of retrofit required to meet carbon targets.
    - Energy efficiency mortgages and preferential loans with favourable interest rates and long-term repayment periods may be more suitable for homeowners with good credit; grants and subsidies may be better suited for lower-income households or rented homes (114).
    - UK homeowners could benefit from financial incentives which provide access to low-cost institutional capital such as PACE, or public co-financing schemes such as those in the US which reduce risk for and achieve higher private investment.
- Financing mechanisms can be effective where they also support general property improvement works or wider sources of value such as thermal comfort.
- The Government could set up an initiative to promote a saving fund amongst owner-occupiers for building maintenance, modernisation and energy efficiency.
    - In practice various financial incentives have been unsuccessful due to anticipated energy savings being overestimated, and now face additional challenges in their implementation including higher construction costs, interest rates and energy prices (114,130).

For England and Wales, we recommend that a national retrofit programme with financial incentives for 'able to pay' homeowners and a 'one stop shop' and advice service linked to local and regional hubs could help to support the customer retrofit journey and develop supply chains.

- A national 'one stop shop' and advice service could link to similar facilities in Scotland and Northern Ireland, via the Energy Savings Trust. Drawing upon international examples in Canada, France, Germany and Ireland, this national retrofit programme and 'one stop shop' scheme could provide financial incentives for 'able to pay' household renovations and higher incentives for lower-income households, and support deeper retrofit (multiple measures). Opportunities to develop a skilled workforce for quality retrofit could be integrated as part of a national, regional and local network of 'one stop shops', or through requirements for accessing retrofit grants and loans.

- The Energy Saving Trust and Green Alliance (97) recommend that the UK Government launch a national home energy retrofit scheme for England, with long-term public funding and policy commitment.
- A feature of several of the national 'one stop shop' schemes identified in our review is the integration of policy support for different types of technologies and interventions, including thermal fabric improvements, low carbon heating and microgeneration. Despite this, the uptake of such interventions via national 'one stop shops' have tended to be dominated by single measures or shallow renovations. However, in some cases these schemes offer extra incentives for deeper renovations, including low interest loan support particularly targeted at 'able to pay' owner-occupiers, in addition to investment grants typically offered to a wider range of household types and incomes.
- In several European countries, there are examples of national retrofit schemes or 'one stop shops' which include training, certification and/or quality assurance of retrofit tradespeople. In order to receive grants or loans in Germany, the KfW bank scheme requires householders to obtain advice from independent building energy specialists registered on quality assured lists.

In taking measures to grow the required workforce and ensure quality outcomes, the UK building energy retrofit industry should develop a regularly updated licence to trade, minimum competency and training standards and more standardised and comparable qualifications.

- Achieving buildings decarbonisation at scale requires a larger, more diverse and competent workforce, both in the UK and internationally.
    - In Europe, North America and Australia, the housing retrofit industry remains immature and fragmented compared to the dominant repair, maintenance and improvement industry. Supply chains for building energy renovation are typically comprised of small businesses with an insufficient supply of workers who have the competencies needed to deliver high quality work. The construction sector in the UK and EU has been described as a 'low skills equilibrium', where salaries and job security are low, leading to a poor reputation for construction work which is not typically promoted as an ambitious career in schools (29,30).
- The UK labour market for construction and energy efficiency retrofit is largely unregulated, so that there are no minimum or ongoing licensing requirements for workers or businesses with respect to training and qualifications (30). For home energy renovation this applies particularly to insulation and other thermal fabric improvements, increasing the risk of low quality renovations (32).
    - While retrofit installer certification schemes are established in various European countries, these could be strengthened by incorporating a license to trade linked to regularly updated, minimum qualification standards (29).
    - In the UK, there is potential to expand the Microgeneration Certification Scheme (MCS) to cover thermal fabric energy efficiency interventions, incorporating minimum requirements for more holistic, multi-trade competencies (including enhancing understanding between separate trades) and soft skills.
    - Currently the Microgeneration Certification Scheme is focused on specific requirements for microgeneration technologies (including heat

pumps and solar PV), rather than quality assuring for multiple skill sets and competencies to help ensure that any single installation is appropriate, and minimise risks of adverse impacts elsewhere in the home.

5.3 Policy Coordination of National, Regional and Local Retrofit Initiatives

National and local government retrofit policy should be better coordinated, including through dissemination of financing to support uptake of measures at a local level.

- Local authorities can be well placed to identify the least efficient building stock in their areas and respond to the needs, preferences and concerns of local residents, but may generally lack their own resources for financial incentivisation.
- Local authority financing for HER can be funded by national government, following examples of such an arrangement in the Netherlands and the US.
    - Given budgetary constraints on the national government and in addition to any public funding, a pragmatic approach is to encourage local authorities to partner with banks in offering local financing products, as part of a blended finance approach.

National policy programmes for home energy renovation should be integrated with mandatory local area planning to ensure plans actually get delivered.

