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Private household investment in home energy retrofit: reviewing the evidence and designing effective public policy

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Executive summary

What this report is about:

Improving the energy efficiency of Scotland's buildings is an urgent policy concern, and a central element of the Scottish Government's Climate Change Plan and Energy Strategy. Given the long-lived nature of the building stock, the vast majority of the buildings that will exist in 2050 have already been built – placing emphasis on efficiently retrofitting existing buildings, through measures such as improved insulation, more energy efficient glazing, more efficient boilers and more efficient lighting and appliances.

Around half of energy use and carbon emissions from UK buildings are associated with our domestic buildings, mostly to provide space heating. Domestic energy efficiency policies have tended to focus on lower income and more vulnerable households (including those in fuel poverty) and on the most cost-effective, 'low hanging' measures. As the ambition to decarbonise Scotland extends across the building stock, there is an expectation of significant improvements in the energy efficiency of domestic properties belonging to homeowners that are (at least partly) 'able to pay'.

There has been a substantial level of retrofit in Scotland in recent years, and this has helped to contribute to falling energy demand and carbon emissions. These recent changes relate to a building stock that was one of the oldest in Europe and that offered many relatively low cost and non-disruptive measures. Remaining retrofit options are becoming gradually less cost-effective and future retrofit is likely to involve higher costs for lower returns than has been experienced thus far.

The recently launched Energy Efficient Scotland route map sets out an ambition for a potential £10 billion investment in energy efficiency in buildings over its 20-year lifetime. Although precise levels of investment are uncertain, available public funding is likely to remain well below this figure. There is, therefore, a looming investment gap between the available public funds and the investment needed – a gap which could, in theory, be met by private households. Our review therefore considers the question: *"How can public policy more effectively encourage private, 'able to pay' households to invest in energy efficient retrofit?"*

The evidence base reviewed here is international, drawn primarily from published peer-reviewed academic literature but also some non-peer-reviewed, so-called 'grey' literature developed by consultancy groups, independent think tanks, government agencies and others. The review spans evidence from almost 100 documents, primarily from Europe and North America. Our approach has

been informed by the systematic evidence review methods used by the UK Energy Research Centre (UKERC) for over a decade.

Our review considers both *policy effectiveness,* in terms of the overall amount of energy and carbon savings achieved; and *policy efficiency*, in terms of maximising the ratio of private-to-public spending (or 'leverage') and the number of measures that otherwise would not have otherwise happened (or 'additionality'). In terms of specific policies, the review covers measures that directly cover upfront costs, such as grants or loans, as well as indirect measures such as information dissemination, regulations, etc. Although direct incentives and information-based measures are routine parts of retrofit policy packages, limiting policy support to them will have only limited effects. The review therefore also covers supply-side aspects, such as how installers and advisors can support retrofit activity, and the overall retrofit policy package.

What the report is not about:

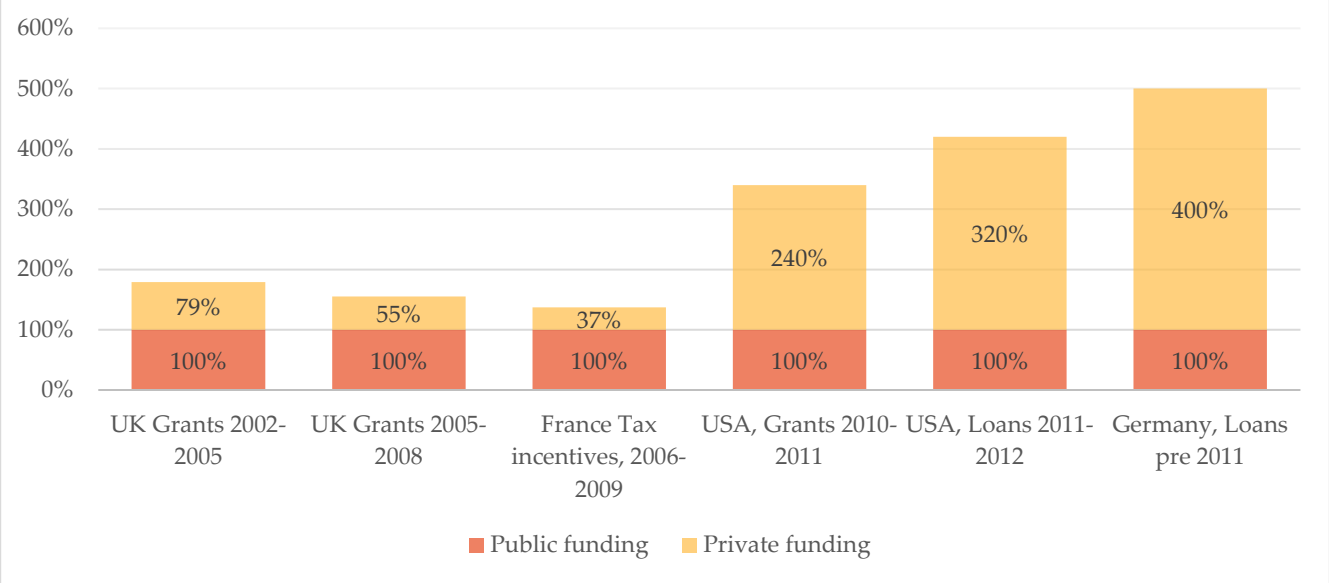
The review focusses on how public policy can be used to encourage homeowners to invest in improving the energy efficiency of their homes. Rather than the detailed impacts of specific retrofit measures, in terms of energy demand or carbon emission reductions, our concern is more on levels of investment in such measures by private homeowners, and how public policy can effectively encourage such spending. Our review is focused on owner-occupier section of the residential sector (with or without mortgages), around 60% of all Scottish households. Much of the findings will, however, have relevance to the other tenures of residential buildings, for example, the private rental sector.

Review Findings

Leverage Ratios

A wide range of retrofit leverage ratios are reported internationally. A number of programmes reviewed here saw leverage ratios of less than 1 (i.e. total private investment was smaller than total public funds). The highest example of leverage in this review was from the 'KfW' loan scheme in Germany, with an estimated leverage ratio of 4. Figure 1 presents leverage figures reported in our evidence review.

Figure 1: Leverage: public-to-private funding ratios

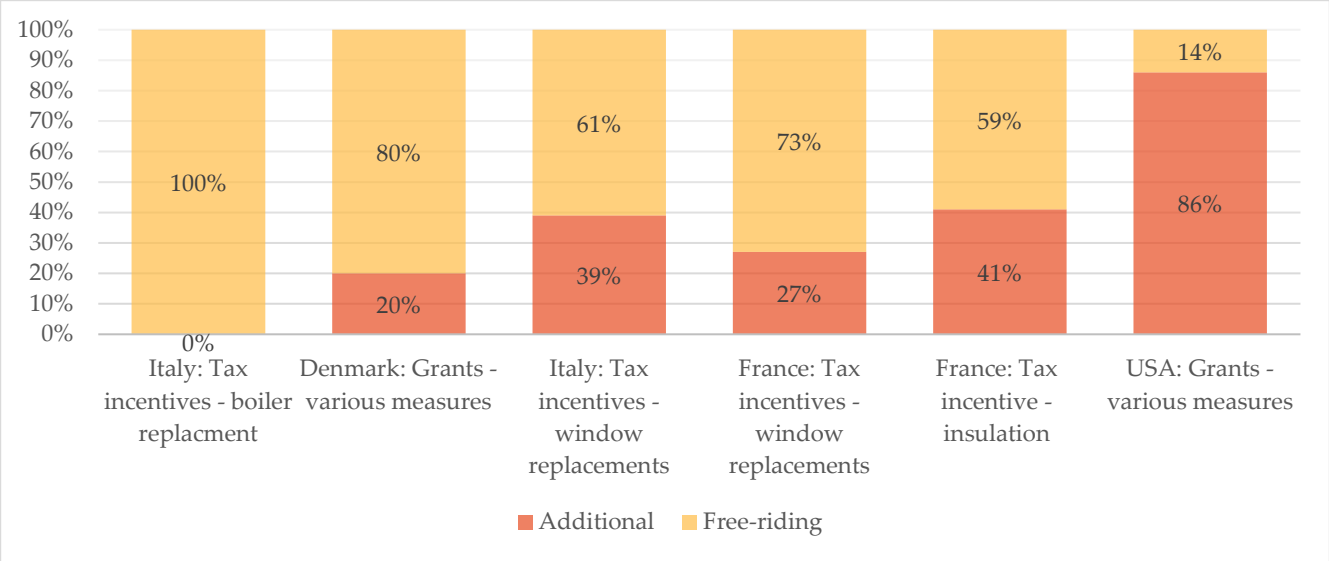


Additionality and free-riding

Additionality is the proportion of retrofit measures that received a subsidy that otherwise would not have been implemented. 'Free-riding' refers to measures that received a subsidy but which would have been carried out even without policy support. The total number of subsidised measures minus the number of free-riders gives the level of additionality: an important measure of retrofit policy efficiency.

Several studies have estimated the level of additionality in retrofit subsidy schemes (Figure 2 shows six estimates reported in the review). Additionality is difficult to estimate reliably, and is most commonly measured using self-reported, ex-post methods such as household surveys. These tend to downplay the importance of policy interventions, so underestimating additionality. Other evidence highlights the potential for positive 'spillover effects', in terms of indirectly encouraged retrofit investments.

Figure 2: Additionality and Free-riding



Reported levels of additionality and free-riding vary with the type of measure involved. Free-riding is typically higher when retrofit involves 'replacement' measures such as windows, doors, and heating systems, and lower for 'supplementary' measures that have no prior equivalent, such as new insulation. For measures that are typically replaced only when they malfunction, such as a boiler, free-riding can be as high as 100%. Policies should therefore reflect the specific measures involved. In some countries, 'replacement' measures – for example, for replacement boilers and windows – involve *minimum regulatory standards*. Focussing public funds on supplementary measures is likely to lead to lower free-riding and higher additionality, although this may limit overall policy impact. Households that are most ready to invest are associated with higher leverage ratios (as they require least added incentive), but are also likely to show lower additionality, as they are likely to invest anyway.

Financial incentives

Financial incentives to encourage retrofit can be broadly divided into those that don't require repayment (such as grants and tax incentives), and those that do (such as loans). Loans may involve a subsidy to reduce interest rates, but ultimately still involve repayment. Incentives that do not require repayment are the most common method of subsidising the direct cost of retrofit, and they tend to achieve higher uptake rates than loans; though loan programmes tend to achieve higher leverage ratios. Due to their relative attractiveness to households, grants and tax incentives are often considered an appropriate means of 'kick-starting' interest in retrofit, but as policies extend more widely, there may be a need for a transition to less popular loan mechanisms.

Readiness to retrofit and supply side aspects

Identifying 'ready to retrofit' households can be difficult; the only common factor that universally indicates a readiness to invest is a belief among homeowners that retrofit offers increased comfort and reduced bills. Demographic and other variables such as house type, age of occupants and income have inconsistent influence across different studies. There are, however, some aspects which can be usefully identified. Trigger points – points in time when investment in retrofit is more likely – include moving house and other more general home renovations. At these points, the costs and disruption associated with retrofit can be minimised. The vast majority of retrofit takes place alongside general renovations, and households do not normally think of retrofit as distinct from non-energy home renovation. Policy support should therefore seek to incentivise retrofit through businesses of general repair, maintenance and home improvement.

A recurrent theme in the evidence is the need to develop proactive, integrated retrofit supply chains, alongside demand side aspects. Some of the least successful policy initiatives reviewed here focussed solely on demand-side incentives. A more balanced 'supply-push and demand-pull' approach, involving training for salespeople and installers, is important for overall policy effectiveness. Supply-side firms and intermediary advisors can be effective proponents of energy efficient retrofit, and offer the opportunity to integrate it alongside much more prevalent general home renovations.

Information aspects

It is frequently suggested that if households were more aware of the benefits of energy retrofit they would be more interested in investing in it. However, the international evidence reviewed here suggests that policy measures that seek to increase householders' awareness of energy use and retrofit options (such as energy performance certificates and personal energy assessments) have a very limited effect in encouraging retrofit in practice, and should be seen as a 'supportive' or supplementary form of policy. This is partly due to how retrofit is framed: a focus on household retrofit as solely or primarily an exercise in direct cost saving is repeatedly criticised for offering an overly narrow view of homeowners' decisionmaking. Wider framings, such as how information-based interventions can affect a property's sale or rental value, offer opportunities for more effective policy.

Policy packages

Policy stability and predictability are important for retrofit policy effectiveness, both for the development of householder demand for and the capacity of supply side actors to respond. Stability is particularly valued in terms of a policy programme's identity and branding – with little benefit from rebranding if the approach is largely unchanged. However, policy programmes need some flexibility, to respond to evidence of poor results or changing contexts. Finally, simplicity in application processes are also important, particularly to encourage households with low levels of pre-existing interest.

There are tensions between policy efforts to maximise overall effectiveness (the reach and impact on the total building stock) and efficiency (the additionality of public spending). No one policy measure can be considered in isolation: private household investment on energy retrofitting is embedded in particular behavioural, technical and cultural contexts, and these need to be taken into account in any effective and efficient policy approach. The effectiveness of retrofit policy is also sensitive to the specifics of building stock and the wider energy system, and also capacities within government to develop, deliver and review policy programmes: the 'institutional fit' of policies. Therefore, this review does not attempt to 'pick a policy winner'. Effective policy involves a stable yet flexible package which informs, incentivises and regulates household demand for retrofit, the businesses that supply it, and the intermediary bodies that support it.

Glossary

- **Additionality:** the degree to which a policy programme facilitated activity that was additional to that which would have taken place without the existence of the programme
- **BBNP**: Better Buildings Neighborhood Program. USA policy programme incorporating 41 different state or local energy retrofit schemes
- **Building fabric:** the basic elements of the building, such as walls, roof, windows etc. Building fabric measures include insulation, double and triple glazing, draught-stripping
- **CCP:** The Scottish Government's Climate Change Plan (2018)
- **Counterfactual:** a description of what would have happened in the absence of a particular policy programme; offers a baseline from which additionality and free-ridership can be measured.
- **EA:** Energy Assessment. An assessment of a property's current energy performance and/or potential for energy retrofit, which is carried out by a qualified professional
- **Energy Retrofit:** a substantive change to a property's existing energy system or energy/environmental performance
- **EPC**: Energy Performance Certificate
- **ESO**: Energy Supplier Obligations – government policy that obliges energy suppliers that conform to certain criteria e.g. number of customers, to instigate energy efficiency measures, normally outside their organisation.
- **ESVA**: Energy Supplier Voluntary Agreement – energy supply companies voluntarily agree to facilitate energy saving measures with the possible incentive of a tax reduction (can be used alongside ESOs).
- **Free-riding**: a measure of the extent to which households participating in a programme would have taken the energy efficiency actions promoted by the programme even without the programme's incentives
- **GD:** Green Deal. UK policy programme that ran from 2012-2015 that involved on-bill financing for energy retrofit.
- **Household**: the occupant(s) of a property potentially investing in and/or benefiting from retrofit
- **Installers:** the supply-side actors that carry out energy retrofit labour.
- **KfW:** Kreditanstalt für Wiederaufbau, a German government-owned development bank that helps to facilitate retrofit incentive programmes
- **Leverage:** relative ratio of private-to-public funds within retrofit investment
- **Obligated parties (OP):** energy supplier or other party that is obligated as part of an Energy Supplier Obligation (ESO) obligations as part of an Energy Supplier Obligation (ESO)
- **Policy instruments:** refers to a type of policy programme for example, grants, loans, energy audits or regulatory standards.
- **Programme:** any set of practical actions through which a policy is realised
- **Public funds:** For the purposes of this review, funding that is instigated by a public policy intervention – whether from government revenue or hypothecated sources like energy supplier obligations –will be referred to as public funding.
- **Renovation measures:** General, amenity, non-energy home improvement or renovation.
- **Retrofit measures:** used in relation to an instance of a distinct retrofit installation, for example, the installation of double glazing is a retrofit measure, as is the installation of internal wall insulation. If these installations take place at roughly the same time, as part of the same project, they are still considered distinctive measures.
- **RMI:** Repair, Maintenance and Improvement. General, amenity, non-energy home improvement or renovation.
- **SME:** Small and Medium-sized Enterprises

- **Trigger points:** a point in time when retrofit is perceived to be more feasible for a household
- **Voluntary Agreements:** agreement between government body or regulator and private company e.g. energy supplier to carry out energy efficiency measures outside their organisation.
- **Whole house retrofit:** an approach to retrofit that considers all relevant parts of the home energy system and all relevant opportunities for home energy efficiency.

Note: some of the definitions in the glossary are taken from Wade and Eyre (2015)

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Content

1. Background

This the first evidence review produced by the ClimateXChange Energy Policy Effectiveness (EPE) project at the University of Edinburgh. The EPE project was set up to carry out systematic evidence reviews for policy questions relevant to the Scottish energy sector. By taking a systematic approach to evidence collection and review we aim to provide valuable insights into the deeply complex and multi-faceted issues associated with energy policy.

1.1. Changing how we heat our buildings

Over 50% of the energy consumed in Scotland is used to provide heat (Scottish Government, 2017b). On average in the UK around 75% of heat is used in buildings – housing, commercial and public – with the rest used for industrial processes (DECC, 2013). Given low demolition and construction rates the existing building stock is forecast to comprise the majority of the future stock for many decades to come – in the UK it is estimated that between 66% - 80% of the buildings that will exist in 2050 have already been built (Kern, Kivimaa, & Martiskainen, 2017; Royal Academy of Engineers, 2010; Schröder, Ekins, Power, Zulauf, & Lowe, 2011).

In our homes the majority of energy is used to provide space heating (~70%), and water heating (~13%), with energy use for lighting and appliances (~15%) relatively small in comparison (BEIS, 2017). Approximately 60% of the heat consumed in Scottish buildings is in residential properties, with the rest in commercial and public buildings (BEIS, 2016). As in the rest of the UK, the vast majority of homes in Scotland are currently heated via a gas grid. Gas is the primary heating fuel for around 80% of homes, with 12% using electricity for heating and 6% using oil (Scottish Government, 2016b). How we heat our existing homes, therefore, is an area of critical importance within our energy system.

Climate change policy and carbon emission reduction targets are driving an energy system transition. The transition to *a low carbon energy system* will involve the implementation of a variety of low carbon heat *supply* options (many of which are largely novel to the Scottish context). Alongside these there is also the potential to improve the efficiency of heat use or reduce our overall *demand for* heat. As a result of these multiple supply and demand options there are many potential transition pathways for the heat sector, leading some to suggest that there is a greater 'flexibility' (and uncertainty) within heat system transition than there is in other sectors (Watson, Gross, Ketsopoulou, & Winskel, 2014).

Options that address our current demand for heat are sometimes associated with 'multiple benefits': carbon reduction, more affordable warmth, public health improvements and energy security (IEA, 2014). There are, however, many different reasons why - cost, hassle and competing priorities- improving home energy efficiency can be difficult for both households and government (Murphy, Meijer, & Visscher, 2012; Rosenow & Eyre, 2016; Weiss, Dunkelberg, & Vogelpohl, 2012).

1.2. Energy efficiency retrofit policy and heat demand in Scotland

Energy efficiency retrofit *is defined here as any substantive change made in order to effect the energy consumption and/or environmental impact of the property. This can involve changes to a building's surfaces, the building 'envelope' i.e. it's walls, floors, ceilings, lofts, windows doors, or to its system of heat and electricity provision i.e. new boiler, electrical appliances etc.*

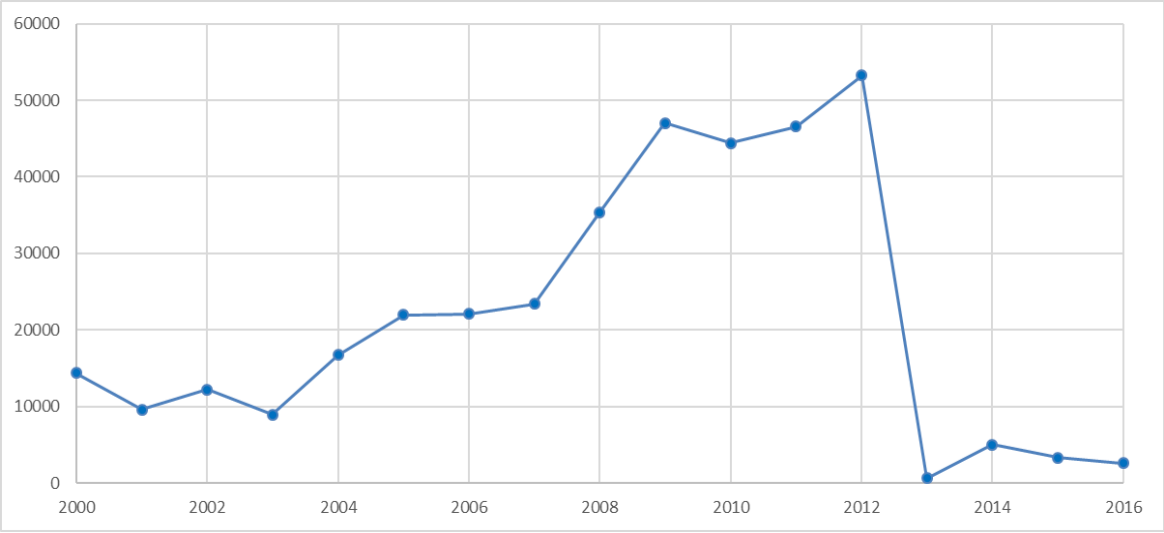
In recent years Scotland and the rest of the UK has seen government policy programmes that encourage energy efficiency retrofit of existing buildings. Largely as a result, there has been a huge

increase in retrofit measures such as loft and cavity wall insulation in Scotland in the last 10 -15 years. However, as a result of relatively recent changes in UK policy, retrofit implementation levels in Scotland have dropped dramatically in the last few years (see Figures 3-4). A similar decline took place throughout the UK at this time (ACE, 2014; DECC, 2016).

Table 2: Examples of policy options to support home energy retrofit

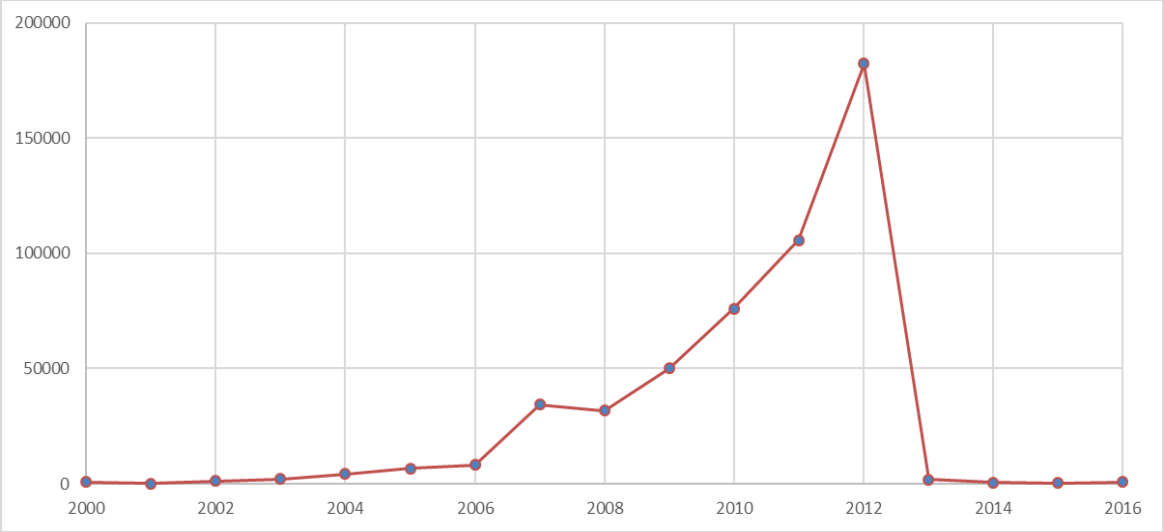
Retrofit policy measures for home owner-occupiers		**Examples in Scotland**
Financial incentives	Grants	Home Energy Efficiency Policy Scotland – Area Based Schemes (HEEPS-ABS)
	Tax incentives	Energy Efficiency Discount scheme – council tax reduction
	Loans	Home Energy Scotland Loan – 0% loan up to £38,500 for energy retrofit
Information based schemes	Energy Performance Certificate	EPCs are required for all homes that are sold or rented

Figure 3: Cavity wall insulations in Scotland: 2000 – 2016 (HEED, 2017)



Source: Homes Energy Efficiency Database 2017, Energy Saving Trust

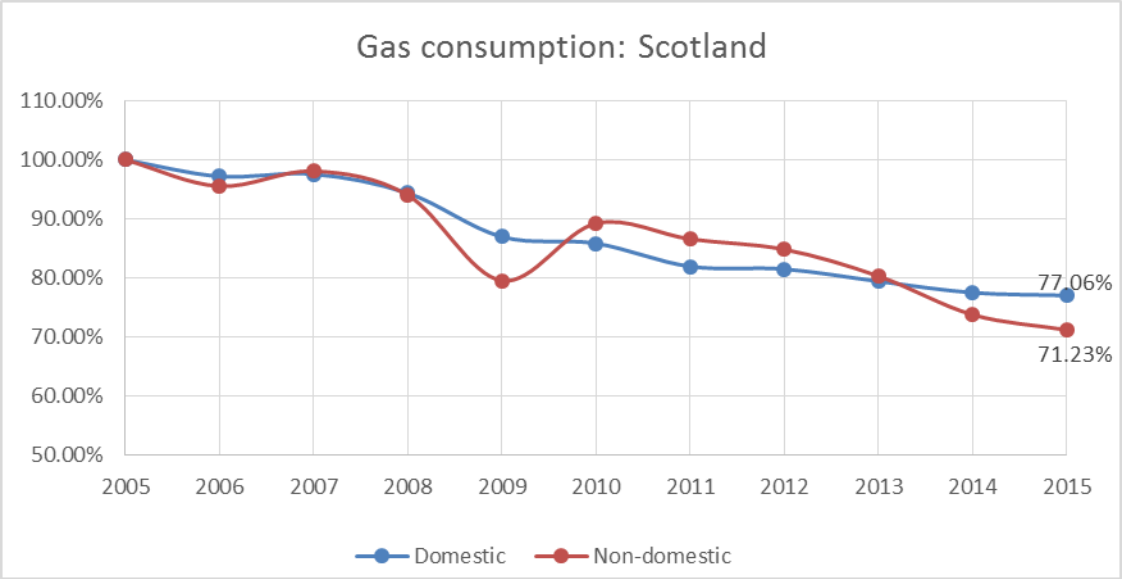
Figure 4: Loft insulations in Scotland: 2000 – 2016 (HEED, 2017)



Source: Homes Energy Efficiency Database 2017, Energy Saving Trust

Meanwhile, demand for heating in buildings has fallen substantially over the past 10 years (see Figure 5). This decline cannot wholly be attributed to the retrofit of existing buildings – it is also associated with underlying energy price and behaviour changes – but the improved energy efficiency of our homes and workplaces in the last 10-15 years has had a significant bearing on the fall (Adan & Fuerst, 2015; CCC, 2017; Webber, Gouldson, & Kerr, 2015).