- In England there is no requirement for local authorities to conduct comprehensive heat or whole system energy planning, while the Welsh government has commissioned Local Area Energy Plans (LAEPs) in each local authority area.
- We recommend mandatory requirements and a consistent methodology for LAEPs in England and Wales (as appropriate), including integrating granular local data on building stock energy performance, tenure, socio-economic factors and grid capacity. This could follow a similar approach to Scotland where centralised guidance and technical resources have been set up to support the development of Local Heat and Energy Efficiency Strategies.

There is a role for national and local government to facilitate effective intermediaries, which can be achieved if government and intermediary goals are reasonably aligned.

- Intermediaries could help to bridge the gap between national government and millions of private homes. They may include ‘one stop shops’, installers, craftspeople, construction firms, architects and energy advisers, but issues with consumer trust may need to be addressed.
- Intermediaries are often involved in consumer decisions on whether or not to retrofit in ways which may have positive or negative outcomes for technological diffusion. To effectively support HER, intermediaries such as craftspeople need to be convinced that energy efficient renovation measures are useful (161).

Establish regular collaboration between UK and devolved governments to foster mutual learning and greater consistency in policy design and implementation across the UK.

- Retrofit policy design and delivery vary across UK regions and devolved administrations. Scotland and Northern Ireland have separate information and advice services for householders (Home Energy Scotland and Northern Ireland Energy Advice Service, respectively), which offer signposting to grants and/or loans for building energy retrofit, administered by the Energy Saving Trust.
- A clear policy gap is a lack of a similar advice/signposting service for England and Wales.
- National advice/information services (forming part of a national 'one stop shop') should be supported by a linked network of local and regional 'one stop shop' hubs, with advice tailored to support homeowners and householders of different tenure types, including at key trigger points such as moving home or carrying out general renovation work.

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Appendix

Expert Group Advisers

The expert advisers were asked to comment on the scope of the project and the proposed approach, advise and assist the project team in the selection of relevant evidence sources, and review draft results. We further extend thanks to Nick Eyre and Jess Britton for their helpful comments in reviewing the final drafts of the working paper. The following expert advisers contributed to the project:

Jess Britton (UKERC and Edinburgh University)

Sara Edmonds (National Retrofit Hub)

Nick Eyre (University of Oxford)

Gavin Killip (Nottingham Trent University)

Simon Rayner (Climate Change Committee)

Joanne Wade (Association for Decentralised Energy)

Review Search Terms

Table A1: Search terms applied for rapid evidence assessment in Web of Science and Overton[8]

Energy efficiency	Sector	Policy	Governance	Delivery model
energy	'able to pay'	'net zero'/'nearly zero'	governance	'public sector'
efficiency/'energy efficiency'	'owner-occupier' /'owner-occupied'	policy	government	state
'energy conservation'	occupie*	strateg*	international	public-private
'energy saving'	homeowner	regulation	federal	partnership

[8] * indicates search terms where truncation has been applied by placing an asterisk after a word stem to instruct databases to search for alternative word endings.

‘energy performance’	household	obligation	natio*	‘one stop shop’
weatheriz*	‘private household’	mandat*	regio*	market
thermal	residential	incentiv*	local	private
fabric	domestic	investment	‘local authority’	‘private sector’
insulation	home	subsid*	municipa*	‘business model’
retrofit	dwelling	financ*	community	ESCO
refurbishment	building	information	‘area-based’	‘energy service’
renovation	NZEB	awareness	‘place-based’	company
shallow		advice		
deep		engagement		
‘single measure’		voluntary		
‘multiple measure’		standards		
‘whole house’		quality		
		skills		
		training		
		‘supply chain’		

Relevance Ratings

Returned results were filtered manually for relevance based on their title and abstract. If this was not sufficient to determine relevance, further inspection of the main text was performed. This allowed attention to be focused only on those documents which were most directly useful in addressing the research questions. Each document was assigned a relevance rating from 1-4 according to the following criteria:

1. Article shows clear discussion and/or data that is directly relevant to some or all of the research questions, and includes material on owner-occupied households specifically;

2. Article shows clear discussion and/or data that is generally related, but is not directly relevant, to any of the research questions, e.g., it includes a wider discussion of home energy renovation policies but not explicitly pertaining to owner-occupiers;

3. Article mentions at least one of the search terms, but is of only limited relevance to the research questions, including studies which focus exclusively on energy efficiency retrofitting in non-owner-occupier households (e.g. social housing, private landlords with tenant occupiers);

4. Article is found to be irrelevant or duplicate on closer inspection, or is not accessible (e.g., page not found, incomplete access to book chapter, main text not in English language).

The Technology and Policy Assessment Team

The UKERC Technology and Policy Assessment (TPA) team was set up to inform decision-making processes and address key controversies in the energy field. It aims to provide authoritative and accessible reports that set very high standards for rigour and transparency. Subjects are chosen after extensive consultation with energy sector stakeholders.

The TPA has been part of UKERC since the centre was established in 2004. The primary objective of the TPA is to provide a thorough review of the current state of knowledge through systematic reviews of literature, supplemented by primary research and wider stakeholder engagement where required.