Figure 5: Gas consumption in Scotland 2005 – 2015 (BEIS, 2016)



Source: Dept. Business, Energy and Industrial Strategy (BEIS). Total gas sales, subject to a weather correction factor

Energy use in buildings has been a particular policy concern in Scotland since devolution. The Scottish Government has more control over the demand side aspects of heat policy than over the supply side, with energy efficiency recently receiving the status of a 'national infrastructure priority'. In the 2018 Climate Change Plan (CCP) the Scottish Government set out various targets for efficiency improvement so that by 2050 all homes and commercial buildings in Scotland would be "near-zero carbon wherever feasible"

1.3. Public and private investment in energy efficiency retrofit

The multiple benefits associated with retrofit apply to both government (in terms of decarbonisation, reduced demand and energy security) - and to private households (in terms of energy bill savings and a more comfortable home). As a result, investment in retrofit comes from both public and private funding sources.

The 2018 Scottish CCP sets targets for residential buildings in Scotland to further reduce emission by 23% by 2032 (relative to 2015). The Energy Efficient Scotland Route Map sets out an ambition for 'all Scottish homes to achieve an EPC rating of C by 2040 (where technically feasible and cost-effective)'. It is estimated that more than £10 billion would be needed to bring "the vast majority of homes in Scotland to an EPC rating of C" (Existing Homes Alliance Scotland, 2016). Although the precise levels of investment in residential energy retrofit are uncertain, available public funding is likely to remain well below this figure. There is, therefore, considerable potential for private household investment in retrofit.

Internationally, retrofit policy in the past has often, understandably, prioritised the most cost-effective and least disruptive retrofit measures such as loft and cavity wall insulation. This approach, however, means that remaining retrofit opportunities are likely to be more expensive and more technically difficult than those of the past (Galvin, 2010) – raising questions over how any long term, retrofit programme, which will need to tackle more hard to treat aspects, can be best facilitated. Current policy mixes in Europe are focused on retrofit that is of moderate cost and complexity, with this approach not appropriate for the achievement of deeper energy savings (Rosenow, Kern, & Rogge, 2017).

Given this background the Energy Policy Effectiveness project has decided on the following review question.

- *How can public policy more effectively encourage private, 'able to pay' households to invest in energy efficient retrofit?"*

1.4. Energy Efficient Scotland Programme

As in many other countries, retrofit activity in Scotland is supported by a wide variety of policy instruments within an overall policy package. Many of the existing policy instruments that influence retrofit activity in Scotland emanate from EU or UK levels of governance. For example, Energy Performance Certificates that are required for all homes being sold or rented result from the implementation of the EU Energy Performance of Buildings Directive of 2002, and the large numbers of cavity wall and loft insulations that have been seen in Scotland in the last 10-15 years are predominantly the result of UK-wide Energy Supplier Obligations.

Alongside the UK and EU-wide policies, there are also policy programmes that are specific to Scotland, but that are designed to work in tandem with UK-wide policy. The Home Energy Efficiency Programme for Scotland (HEEPS) incorporates a variety of schemes including Local Authority specific grant schemes and a 0% loan scheme that can be used in conjunction with the grants (Ryan-Hume, 2016). The new Energy Efficiency Scotland Programme (EESP), launched in May 2018, is intended as a 15-20 year programme that will incorporate additional policy programmes seeking to attract households to invest in retrofit.

The funding that is available from HEEPS and EESP means that Scotland is likely to receive a more generous policy package for retrofit than the rest of the UK in the coming years. In the last few years - 2014 - 2016 - roughly half of the energy efficiency measures installed in Scotland where supported by the Scottish specific HEEPS-ABS and half by the UK wide ECO scheme (Scottish Government, 2016a, 2017a). See (Ryan-Hume, 2016) for more details on retrofit policy in Scotland and how it interacts with UK-wide policy.

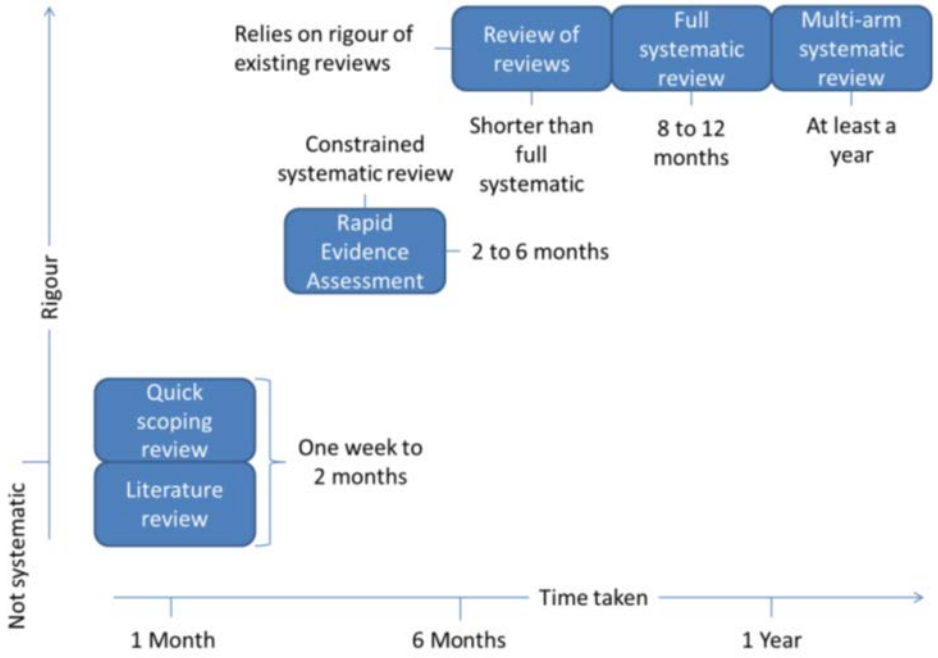
2. Methods: our approach to evidence review

The use of systematic review and 'what works' initiatives in public policymaking reflects a desire to reduce the selective and opportunistic use of evidence and foster an evidence-informed approach. There are various challenges to applying evidence based policy and practice in energy policy as evidence generation can be inhibited by the scale, investment levels and social embeddedness of energy systems.

Systematic evidence reviews are used routinely in a variety of policy domains, to signify evidence assessment that is more wide-ranging and transparent than the conventional alternative of a narrative review. Such an approach is intended to move analysis away from the selective use of evidence, or the use of evidence to back pre-defined positions.

Our evidence review is an example of a 'Rapid Evidence Assessment', taking place over a period of around 6 months. This was followed by a period of expert peer-review, revision and editing, of around 4 months.

Figure 6: UK Energy Research Centre's Technology and Policy Assessment unit timescales for different forms of evidence review (Speirs, Gross, & Heptonstall, 2015a)



In the following section we outline the method used in this review to choose the topic, gather and then assess evidence.

2.1. Stage 1: Topic selection and preliminary review

The research topic for evidence review has been agreed between the project team, and our project advisors, including the Scottish Government. It is important that this is a process of co-design, with the research systematically bringing together a variety of relevant evidence on a topic that is policy relevant.

The evidence review established a broad focus by agreeing a review question that is currently of relevance to Scottish energy policy. The review question was subject to an initial literature review,

carried out to identify *more focused* research questions. The initial literature review also determines the extent of the evidence base available to address each research question.

The review question is connected to a particular 'Policy Outcome' in the Scottish Climate Change Plan 2018 (CCP).

- *Review question:* "How can public policy more effectively encourage private, 'able to pay' households to invest in energy efficient retrofit?"

This is associated with Policy Outcome 1 from the Residential chapter of the Scottish CCP

- *Policy outcome 1*: By 2032, the energy intensity of Scotland's residential buildings will fall by 30% on 2015 levels.

In order to bring focus to the review, the project team spent one month carrying out an initial evidence review of the possible explanatory factors related to the question. A long list of such factors was compiled from a search of academic and non-academic literature.

A conventional systematic literature review has precisely defined research questions before beginning to search the literature (Curtin, et al., 2016). An alternative 'realist' perspective on systematic reviews argues that 'candidate' questions should be proposed from which the initial literature review stems. These candidate questions can be revised if the initial literature review suggests that alternative research questions should be posed. As Pawson et al. (2005) observe, systematic reviews with a realist perspective may involve the "search stage influencing question refinement and vice versa". Such a situation may arise if, in the course of the initial literature review, it became clear that the available evidence is insufficient to address the candidate question, and that a different, but related question could be addressed. Our review adopts a similar approach. We identify factors that affect the review question and then use these factors to help structure the evidence review. The final list of factors was modified from an original list during the review process.

Evidence review final sections

1. Private household investment and public policy: what evidence is there on the existing rates of private investment in home energy retrofit leverage and the level of 'additionality' of these investments.
2. Demand-side - policies aimed at households: what does the evidence say about policies to incentivise private household demand for retrofit?
3. Supply-side – policies aimed at actors involved with the delivery of retrofit: what does the evidence say about policy options that are used to support the supply of retrofit goods and services?
4. Overall policy package dynamics: What can be done to offer an overall policy support system that is stable, simple and flexible?

2.2. Stage 2: Systematic evidence review

The review process begins with a systematic evidence gathering stage. Our approach to evidence gathering is similar to that used by the Technology and Policy Assessment function within the UK Energy Research Centre (Speirs et al., 2015a; Speirs, Gross, & Heptonstall, 2015b), but also draws

on other approaches to systematic evidence gathering and searching (Kirst & O'Campo, 2012; Papaioannou, Sutton, Carroll, Booth, & Wong, 2010; Ricardo-AEA, 2015; Sorrell, 2007)

2.2.1. Evidence sources

As in other approaches to evidence review, our search is based on the use of internet search engines. For this review we primarily focus on academic, peer-reviewed literature from a limited geography following the approach of a UKERC review on the level of energy savings from energy efficiency programmes (see Wade and Eyre, 2015). The use of peer-reviewed literature is aimed at providing a quality assurance with respect to the evidence considered.

The peer-reviewed literature is complimented with additional 'grey' literature – evidence conducted by consultancy groups, independent think tanks, government agencies and others – in some sections of the review. Sections where it was appropriate to consider 'grey' literature were identified with the use of a topic specific expert group that carried out a peer-review of the draft study (see Section 2.2.3.)

In order to limit the scope of the review a timeframe of the last 10 years, 2008-2017, was applied. The review predominantly covered research from Europe and North America (countries with suitably similar histories of industrialisation and potential for retrofitting their existing building stocks) with evidence from other regions included where particularly relevant. No search engine will have a complete coverage of all literature and so multiple search engines were used (Ricardo-AEA, 2015).The academic search engines used here were those recognised as having the most comprehensive coverage of peer-reviewed literature and which are able to produce repeatable results: Scopus https://www.scopus.com/search/form.uri?display=basic and Web of Science http://wok.mimas.ac.uk/

Table 3: Search terms

Policy related terms	**Retrofit related terms**	**Policy effectiveness related terms**
Policy	Energy	Effective
Program(me)	Efficiency	Effectiveness
Mechanism	Retrofit	Evaluation
Instrument	Private	Assessment
Finance	Investment	
	Household	

These search terms returned almost 1000 academic papers. The titles and abstracts of these papers were reviewed and ranked in terms of their relevance to the review question. 183 articles were ranked as potentially relevant. These articles were then subject to a second round of light-reading and categorised into those likely of close relevance to the review and worthy of a full reading, and those deemed less relevant and not worthy of a full reading. 81 articles were given a full reading as part of the final evidence review.

2.2.2. Evidence coding

Articles that received a full reading were coded using a variety of criteria.

- Geographic region: to what geographic / policy jurisdiction context does the evidence apply?
- Policy option: what specific form(s) of policy option are under investigation?
- Sector: is the evidence related to the domestic / housing sector, or other sectors e.g. commercial buildings
- Time period: the year of publication and the period of implementation or assessment of the policy programme under investigation.

2.2.3. Expert group peer review

The draft evidence review was subject to peer-review from the overall Energy Policy Effectiveness project advisors and a group of topic specific experts – details of which can be found in the Acknowledgements section. Feedback from this review highlighted sections where additional evidence including 'grey' literature should be included in order to more comprehensively address the review question. Following peer review a further three months was spent addressing the expert feedback. The final review contains evidence from 81 peer-reviewed academic papers, 4 conference papers (3 of which were peer-reviewed), 1 book chapter and 12 'grey' literature documents.

2.3. Efficiency, equity and institutional fit: broader effectiveness criteria

The Energy Policy Effectiveness Project approaches the problem of policy effectiveness not just in terms of meeting specific policy objectives: carbon emission reduction, fuel poverty alleviation, etc., but also in terms of how *efficient, equitable* and *institutionally feasible* the policy options might be (IRENA, 2014; Mitchell et al., 2011).

This particular evidence review focuses on the *effectiveness* and the overall *efficiency* of public policy in encouraging household investment in energy retrofit. Effectiveness in this area entails the level of energy and carbon savings achieved. Efficiency can be measured in terms of the level of private investment that is leveraged in home energy retrofit relative to the utilised public funds.

This review does not focus on the other additional aspects of policy effectiveness i.e. equity and institutional fit. By using different types of policy instrument, government policy seeks to affect the financial contribution to retrofit of particular sections of society. These different instruments can be designed in a variety of different ways, with the source and distribution of their funding raising social equity questions. The review generally does not focus on how governments decide to fund the policy instruments that are considered here. The institutional fit of policy instruments needs to be addressed on a case-by-case basis and has the potential to change over time or with changes in political administration. This report does not consider the specific national institutional fit of the different policy instruments, unless highlighted in the evidence reviewed.

2.4. Limitations of the Evidence Review

Breadth but not depth

The review question is relatively broad and addresses a number of factors that are identified as influencing policy effectiveness in this area. This breadth is in contrast to many systematic evidence reviews where a narrow focus in sought in order to comprehensively assess the balance of evidence on a particular issue. The approach taken in this review enables assessment of multiple potential factors but may also entail a limited amount of evidence on some of these factors.

Evidence reporting – systematic evidence gathering for a narrative synthesis

Due to the lack of controlled experimental research within energy policy making and the breadth of the research question that we address (see Sorrell, 2007), the review does not systematically report all of the findings from each piece of evidence gathered, as this would produce an incomprehensible level of detail. Instead, we employ a more narrative and subjective approach to the gathered evidence. We attempt to extract what we consider to be the most relevant evidence to the review question at hand.

Evidence base and review structure

The field of energy investment decision making is thought to lack the "accumulation of knowledge that characterizes organized areas of scientific investigation" (Kastner & Stern, 2015). Studies routinely consider different explanatory variables using different methodologies. Nevertheless, by systematically bringing together a collection of these studies we aim to extract insight and draw lessons that can help address the review question.

Our review is structured by separating the evidence into that which applies directly to households, that which applies to supply-side actors and evidence which applies to the overall policy package. Some of the evidence considered involves articles that simultaneously assess multiple policy options, for example, an article may evaluate a retrofit programme that incorporates both grants and loans. As a result, a particular source of evidence such as a journal article may be mentioned in multiple sections and chapters. Whilst the majority of studies considered here evaluate a single or discrete group of policy measures, some of the articles considered are themselves reviews of evidence.

Context

The review is based on evidence from countries and regions around the world that are engaged in similar processes of energy system transition and energy retrofit promotion as that in Scotland. The use of international evidence to inform activity in the different contexts is however, problematic. Evidence from different contexts regarding the same variable or the effectiveness of similar policy interventions may produce very different results (Radaelli, 2000). This review reflects on the context of evidence generation, and seeks to identify and understand similarities and differences in evidence findings.

Quantitative and qualitative findings

Some of the studies considered here use statistical methods to establish the relationships between different *quantified* variables, for example, survey results that compare demographic details to levels of interest in retrofit. Other studies attempt to explain the effectiveness of a policy programme using *qualitative* evidence, often gathered via interviews with relevant experts. While the former has appeal in seeking to offer quantifiable cause-effect relationships, this is often unrealistic or potentially misleading, and the latter approach may be a more realistic response to the difficulty of determining the impact of policy in complex and open social systems. Some studies involve mixed methods, with qualitative analysis used to try and explain quantitative findings.

3. Private household investment and public policy: additionality and leverage

This section reviews the evidence on the effectiveness of public policy in encouraging private household investment in energy retrofit. Evidence on the quantitative levels of policy additionality – the extent to which policy supported retrofit activity that would not have happened in its absence - are assessed, as well as evidence on the relative levels of private-to-public funding that have been found in relation to existing policy programmes.

3.1. Additionality of policy

An important feature of retrofit policy programmes is the degree to which the investment in retrofit associated with the programme would have occurred irrespectively i.e. whether it can be considered 'additional', or whether those taking part are 'free-riders' and would have implemented the retrofit in the absence of the policy. The additionality of a retrofit policy programme is normally expressed as the ratio of the total number of retrofit measures (or total retrofit investment) in a specific time and place that would not otherwise have occurred.

When considering retrofit investment that entails the 'replacement' of an existing component of the property, for example, an existing heating device, with a more efficient one it is also necessary to only include *cost differential* i.e. the additional cost of the measure, that which is above what would have been spent if the replacement was 'like-for-like', and did not entail an efficiency improvement.

Additionality is expressed as a % of retrofit measures installed i.e. an additionality of 50% means that 50% of retrofit measures that were supported by the programme are additional. From the additionality estimates gathered for this review (see Table 5) there is some indication that additionality may be lower for retrofit that entails the 'replacement' of existing building components i.e. heating system technologies and building fabric components like doors and windows. Although there is limited evidence, more free-riding should be intuitively expected when a subsidy is applied to a component of a home that will go through a natural replacement cycle, as opposed to a component that is new or 'supplementary' e.g. new insulation. Levels of additionality may, therefore, be higher if financial incentives are applied to supplementary measures rather than replacement measures.

It is important to stress that additionality is difficult to estimate, and the shortcomings of the assessment methods are widely accepted within additionality estimation research (L.-G. Giraudet & Finon, 2015; PWP, 2017). Estimation of additionality is most often carried out via self-report surveys, although econometric methods such as logic/ranking/discrete choice modelling are occasionally used. Econometric approaches are generally considered preferable but are more costly and rely on the existence of appropriate data (PWP, 2017). An example of the limitations of self-report surveys are highlighted by Skumatz and Vine (2010), who find ex-post (after retrofit) survey methods reporting lower additionality than ex-ante (before retrofit) methods (10-20% lower).

In the US context the term additionality is not normally used and instead, efficiency programmes distinguish between 'gross' and 'net' savings using the term Net-to-Gross (NTG) (de Lovinfosse, Janeiro, Blok, & Larkin, 2012). Although expressed as *energy savings,* the savings figures used in NTG calculations are normally ex-ante technical estimates and therefore NTG, like other additionality estimates, is an expression of % of retrofit measures installed. There are different approaches to estimating NTG with the possible inclusion of positive spillovers (from participants and non-participants) and market effects. These are explained below.

Table 4: Additionality estimates from different retrofit schemes

Source	Policy instrument	Context	Retrofit activity	Method of calculation	Additionality
Alberini et al., 2014	Tax incentive (income)	Italy, 2007-2009	Heating system replacement	Multi-year, multi region consumer survey	0% additionality
Alberini et al., 2014	Tax incentive (income)	Italy, 2007-2009	Door or window replacement	Multi-year, multi region consumer survey	30-40% additionality
Nauleau, 2014	Tax incentive (income)	France, 2005-2011	Windows/Glazed surfaces	Household survey conducted before and during period of policy	15-39% additionality
(Nauleau, 2014)	Tax incentive (income)	France, 2005-2011	Opaque surface insulation	Household survey conducted before and during period of policy	23-58% additionality
(Bundgaard et al., 2013)	Subsidies and/or advice	Denmark, 2006-2011	Various measures	Phone survey on likelihood to retrofit without grant	20% (corrected - 6-8% was actually recorded)
(Bard et al., 2011)	Grant	Maine, USA	Various measures	Survey on likelihood to retrofit without grant	86% additionality
(USDOE, 2015a)	BBNP in the USA – involving multiple policy mechanisms	USA	Various measures	Self-report survey	94% NTG ratio

Participant spillovers entail retrofit measures that are influenced by the policy programme but which don't receive actual subsidy from the programme. Non-participant spillovers are retrofits carried out by households that did not participate directly in a scheme but were indirectly motivated to retrofit by the programme. Closely related to this are *market effects,* when a policy programme is thought to have changed the market structure increasing overall retrofit uptake (PWP, 2017). Some authors refer to some programme participants as 'free-drivers', i.e. early adopters of retrofit that trigger wider market transformation (L.-G. Giraudet & Finon, 2015).

These direct and indirect effects can be summarised as:

- Net savings = gross savings - free rider based savings + positive spillovers + market effects (Vine, Hall, Keating, Kushler, & Prahl, 2012)

These multiple approaches to conceptualising additionality mean that estimates are often not directly comparable. Unlike additionality ratios, NTG calculations can lead to estimated ratios that are greater than 1 i.e. programme additionality of above 100% (PWP, 2017; Skumatz & Vine, 2010).

The non-academic literature on additionality (which tends to focus on the USA) regularly observes different levels of additionality for different measures (de Lovinfosse et al., 2012; Skumatz & Vine, 2010). This variance is corroborated by our review of the academic literature. In Italy, Alberini et al (2014) found almost 100% free-riding on a scheme that offered subsidies for replacement boilers, but that a similar scheme for replacement windows offered about 40% additionality. In France meanwhile, Nauleau (2014) finds higher additionality with respect to insulation (walls, rooves etc.), 23-58%, than for windows, 15-39%.

In summary, it is important to be aware that investment in retrofit associated with a policy programme is unlikely to be entirely 'additional' investment, but also to note that policy programmes are likely to instigate wider spillover and market effects that promote retrofit beyond that which is directly subsidised. Additionality could be increased by using financial incentives for supplementary measures like wall insulation, rather than for replacement measures, which can be covered by minimum regulatory standards as is the case with respect to new boilers and windows in some countries (see Section 4.3.2).

3.2. Leverage: relative private and public investment

This section considers the extent to which private household funds have been used alongside public funds within existing retrofit policy programmes. The relative ratio of private-to-public funds within retrofit investment is often referred to as the *leverage* ratio. As with additionality, leverage is defined in different ways in different analyses. Table 5 contains the leverage estimates that were found in this evidence review – only three studies were found to have leverage estimates suitable for inclusion.

Table 5: Leverage: examples of public-to-private funding ratios*

Scheme	Leverage (% of private funds relative to public funds	Source
UK, ESO - 2002-2005	79%	(Rohde, Rosenow, Eyre, & Giraudet, 2014)
UK, ESO - 2005-2008	55%	
France, ESO and Tax credits – 2006 - 2009	37%	
Denmark, ESO - 2011	240%	
USA, HESP grants scheme – 2010-2011	240%	(Gillich, 2013)
USA, PACE loan scheme – 2011-2012	320%	
Germany, KfW loan scheme – pre 2011	400%	(Rosenow, Platt, & Demurtas, 2014)

** Some estimates are known to include only additional retrofit, while some estimates do not refer to levels of additionality)*

UK data: only including data for the 'able to pay' population in the programme. Includes third party contributions i.e. housing association, local authority, in overall public funds. Data relates to private funding contributions that are additional – estimates assume 80% programme additionality. Does not include indirect – programme development and administration – costs.

France data: data applies to whole population, with no focus on priority or able to pay populations. Includes energy supplier obligations and tax credit programme contributions to overall public funds. Programme assumes 100% additionality. Does not include indirect – programme development and administration – costs.

Denmark data: data applies to whole population, with no focus on priority or able to pay populations. This estimate assumes that 10% of the retrofit measures supported by the programme were additional. Does not include indirect – programme development and administration – costs.

USA data: data applies to whole population, with no focus on priority or able to pay populations. Assumed 86% additionality. Does not include indirect – programme development and administration – costs

Germany data: data applies to whole population, with no focus on priority or able to pay populations. Does not include indirect – programme development and administration – costs. Additionality estimates unknown.

The variation in levels seen above will to some extent be reflective of whether the scheme has a focus on certain priority social groups e.g. low income or elderly households, that will be less able to make a contribution to the cost of retrofit. This is the case, for example, with respect to the UK schemes where a significant portion of public funds are ring-fenced for allocation to vulnerable groups, whilst the German loan scheme has a much lower proportion of funds allocated to certain social groups (Kerr, Gouldson, & Barrett, 2017). It is also important to note that there are some significant differences in scale in the schemes documented above for example, a couple of hundred loans contributed to the PACE loan figure whilst many thousands of loans contributed to the KfW loan figure. Nevertheless, the figures in Table 5 indicate precedents for private to public investment ratios in retrofit schemes.

For the purposes of this review, public funding is defined as that which is instigated by a public policy intervention, including funds sourced from general government revenue or from a levy on the

consumption of a particular good i.e. energy consumption and energy supplier obligations (see Section 4.1.4). Although some public funding is necessary to facilitate all policy instruments within an overall policy package, in many policy instruments, (for example, information-based instruments such as EPCs) public funds are not used to cover the *direct cost* of retrofit i.e. the cost of materials, labour, delivery and installation.

In terms of quantitative comparisons of leverage, this evidence review only considers the public funds that are used to cover retrofit's direct costs and does not include public funds that are used to cover the indirect costs i.e. development, administration or marketing, of retrofit policy programmes, in the leverage calculations. Not all leverage figures encountered in this contained indirect cost estimates and the approach of only considering direct costs was taken in order to report leverage figures that are directly comparable with each other. The indirect costs of a retrofit policy programme can vary considerably.

Many policy instruments do not contribute to the direct cost of retrofit e.g. information based policy or regulation, but instead will use public funds to cover indirect costs involved in their administration. Although these policy instruments have the potential to 'leverage' private investment in retrofit with the use of public funds, they are not included in the leverage estimates reported in this review as no details were provided in the evidence used here.

Estimates of indirect costs encountered in this review range from 18% of overall programme costs in the UK between 2002-2008 (E. Lees, 2006; E. W. Lees, 2008) to 65% for the French supplier obligations schemes (L. G. Giraudet, Bodineau, & Finon, 2012). Public funding that covers the direct cost of retrofit can come from a combination of distinct policy instruments e.g. a grant alongside a subsidised loan. Public funds can also come from a combination of distinct *sources* e.g. central government funds used alongside local government or third party funds. Comparing policy instruments in terms of their relative direct to indirect costs is, therefore, particularly complex and context-dependent. The relative indirect costs for the French supplier obligation, for example, do not take account of the contribution to direct costs from a different policy instrument (a tax incentive).

The leverage ratio estimates used here cover the funds invested by the private beneficiary relative to any and all available public funds (even if from multiple funding sources) used to directly cover the cost of retrofit. Funds that are available from third parties are included in the public funds category.

$$\text{Leverage ratio} = \frac{\textbf{Private household funds}}{\textbf{Public funds}}$$

$$\textit{potentially from multiple public sources i.e. central government funds, energy supplier obligation, local authority etc}$$

4. Demand-side: policies aimed at households

This section considers the policy options that apply directly to households. The evidence on financial incentive instruments such as grants and loans is examined alongside energy supplier obligations, a policy instrument often used to instigate financial incentives. This is followed by the studies related to information-based policy and overall policy design.

4.1. Financial incentive options: public funds to lever private investment

There are a variety of policy options designed to improve the financial proposition for a household investing in retrofit, by either issuing public funds or reducing the household's tax obligation. These measures see the direct financial cost of retrofit shared by public and private funds. Measures can be used in combination i.e. a grant that is available only with a subsidised loan. Ultimately specific policy measures work within a *policy package* (see Section 4.3), with financial incentives normally working alongside information programmes and standards and regulations. The effectiveness of specific financial incentives for retrofit can, therefore, be difficult to distinguish.

Table 6: Different types of financial incentive for retrofit

Type of financial incentive	Definition
Grants	Receipt of funding that covers the upfront investment cost of retrofit and does not require repayment.
Tax incentive	Indirect receipt of funding via a reduction in tax obligation that covers the upfront cost of retrofit and does not require repayment.
Loan	Receipt of funding that covers the upfront investment cost of retrofit, which has to be fully or partly repaid over time.

In this review we consider the possible financial incentive options from the perspective of the household. There are multiple variations on the basic types of financial incentives outlined above e.g. income tax or house purchase tax incentives, or loans that are repayable through energy bills. For the purposes of this review, funding that is instigated by a public policy intervention – whether from government revenue or hypothecated sources such as energy supplier obligations – will be referred to as public funding. Reductions in the existing tax obligation of the household that is in receipt of retrofit is also considered as public funding.

4.1.1. Grants

Grants are probably the most widespread policy instrument for energy retrofit support (Curtin et al., 2016; Rosenow, Fawcett, Eyre, & Oikonomou, 2016). In this section we review the use of public funds for grants i.e. a one-off payment to a household to cover the cost of retrofit.

In a systematic review of both quantitative and qualitative ex-post assessments of policy programmes, Curtin et al. (2016) assess the impacts of "technology specific financial incentives for low carbon

technologies". While the study is not focused solely on energy retrofit the results refer to some retrofit policy programmes and provide useful comparisons of policy options. The authors find various studies that "illustrate the effectiveness of grants in mobilising investment from individuals", and highlight *simplicity* as a "key success factor" (see Section 6.3). A potential downside of the use of grants is that they may put inflationary pressure on costs (inflationary pressures likely apply to other financial incentives), and can be associated with stop/start investment cycles, with evidence of sudden termination in a number of programmes (see Section 6). The authors note that most households will not operate in an 'economically rational' fashion and so the capacity of financial incentives to change behaviour is limited.

Hoicka et al. (2014) consider four retrofit programmes in Canada, including a mix of information-based programmes and grants. They found that many fewer households were attracted by a performance based grant scheme (where the level of subsidy depends on the amount of energy saved) than by a scheme that offered a fixed level of grant for different retrofit options. Uncertainty in the level of financial incentive in the performance based programme may have contributed to the lack of interest. Despite its attractiveness to households, the analysis also shows that the scheme with the guaranteed grant per measure was substantially costlier in terms of funding offered per energy saving. This trade-off between overall energy saved and energy saved per unit of public funding (put differently, between policy effectiveness and efficiency) is also found in other research; Gillich (2013) finds higher overall energy savings from a grant scheme but higher private-to-public investment from a loan scheme.

In another study of retrofit programmes in Canada, Hoicka and Parker (2017) assess data from nearly 20,000 follow-up home verifications of retrofit installations - verifications of retrofit installed using a government grant. Grants were offered with advice, with the authors interested in the extent to which advice was adhered to and also whether the programme of grants helped to encourage a 'whole house, systematic' approach to retrofit; an approach they consider desirable. They conclude that "grants offered for a limited time are less compatible with the house as a system approach" (see Section 4.3.6.).

Despite a reputation for simplicity there is still the potential for households to withdraw a grant application after they have begun the uptake process. Collins and Curtis (2017) examine data in Ireland of applications for a retrofit grant in order to determine which applications are abandoned and why. Around a quarter of applications were abandoned at some point. Predictably, the authors find that more complicated, comprehensive retrofits are more likely to be abandoned. They also find that rural households are more likely to abandon than urban ones, apartments more likely than houses and older dwellings more likely than newer. They observe that applications made via an 'obligated party' i.e. an energy supply company are less likely to be abandoned than private applications, suggesting that an independent third party (intermediary) may be useful as a go-between for households, the installers and the funding body. The study does not, however, contain an analysis of *why* the rates of abandonment might be different.

4.1.2. Tax incentives

In their systematic review of financial incentives, Curtin et al (2016) find evidence that tax incentives can be effective in mobilising investment, but there is limited (and mixed) evidence on their cost-effectiveness. The study considers some of the potential downsides of tax incentive policy support. Similar to grants, a potential for stop-start support is identified. Unlike grants, tax incentives are not commonly useful for addressing barriers to retrofit presented by prohibitive upfront investment cost, as they are ordinarily received only after the retrofit investment has been made. They also cannot

necessarilly be applied to all households, as not all households are liable to pay all taxes. Finally, it is also critical to consider the saliency of the particular tax, i.e. “its visibility, transparency and the attention drawn to the tax incentive”. The importance of a tax (and related incentive) being *visible* is reiterated by Murphy et al (2012).

Crandall-Hollick and Sherlock (2016) examine the use of income tax rebate incentives for encouraging retrofit in the USA. Whilst they do not estimate energy savings or additionality from such schemes, they give some recommendations on programme design. Similar to Curtin et al, the authors note that there is a time-lag between receiving the incentive i.e. at the point of tax return and the work being carried out, and that this delay might “reduce the incentive power of the credit”. Income tax schemes apply only to households that pay over a certain threshold of income tax, and thus will not apply to all households i.e. retirees, those on low incomes etc. The report highlights that in the USA residential energy-efficiency tax credits are predominantly claimed by middle- and upper-income taxpayers (see also Curtin et al, 2016). The more resources a household has, the greater the possibility of leveraging investment beyond the public funding offered. It is pointed out, however, that if the upfront costs of retrofit are what is prohibiting credit constrained households from investing, then if the tax credits are utilised mainly by higher-income households, then they may not be the most effective policy option. An income tax incentive scheme such as this would face obvious questions over its equitability.

Alberini et al (2014) examine the effect of two different tax credit mechanisms in Italy on the uptake of retrofit. Using a multi-year, national consumer survey the authors carry out a regression analysis controlling for dwelling and household characteristics and economy-wide factors. The first incentive scheme applies to window replacements while the second to heat system replacement. Their results show the tax incentive for windows, raised replacement rates by 40 %. Meanwhile, the policy that applies to heating systems resulted in almost 0% additionality and “complete policy ineffectiveness”. According to the authors the difference may be to the nature of replacements i.e. that heating system replacement is more likely done in emergencies and thus will happen regardless of government incentives.

These findings demonstrate the considerable potential for free-riding on incentives schemes. Incentive schemes that target supplementary rather than replacement measures – measures that do not currently exist within a home – are likely to involve less free-riding. Alternatively, incentives could be available for replacement measures only if they involve the implementation of supplementary energy retrofit improvements. Replacement measures are often the subject of regulation rather than (or in addition to) incentives i.e. regulatory standards for new boilers and electrical appliances (see Section 4.3.2.).

Using a survey of French households Nauleau (2014) gauges the impact of an income tax credit system for home insulation over the period 2002-2011. They estimate that free-riding varied between 85% and 61% for windows or glazed surfaces replacements, and between 77% and 42% for opaque surface insulation. The higher additionality for supplementary measures such as insulation suggests that relatively higher levels of private investment (private relative to public funds) in retrofit may be achieved if public funding is used for financial incentives that only apply to supplementary measures.

4.1.3. Loans

Government backed loans used to support energy efficiency investment can be referred to as soft, subsidised, concessional (or a variety of other titles) and will often come with preferential terms to those available in commercial finance markets. As outlined by Kempa and Moslener (2017) a variety of features of a loan can be made preferable: lower interest rates, favourable lengths of repayment

and by the order of repayment in event of default. Government options for enacting preferential conditions include the use of public funds to buy-down the interest charged by a commercial lender, or by the use of loan guarantees or loan loss reserves to cover some of the risk of the lender, with the intention of reducing interest rates. For example, in the multi-state Better Buildings Neighborhood Program (BBNP) in the USA substantially more funds were used to create loan loss reserves ($74.6 million) than to buy-down interest rates ($10.4 million) (USDOE, 2015b).

Due to the number of variables – interest, repayment period, order of repayment, risk profile of recipient etc. – analysing the effectiveness of preferential loans is more complicated than that of grants (Kempa & Moslener, 2017). To add to the complexity, many loan programmes are administered alongside grants.

In their review of evidence Curtin et al (2016) cite research that suggests tax incentives are more popular than subsidised loans. As a "stand-alone" measure, subsidised loans tend to be less effective than grants and tax incentives, although there are few studies that look at the cost effectiveness of subsidised loans. Rosenow et al. (2017) observe that loans for retrofit are most often used to fund work that is of higher cost and complexity.

Preferential loan conditions require careful consideration. One way of reducing the interest on a loan is for it to have some collateral attached. Property Assessed Clean Energy (PACE) loans in the USA – where the financing of retrofit involves a debt that is repaid through property taxes – have a system of collateral or securitisation. According to Rosenow and Eyre (Rosenow & Eyre, 2013b) the property tax repayment is senior to other payment liabilities e.g. mortgages, with the default risk thus significantly reduced. This system has, however, recently been legally challenged by leading mortgage providers in the USA. The financing typically comes from local government authorities issuing bonds, with local authorities fully administering some schemes (Gillich, 2013).

Kempa and Moslener (2017) point out that loan guarantees offered by government will often not be 100% as this would "induce moral hazard" weakening the monitoring incentives of the lender. Speer (2012) highlights that in the case of a public funds subsidising interest rates there needs to be a good relationship between the private lender and the public funder so that initial rates are not set above the market rate, in anticipation of the public subsidy. Štreimikienė (2016) outlines that loans for energy retrofit in some Baltic States that involve fixed rates of interest for a period, followed by a variable rate, with energy assessments also covered by the loan. Pollo (2017) lists a number of constraints on the housing retrofit market in Italy and highlights the difficulty in lending for energy efficiency improvements at the single household level, as the work may be complex and lending practises conservative. It is noted that the scale of potential lending i.e. "small to medium size" will not attract enough interest from large financial institutions.

In recently completed research from the UK, Gillich et al. (2017a) consider the effectiveness and programme design of two major retrofit market support programmes – the Green Deal (GD) in the UK, and the Better Buildings Neighborhood Program (BBNP) in the USA. Both schemes use a mix of loans and grants for retrofit support and both are aimed at the 'able to pay' demographic (although which households are 'able to pay' is not defined in relation to either scheme).

The similarities between the schemes are in their 'scale and ambition' and their use of both grants and loans. Both schemes have the stated objective of "fundamentally and permanently enhancing the market for domestic energy efficiency retrofits". The BBNP is a heterogeneous scheme with different approaches in different states, while the GD has a relatively uniform approach across the UK. Only the BBNP schemes that offered loan programmes are considered in the comparison. The analysis sets

out to compare the policy programmes in terms of their 'marketing and outreach', 'workforce engagement' and 'financial incentives'.

The study uses the 'conversion rate' i.e. the percentage of assessments that eventually lead to retrofit, as a quantitative means of comparison. It supplements this with qualitative evidence from semi-structured interviews that seek to explain the relative effectiveness of conversion with reference to "programme design and management decisions related to the marketing, outreach and workforce engagement strategies." The study contrasts the success of the BBNP in terms of conversion rate to the failure of the GD; BBNP has a conversion rate (9.1%) much higher than that of the GD (2.8%). Alongside this, the BBNP roughly achieved its objectives on implementation, energy savings and jobs, while the GD was effectively ended by low take-up and concerns about industry standards.

In terms of marketing and outreach, both schemes conducted considerable market research prior to the design of their programmes. The GD approach focused primarily on the upfront cost barrier, with an expectation that creation of demand in a market would be likely to bring forth supply. Within BBNP, the most effective means of generating participation was through personal outreach and Community Based Social Marketing (CBSM) using trusted messengers. Gillich et al. (2017a, 2017b) emphasise the deeper connection that the CBSM approach facilitated, with cold-calling and mass-media used to drive awareness but making the messenger as important as the message was seen as critical. For BBNP 'word of mouth' was the most common means through which participants entered the programme, while for the GD it ranked fourth behind direct sales, leaflets and contact with a utility company. Word of mouth is cited as the most common source of new participants in retrofit programmes in other studies in North America (e.g. Hoicka et al., 2014).

With regard to the financial details of the policies, the authors observe that while in some states a lower interest rate was more likely to drive take-up, there was at times only modest difference in sign-ups between rates e.g. between 4% and 7% in the Michigan scheme. In addition, some schemes were able to remove loan subsidies altogether once the market had matured and "lenders were increasingly comfortable lending for energy efficiency". The ratio of funds used for subsidising interest relative to other aspects of the programme e.g. rebates offered alongside a loan, should be addressed on a case-by-case basis. Gillich (2013) notes, for example, that the addition of a small "lead-in" grant for 'easy upfront measures' with the PACE loans in the USA was seen as an effective means of encouraging uptake of these.

Gillich et al. (2017b) attempt via further analysis of the BBNP's 41 different versions in the United States to propose a model of the 'optimal' retrofit programme, and to consider how this can be applied to the UK market, based on an extensive review of US experience. In terms of programme design, a full awareness of the existing policy landscape and the current state of the market (possibly including segmentation analysis) is recommended. There is a suggested consensus on the effectiveness of Community Based Social Marketing (CBSM) – active engagement at the community level -- and a recommendation that this should be given greater focus in the UK.

One key message is the idea that programmes should distinguish between *marketing* and *outreach*. Other recommendations include communication between the programme administration and the workforce and between workforces. Developing intermediaries is advocated, such as 'energy advisors'. However, financial incentives need to be carefully calibrated to programme location and length. The authors cite evidence from Michigan that the most effective uptake of retrofit was seen with relatively low assessment rebates and higher retrofit rebates, and having some charge for energy assessment may filter-out less serious customers.

A third paper from Gillich (2013) examines financial incentives for energy retrofit in Maine, USA comparing a grant scheme to a loan scheme, as the State government replaced the existing Home Energy Saving Plan (HESP) grant scheme with a new Property Assessed Clean Energy (PACE) loan scheme. The grant programme was more cost-effective than the loan programme in terms of energy saved per unit of public funding, although it is not clear whether it was funding lower hanging fruit (i.e. more cost-effective retrofit). The loan scheme had a higher degree of private-to-public funds leverage, but lower overall energy savings because its uptake was much lower. The recurring observation is that loans are less attractive to households than other financial incentives. However, Gillich (2013) suggests that loan schemes such as PACE given their higher leverage, could be more economically sustainable in the long term. Overall, loan programmes can take a while to gain traction, "but can play a key role in generating a more long-term market change" (Gillich et al., 2017a).

Rosenow and Eyre have conducted both ex-ante (2013) and ex-post (2016) assessments of the Green Deal (GD). The ex-ante assessment suggested that the scheme may struggle to attract uptake due to its above commercial rates of interest. The analysis also draws attention to the need for a comprehensive policy package to address the many different additional barriers to retrofit (see Section 4.3.1 and 4.3.2), suggesting that the GD would be unlikely to shift households from non-interested to interested. The ex-post assessment also draws attention to the prohibitively high levels of interest, but also, the perceived narrow marketing strategy that focused on the financial proposition, rather than the "greater aspirations that people have for themselves in their home: comfort, well-being and health."

An earlier GD assessment (Rosenow et al. 2013) compares the GD to the German CBRP loan scheme. The schemes operate with very different interest rates: the GD with a high, commercial rate, addressing only retrofit measures that are deemed cost-effective, while the CBRP offered lower levels of interest for measures that achieve a certain level of energy saving. The two loan schemes do not necessarily have to be alternatives: "one could even imagine a policy landscape in which both schemes operate, focusing on different technologies and segments of the building stock".

Zhao et al. (2012) assessed consumer responses to home energy financial incentives for a variety of residential energy-efficient and renewable energy (EERE) products, including solar panels, high-efficiency air conditioning and house insulation. The study found that up to a quarter of respondents would invest in insulation if 30% of the upfront cost was covered by a tax incentive, while around 30% of respondents considered themselves 'very likely' to take up the offer of a loan for insulation if it was offered at 0%. In line with other studies (Curtin et al., 2016; Gillich, 2013; Gillich et al., 2017b) one off payment of public subsidy (in this case tax credits) were valued much higher than interest-free loans.

4.1.4. Energy Supplier Obligations

One of the most common mechanisms for retrofit policy support has been the use of Energy Supplier Obligations (ESOs), sometimes termed white certificates. Retrofit ESOs typically entail the requirement for a certain amount of retrofit support activity or overall energy savings being placed on energy suppliers, network operators or other parties. What is acceptable as retrofit support activity varies from scheme to scheme, with ESOs used to support any of the policy instruments outlined above i.e. grants, tax incentives or loans, as well as other forms of support than do not directly cover the economic cost of retrofit such as advice or energy audits. Required levels of retrofit support activity are typically monitored using the allocation of certificates for certain pre-defined actions. ESOs often involve a trading mechanism to allow obligated parties (OPs) to buy certificates that account for obligated retrofit activity, or sell any excess certificates for retrofit activity for which they are responsible.

As ESOs ordinarily entail a target for level of activity rather than a funding target, OPs are incentivised to carry out their obligation as cost-effectively as possible. As highlighted, there are a variety of means by which OPs can achieve their target that vary from scheme to scheme; ordinarily, however, OPs can gain full credit for activity that they only partly incentivise, providing an inducement for them to leverage as much private household funding as possible (Rohde et al., 2014).

An important observation with respect to ESOs, frequently made in the research literature, is their cost-optimisation. With respect to ESOs in the EU, Moser (2013) points out that "suppliers prefer to implement measures at those households which enable them to minimise their costs". Rosenow and Eyre (2013b) point out that ESOs have historically all targeted marginal cost optimisation, while Schlomann et al. (2013) suggest that identification of the most cost-effective options is an important advantage of ESOs.

However, this emphasis on cost-effectiveness has its drawbacks. Citing Vine and Hamrin (2008) Weiss et al. (2012) argue that ESOs can lead to the pursuit of short-term, inexpensive measures, instead of those with a "longer-lasting, broader impact. As a result of this the authors ultimately do not recommend ESOs for future German retrofit policy. Rohde et al (2014) highlight that leverage in Danish ESOs may be much higher than its UK and French equivalents as it encourages support at the time of the "regular maintenance cycle", so requiring less public subsidy. This approach has, however, implications for the scheme's additionality as "the higher the leverage factor, the lower the additionality".

This again highlights the important dynamic between leverage and additionality (the recurring tension between policy efficiency and overall effectiveness). OPs seeking cost-optimisation will tend to focus on activities that require the least incentive and thus are the closest to happening anyway, in order to achieve higher levels of private household contribution to activities for which they gain credit. Such an approach, unchecked, is also likely to lead to a targeting of those households most able to pay for retrofit, with implications for equitable distribution. As a result, ESOs in the UK, and other countries, involve a ring-fenced requirement for some retrofit support to be focused on certain priority social groups.

Combining ESOs with energy supplier voluntary agreements (ESVAs) is suggested as a means of encouraging larger, more expensive retrofit projects by Oikonomou et al. (2009). The authors assess the potential of such an approach in a theoretical sense, imagining the operation of a fictional scheme, based on existing VA and ESO schemes in the Netherlands. The ESVAs are envisaged as involving a tax incentive for the energy supplier if they achieve greater energy savings than they are required to by the ESO. The analysis lays out the possible operational variables and interactions of the combined policy package, and some of the potential problems, such as double counting of savings, and the conditions that would need to be met for an effective operation of such a scheme i.e. high compliance, strong regulatory framework, low administrative costs etc.

4.1.5. Financial incentives summary

Grants can be a quick and relatively straightforward way to kick-start retrofit uptake and there is consistent evidence that they can promote uptake. Grants linked to the energy saved by the retrofit may be less popular than fixed grants, but may offer higher energy savings per unit of public spend – better leverage efficiency.

Tax incentives are another common form of retrofit incentive but they have some downsides as identified in the evidence here. They do not address the upfront cost barrier and they are almost inevitably received sometime after retrofit expenditure. There are substantial levels of free-riding reported in some studies, although this is a feature of all retrofit policy instruments. The two studies that measure free-riding here both suggest that additionality is higher when a measure is supplementary or 'additional' to the household.

The use of policy to offer preferential loans for energy retrofit might be seen as attractive to those managing limited public funds looking to achieve public policy objectives. There are a wide variety of ways to package loans e.g. on-bill financing (Green Deal) or linked to property tax (PACE), and there a variety of means of improving loan terms e.g. public funds buying down interest or loan guarantees. The evidence consistently suggests, however, that loans are less attractive to households than grants and tax incentives. Some studies find a higher ratio of private-to-public funding from the use of loans rather than grants, but the low uptake of loans mean that overall energy savings are higher from grant schemes, again suggesting a tension between policy efficiency and overall effectiveness. Community based marketing schemes and policy programme engagement with the supply-side have had some successes in promoting the use of loans for retrofit

4.2. Information-based policy - convincing households to retrofit

A lack of information, or 'information asymmetry', about home energy efficiency opportunities or home energy use more generally, is regarded as a principle reason for a lack of investment (Brounen et al., 2013; Johnson et al., 2012; McDonnell and Sinnott, 2010; Pollo, 2017; Tuominen et al., 2012; Zuhaib et al., 2017). Information based policy mechanisms, are however, perceived at times as having no more than a supportive role in overall strategy; they also have a reputation for being the most difficult to evaluate (Murphy et al., 2012).

In this section we consider evidence on the effectiveness of methods that can be used to convince households about the positive consequences of retrofit.

4.2.1. Explanatory variables: explaining why households retrofit

There is a considerable amount of research that looks at the variables that may be positively or negatively associated with a household's decision to retrofit. Although not directly related to the design of policy this section involves a review of the international evidence on the variables that can explain likelihood to retrofit.

Kastner and Stern (2015) review 26 empirical studies that consider "major energy-relevant investment decisions" i.e. across a broader set of investments rather than just retrofit. They make some tentative conclusions that apply across energy investment decisions. The most important variables for explaining why a household might invest in retrofit relate to expected positive consequences: independence of energy supply, improved thermal comfort, environmental and financial consequences are seen as the most important, with aesthetic and social consequences considerably less important. The review suggests that variables that are easier to measure i.e. demographic and house type variables, have much less explanatory power than positive expectations, but that easier to measure variables are the focus of the majority of studies. Demographic variables including gender, education and occupation were rarely associated – positively or negatively – with energy investment decisions. Income, however, has a relatively strong positive relationship with energy investment decisions.

Kastner and Stern raise concerns about the validity of self-reported studies, such as surveys. They highlight that such methods can give rise to bias toward emphasising virtuous influences such as environmental concern, while downplaying the role of some other variables such as social influences i.e. social norms and the influence of others.

Using the results of an online survey of almost 4,000 Norwegian households, Klöckner and Nayum (2016) consider how the drivers for and barriers to retrofit may have different significance at different stages of a decision making process. The most important drivers are the expected consequences of comfort improvements, better living conditions and an expected reduction in energy costs, while the most important barriers at this stage are not owning the property and "feeling that the right time has not yet come".

When moving from the "what to do" to "how to do it" stage, access to information and expected reduction in energy cost were now the main drivers, while not managing to make a decision and "feeling the right time has not yet come" were considered the principle barriers. At the final stage of planning implementation barriers included the time demand of supervising work and again "feeling that the right time had not come". The main drivers at this point were the expectation of a payback in a reasonable time and comfort improvements. As the "right time has not come" barrier is prominent at every stage, the researchers recommend targeting people during the installation of a major planned or an emergency refurbishment. The contractor involved in such refurbishments is considered an appropriate intermediary.

Overall, comfort and health drivers are more important than economic drivers, as they have greater relevance at all stages. The study concludes that overall economic drivers grow in importance as the stages progress, but that subsidy support is more important in the earlier 'getting interested' stage. The expected consequences of comfort, living conditions and bill savings can be the most effective messages to raise initial interest, and accessible information and subsidy support become more relevant in the 'how to' stage.

Aravena et al. (2016) use survey data of Irish households involved in the Home Energy Saving subsidy scheme. Like Klöckner and Nayum (2016) they consider whether perceived motivational determinants change during the retrofit process, as well as across different retrofit measures. The survey is taken by households that have signed up to a retrofit grant scheme and thus already have the intention to retrofit. They identify three stages: 'grant application', 'ex-ante decision' (the grant has been awarded but the work has not yet been carried out) and finally an 'ex-post decision' stage (the point after the household has implemented and experienced the retrofit).

At all stages of the decision-making process, from application to considering further investment, economic factors (particularly energy bill savings) are the main drivers. Comfort gains were consistently found to be the second main driver at each stage. The environmental factor did not score highly, and households that were more motivated by the environmental factor were found to be less likely to complete the retrofit. The importance of the different motivational factors was similar across the different decision stages, suggesting that behaviour changes may not occur after retrofit. In line with other studies, Aravena et al. (2016) found that most background variables (demographics, house type etc.) were not strong determinants of investments in retrofit.

In Denmark, Christiansen et al. (2014) analyse the results of an online survey of over 700 home owners that have recently received an Energy Performance Certificate (EPC). Improved thermal comfort was the most important reason for retrofit, with energy bill savings also rating highly. The researchers make the point that it is "problematic" to distinguish between general renovation and

energy renovation as the qualitative evidence from the research shows that energy-related renovations are often done for other reasons than energy efficiency alone (see Section 5). The study concludes by challenging the perceived economic rationality framing of EPCs in Denmark, and it is suggested that they should emphasise "some of the potential, additional comfort-related benefits of measures".

In the UK, Pettifor et al (2015) assess the success of the Green Deal in terms of how much it affected the intentions of households with respect to energy retrofit. They 'repeat survey' over 500 home owner-occupiers, four months before, and then seven months after the launch of the policy. The researchers divide the sample into three; a treatment group that have intentions to energy renovate, one control group that intend to renovate but have no *energy* renovation intentions, and another control group that have no renovation intentions at all. Between surveys attitudes towards energy efficiency became more positive in both the energy renovator and the non-energy renovator groups, and it is thus suggested that energy efficiency is of potential appeal to all households considering some form of renovation, regardless of their initial intentions. There is often a lengthy time over which renovation decisions unfold and strengthen or weaken, and that viewing decisions in terms of a set of stages may provide more opportunity to encourage renovation. Finally, the authors suggest that there was too much focus on the financial proposition of energy efficiency in the marketing and delivery of the Green Deal and that these drivers are "insufficient to encourage homeowners to make major changes to their homes". More emphasis is needed on information, advice, finance, and quality assurance provisions as "complementary means of achieving broader home improvement objectives" (see Section 4.3.1.).

Based on around 150 semi-structured interviews with individuals in the UK, Pelenur and Cruickshank (2014) assess the relationships between household demographics and motivations for energy efficiency. The authors identify different motivations: saving money, environmental and resource efficiency, warmth and comfort, aesthetics and space, health and safety and time and convenience. Of the demographic variables, none of sex, age, education level, number of bedrooms/occupants were significantly associated with any of the motivations. The 'saving money' motivation was however, strongly associated with households earning over £40,000 while 'resource efficiency' was associated with households earning under £40,000 (this finding contrasts with Kastner and Stern above). Married interviewees meanwhile, were strongly associated with the motivation to save money, with single interviewees strongly associated with resource efficiency. Finally, interviewees living in flats associated with resource efficiency while those living in semi-detached properties associated with saving money. The authors highlight the limitation of their survey in the reporting of perceived motivations, rather than stable observed truths. Self-reported findings like this are subject to various bias (Kastner & Stern, 2015; C Wilson, Crane, & Chryssochoidis, 2015).

In another study, also UK-based, Pelenur and Cruickshank (2012) used the same demographic variables: sex, age, etc. but statistically linked them the perceived *barriers* to energy efficiency, rather than motivations. The authors found no statistically significant association between age, income and number of bedrooms for any of the identified barriers, in contrast to other studies which find age and house size to be factors. As a result, they argue that education campaigns for energy efficiency should not focus on particular age, income or household size groups. However, there are differences between men (who are strongly associated with institutional barriers i.e. those related to government, energy company actions, and the landlord/tenant barrier), and women (who are more likely to feel that they do not have sufficient information, and that family/partner/housemates would be opposed to the changes). Differences in the barriers of different marital status – single respondents were more likely to respond with their 'beliefs' and the 'landlord/tenant' issue, while married respondents were likely to

perceive the barriers of 'family/partner' and 'property' i.e. the physical limitations of the home itself. Those with an education at degree level or above were more likely to be put off by the 'landlord/tenant', the 'property' and the 'personal behaviour' i.e. a "complex barrier which conflated behaviour and attitudes".

To consider the attitudes to residential energy saving policies in South Korea, Yoo et al. (2017) carried out a face-to-face survey with 1,500 residents of Seoul. They conclude that older respondents are more interested in environmental and energy problems, but that younger respondents actually participate more actively in energy-saving practices. They also observed that the lower income group had the most interest in and were most likely to engage in trying to save energy. Overall the authors conclude that tailoring government policy to take account of the diversity of ages and income levels can be useful.

4.2.2. Explanatory variables: the economic argument

A contentious point in the evidence base is the degree to which households are influenced by the economic costs and benefits associated with retrofit. In some studies these are seen as of paramount importance (Aravena et al., 2016); others suggest that they receive too much focus and that the alternative motivating factors and deterrents should receive greater attention (Christensen et al., 2014; Pettifor, Wilson, & Chryssochoidis, 2015). In this section, we look closely at what sources in the review say about the economic framing of retrofit.

Gillich et al. (2017b) concluded that among the programmes they studied "nearly all that tracked homeowner motivations found that the cost of a retrofit was cited as the top reason for non-participants, and the availability of a rebate or financing was given among the top reasons for those who did participate". They recommended that programmes should include financial incentives within their overall policy package.

The evidence review from Curtin et al. (2016) however, sets out the perceived limitations of the economic framing, given that individuals do not necessarily act in an economically rational manner. The view that too much emphasis is put on the economic influences affecting behaviour is connected to behavioural economics and sociological theories, and is regularly encountered in the literature (Bundgaard et al., 2013; Christensen et al., 2014; Pettifor et al., 2015; Rosenow & Eyre, 2013b; Visscher, Meijer, Majcen, & Itard, 2016; C Wilson et al., 2015).

Another perspective is offered by Galvin (2014). At the end of a five-year in-depth study on how retrofit rates in Germany are below that expected by policy makers, Galvin argued that German promotional materials place too much emphasis on economic viability. Economic calculations ignore some hidden costs, such as the hassle of the work disrupting day-to-day life, and make spurious assumptions that mean that the claims of cost-effectiveness ring hollow with many households. He argues that the cost-effective claims "tend to deter homeowners whose understanding of microeconomics is above a rudimentary level". Claims that retrofitting to EnEV (German home energy efficiency) standards is always economically viable should be dropped and instead,

"people who can afford it can be challenged to thermally retrofit their homes, just as they retrofit their bathrooms or kitchens – not because it pays back, but for other reasons: environmental concern; prestige; giving an old home a new lease of life; increased thermal comfort; and a degree of protection from swings in the price of heating fuel."

Finally, the author suggests that the stringency of performance standards in German policy prohibit some sensible retrofit measures because they do not meet the high, legally obligated standards.

4.2.3. Energy Performance Certificates

One of the primary policy mechanisms for providing information on energy efficiency and its benefits is that of Energy Performance Certificates (EPCs). The EPC system is mandated by the EU Energy Performance of Buildings Directive, although the system's implementation varies by member state. Such a system is seen as important in not just providing information to households but also creating categories to which other policy instruments can relate e.g. financial incentives that are available only if a property improves its energy rating category (Killip, 2013b) (see Section 3.3.1.). As Killip observes, the recommendations of EPCs (in the UK) do not represent true 'technical potential' but rather relay information on the retrofit measures promoted by existing policy programmes. The authors suggest that EPCs could be improved by the inclusion of guidance as to which retrofit measures could take place alongside Repair Maintenance and Improvement (RMI) activity (see Section 5).

An online survey of roughly 700 respondents offered interesting data on the usefulness of EPCs in Denmark (Christensen et al., 2014). The survey suggests home owners do not perceive themselves as lacking knowledge on the energy efficiency of their home or how to improve it. Although the EPC is viewed as being reliable, it had limited influence on homeowners' energy retrofit practices. It is suggested that households may find the detail in EPCs too general and trivial. The research challenges the notion that lack of knowledge and awareness are the most critical barriers for homeowners. Suggested improvements to the EPC system include the "usability of the recommendations", such as by including information on how to find qualified tradespersons or by including DIY recommendations. Murphy et al. (2012) cite work by Gram-Hanssen et al. (2007) that also draws attention to the weaknesses of the EPC as a stand-alone tool and adds that it ''will only be effective if the prospective informees are sufficiently interested to want to help themselves to the packages on offer''.

There are several studies that consider the impact of EPCs on a home's retail and/or rental value (see Section 4.3.4.).

4.2.4. Home energy assessments

Energy assessments are distinct from EPCs on account of their "face-to-face element" (Murphy, 2014). For Murphy (2014) an energy assessment can in theory "remove [both] the information deficit and unnecessary information overload by providing bespoke advice". Murphy's analysis of energy assessments in the Netherlands (2014) compared the level of retrofit activity of a group that had an energy assessment with one that did not. She found no demonstrable impact, as the control group carried out as many measures as the assessment group.

The effectiveness of energy assessments for German households is analysed by Frondel and Vance (2013). Using statistical analysis, the authors use a data sample of over 2,500 home owners and consider their retrofit activity over 9 years. The authors conclude that they find some increase in energy retrofit after households have an assessment, but they highlight the difficulty in assessing such changes. They found substantial diversity in how homeowners respond to assessments and note that the effect of an assessment may not always be positive – information can lead a household converting from a positive to negative view of retrofit.

In their review of energy investment decision making, Kastner and Stern (2015) also find face-to-face assessments to have some positive influence on decisions, but again highlight the difficulty in measurement, pointing out that the value of an energy assessment/energy consulting would be more

accurately measured indirectly via long-term observation, rather than by self-reporting. They also suggest that the effectiveness of an energy assessment depends on whether it is performed face-to-face and by a credible source (see Sections 5.2).

Hoicka et al. (2014) observe that as the cost of energy assessments increases those that have a better current energy performance rating tend to lose interest, while those that have a lower rating (and, therefore, more to save) will be more prepared to spend on an assessment. Gillich et al. (2017b) report no relationship between the level of the subsidy available for energy assessments in the US and eventual retrofit uptake. The most effective uptake of retrofit was seen with lower levels of assessment grant and relatively higher levels of retrofit grant.

4.2.5. Information-based policy summary

The evidence reveals considerable diversity between different national contexts when seeking to explain why households might retrofit their property. Results are context-specific with limited international consistency in terms of explanatory variables. There is some consensus that a belief in the benefits best explains why households retrofit, but mixed evidence on which expected benefits are the most powerful. The expectation of a reduced energy bill and improved comfort are, however, the most typically cited as of importance. There is some concern that inappropriate emphasis is placed on the financial aspects of retrofit in promotional tools, and that other motivational factors, such as home comfort, should receive more attention. There is some concern that self-reported data from surveys (that composes the majority of the evidence associated with explanatory variables) is subject to biases and under-reports some factors, for example, social influences.

The evidence suggests that retrofit should be framed alongside general, non-energy home renovations and that there is an opportunity to promote retrofit alongside this kind of work (in line with the findings of Section 5). It is also important to note that retrofit decision-making takes place in distinct stages, with different influences and government policy likely to be more salient at certain points.

The limited amount of evidence available on information dissemination policies suggests that these can play a supportive role in policy packages, and that improvements could be made to EPCs. Finally, energy assessments were found have both positive and negative effects and the face-to-face engagement with households should be carried out by a trusted, credible source.

4.3. Policy package design

This section considers evidence on other aspects of the overall policy package that address household demand for energy efficient retrofit.

4.3.1. Overall policy mix

The evidence highlights the need to consider the overall policy package, and the interaction between different policy instruments when developing policy support for retrofit. Policy instruments have the potential to mutually reinforce one another, or they can partially overlap, with their combined effectiveness potentially less than the sum of the parts.

Rosenow et al. (2016) consider the interaction of different pairs of policy instruments in the EU, and whether combinations of instruments are complementary, overlapping or neutral, i.e. whether they increase, decrease or have no impact on overall effectiveness. They conclude that information measures, energy labelling schemes and standards can reinforce the effectiveness of all other instruments i.e. grants, loans, tax incentives and regulations. Financial incentives used in conjunction

are more likely to overlap with each other. Fiscal measures such as an energy or carbon tax can also act to reinforce these policy instruments but are seen as having greater political challenges than other measures, with the institutional fit varying considerably between policy contexts. Evidence on the dynamics of an overall policy package is considered in Section 6.

Rosenow et al. (2017) highlight that there has been a focus on the 'lowest-hanging fruit' of retrofit opportunities, with the potential to 'lock-out' future, deeper retrofit as households are reluctant to subsequently carry out other, more disruptive projects. The authors suggest that most buildings can expect to be retrofitted once every 40 years. Given that a one-off whole house retrofit may not be practicable for many households, the authors make the case for a comprehensive policy package which allows support for both "one-off improvements and more complex (and potentially staged) solutions)" (see Section 4.3.6.)

4.3.2. Regulations

Various examples of regulation - that legally enforce minimum energy efficiency standards and thus retrofit on existing properties – can be found in countries around the world. They typically apply at the point of adding a new element to a property (an extension) or when renovating an existing element of a property. At either of these points the regulated standards can be applied to the new element or to other existing elements of the property (Murphy et al., 2012).

The effectiveness of such policy instruments has received little evaluation research in the evidence reviewed here. Several sources, however, make reference to the importance of regulations within an overall policy mix. Killip (2013b) highlights the market transformation approach used effectively to promote condensing boilers in the UK, with financial incentives being followed by voluntary standards, and then mandatory ones. Such a ramping up of minimum standards via regulations are routinely applied to new technologies, but are more problematic and less commonly seen in relation to building fabric.

In a further paper Killip (2013b) observes that mandatory minimum standards can limit innovation by acting as a target for installers that is "to be met, but never exceeded". It is suggested that voluntary standards should not only precede compulsory standards, but also be raised when compulsory standards are introduced to promote further innovation. Regulations, although seen as necessary to improve standards, may lead to additional training and accreditation that results in a fragmenting of roles and responsibilities raising the prospect of a need for an integrating intermediary (see Section 5.3).

In their analysis of the policy mix, Rosenow et al. (2016) suggest that regulations can frequently be used to improve the effectiveness of instruments such as information schemes (see Section 4.2). In a further paper Rosenow et al. (2017) observe that regulations are the second most prevalent policy instrument (behind grants) in the residential buildings sector in the EU, suggesting an appreciation of the need for "both carrots and sticks" in an overall policy mix.

In their qualitative evaluation of retrofit policy instruments in the Netherlands, Murphy et al. (2012) find relevant stakeholders (via semi-structured interviews) to be dismissive of the impact of regulations that only apply to new elements of a building, with some interviewees concerned about the legality of regulating for consequential energy improvements to existing elements of a property. Camprubí et al. (2016) observe that if efficiency standards for existing buildings are not made mandatory, their effectiveness is limited. The authors also observe that mandatory standards may have the impact of detering some households – particularly low income households – from carrying out work at all.

4.3.3. Trigger points

In the context of energy retrofit a 'trigger point' is a point in time when retrofit is perceived to be more feasible. As policy makers look to improve policy through innovations in design, such points in time are of particular interest in retrofit research.

Rohde et al. (2014) highlight that leverage of private investment with public funds is much larger in Danish ESOs than in the UK and French equivalents. The primary reason for this is that the Danish scheme encourages support at a renewal point in the regular maintenance cycle. For out of cycle measures, the financial barrier is much more relevant, and offering support at the natural point of refurbishment means that less public funding should be required to direct investment toward efficiency measures. Overall, the authors conclude that the lower the level of additional effort required, the higher the leverage factor, or conversely "consumers with a rather low willingness to pay are less likely to be targeted".

With regard to refurbishment cycles in the domestic sector, Weiss et al. (2012) observe that in Germany there is a standard lifespan expectation of 20 years for heating systems and 40 years for windows and facades. The point of refurbishment for these materials represents "the most opportune moment to make relatively inexpensive energy efficiency improvements". The authors argue that as most renovation projects do not involve any energy retrofit, and that regulation should be used to ensure a minimum energy performance improvement whenever refurbishment is undertaken. An approach that has been adopted in some EU countries (see Section 4.3.2).

Galvin (2014) points out that part of retrofit's costs can be shared with those of general renovation if they take place at the same time, improving the cost-benefit ratio of the energy efficiency improvement and therefore potentially its attractiveness to households. Improved economic viability if retrofit is implemented at the right time is also suggested in German research (Bundgaard et al., 2013). Weiss et al. suggest the majority of energy retrofit measures would be economically viable if "carried out within the customary refurbishment cycle, as only the so called additional costs need be compensated by energy cost savings" (Weiss et al., 2012). A principal recommendation from the authors for German policy is to make better use of general "refurbishment occasions", highlighting the point of transfer of ownership and suggesting the potential of "obligatory energy consultations" at this point (see also Wilson et al., 2015). Caputo and Pasetti (2017) also highlight the repair of a failure or obsolete component as an appropriate trigger.

Emphasis is placed on trigger points in the UK by Simpson et al. (2015) who argue that there "is strong evidence to suggest that public policy should provide greater incentive to implement efficiency measures during minor refurbishments or … routine maintenance." The potential of linking energy retrofit with general refurbishment is made in other UK based studies (Pettifor et al., 2015; Charlie Wilson, Chryssochoidis, & Pettifor, 2013).

The concept of 'anti-trigger points' is raised by Tovar (2012) with households that are "trying to move from their current dwelling" given as an example where there may be low motivation for energy retrofit. This may be countered, however, if households feel the value of their property could be improved with a better energy efficiency rating (see Section 4.3.4.).

4.3.4. Green mortgages and the effect of retrofit on property value

An international study across 10 EU member states (Tuominen et al., 2012) found the most commonly reported barrier to retrofit was the perception that it has a lack of effect on property prices. In the

earlier stages of EPC implementation some research found a limited impact on purchase and/or rental price negotiation and decision making (Fuerst & McAllister, 2011; Watts, Jentsch, & James, 2011).

More recent research suggests that those interested in property purchase or rental better appreciate EPCs and general information of energy efficiency improvement, and that this is being recognised in sale and rental prices (Fuerst, McAllister, Nanda, & Wyatt, 2015; Hyland, Lyons, & Lyons, 2013; Popescu, Bienert, Schützenhofer, & Boazu, 2012). There is some evidence from the UK that property values are affected by energy efficiency improvements (Fuerst et al., 2015). Findings such as these have helped to add weight to the idea of green finance or mortgages, where the energy performance of a building is better reflected in the terms of a loan, with preferential terms being offered to properties that are more energy efficient (Hamilton et al., 2016).

4.3.5. Local Authority involvement

There is some suggestion that more regional (or local authority level) governance of retrofit programmes could help to promote household interest. Long et al (2014) suggested that participants in a retrofit scheme in the north of England were “more confident, and more trusting” in their local authority than non-participants. Again in the UK, Fylan et al. (2016) carried out focus groups to address the challenges of future retrofit. A variety of participants, but particularly those from local authorities, advocated greater local control over the budget for retrofit schemes “to meet the needs of specific developments” (Fylan et al., 2016). The context of home retrofit i.e. highly distributed, small-scale actors, leads Killip (2013b) to suggest that a policy model to achieve market transformation in this sector may be most appropriately devolved to a local level, but still coordinated nationally.

Caputo and Pasetti (2017) argue that it is indispensable to foster a connection between demand and supply at the local scale via public authorities. Such an approach helps to align business opportunities in the same area, improving economies of scale.

4.3.6. Whole house, over time approaches to retrofit

An important consideration when promoting household retrofit is the extent to which policy should encourage whole house/systematic retrofit projects or accept that retrofit work is more likely to occur in more piecemeal fashion ‘over time’. Some experts support the idea of whole house retrofit projects in principle but identify the “associated complexity and resource requirements” as serious obstacles to promotion (Murphy et al., 2012). Further research from Murphy et al. (2011) argues that because of the ambition of climate change targets, whole house approaches should be commonplace, but the design of current policy programmes mean that they “struggle to become mainstream”. Desogus et al. (2013) note the economic logic to doing everything at once: “complete retrofit works should be preferred to partial ones” since the life cycle costs will be lower even though the initial investment will be higher. The economic benefits of a whole house approach are extended to the neighbourhood scale in further research from Italy by Aste et al. (2014), who advocate an integrated work “at the neighbourhood scale.”

However, Fawcett (2014) highlights that many households will find a whole house approach impractical, and are likely to be more attracted to retrofit that takes place over time, spreading the cost and disruption. The authors suggest that such an approach, if managed correctly, can deliver carbon savings of 60% or more. Within retrofit that is taking place over time it is important, however, to consider the order and potential combinations of measures. ‘Low Carbon Retrofit Plans’ specific to a property, are suggested as a means of organising retrofit over time and ensuring cost and savings efficiency.

In summary, a one-off whole house approach to retrofit may be desirable but will be impractical for many households in reality. A whole house approach does not, however, necessarily need to entail everything taking place at one time but rather an organised, planned approach to a property and what the most appropriate order of work is over time.

4.3.7. Progressive/Performance-based incentives

According to Fairey and Goldstein (2006) energy efficiency incentives should be offered in line with performance indicators rather than the cost of implementation i.e. the greater the amount of energy that an energy retrofit saves, the higher its level of incentive payment should be. Hoicka et al. (2014) also claim that performance-based incentives have the largest potential for energy savings.

Whilst advocating an approach to retrofit governance that pays greater attention to actual performance, Visscher et al. (2016) note that this can add to the administrative burden and that a "reliable quality assurance system will be very important". Kempa and Moslener (2017) suggest that tying a subsidy to the performance of an energy efficiency investment can be difficult due to the uncertainty of energy and carbon saving inherent in such an investment (see Section 4.1.1.). While Galvin (2014) suggests that "the strictness of the policy as embodied in the EnEV (German retrofit standard) is at least partly to blame for the reluctance of many homeowners to undertake energy retrofits".

5. Supply-side: policies aimed at actors delivering retrofit

Policy support that addresses the supply side of energy retrofit – actors involved with installing, designing, advising or selling home energy retrofit – was a prominent theme in the research reviewed here. In this section, we consider the evidence – much of which comes from interviews with relevant stakeholders – on how the supply-side of retrofit can be influenced by policy support.

5.1. The incumbents: current energy retrofit supply-side actors

Multiple sources highlighted that when considering the actors involved with the supply of energy retrofit it is the important to also consider those involved with *supplying general renovations or refurbishment*, so called repair, maintenance and improvement (RMI) (Owen, Mitchell, & Gouldson, 2014; Pettifor et al., 2015; C Wilson et al., 2015). As highlighted by Wilson et al. (2015) the vast majority of retrofit (in the UK and USA) takes place alongside general renovations, and seeing retrofit as distinct artificially decontextualises it for many households. The supply of retrofit and RMI goods and services is heterogeneous and dispersed, with multiple micro-enterprises. These micro-firms will frequently operate in "temporary multi-firm configurations" (Dunphy, 2016).

The sector has a reputation for being conservative and risk averse (Dunphy, 2016; Gooding & Gul, 2017; Killip, 2013a, 2013b; Owen et al., 2014). Reporting on the construction industry with regard to energy retrofit in Ireland, Dunphy suggests that low margins often impede innovation, helping to explain the sector's conservatism. In their review of policy in the Netherlands, Murphy et al. (Murphy et al., 2012) cite previous research on the Dutch context from Tambach et al. (Tambach, Hasselaar, & Itard, 2010), which identified a lack of motivation from the "incumbent renovation regime" as a major barrier to transition. Considering the UK, Killip, however, suggests that the sector is more innovative that its reputation suggests, highlighting the potential for innovations in terms of practices, rather than product innovations (Killip, 2013a).

In the context of an Irish retrofit industry – which is growing rapidly due to incentives – Zuhaib et al. (2017) carried out a survey, a workshop and a series of in-depth interviews to understand the attitudes and approaches of the retrofit industry professionals. They perceive a "huge skill gap" with a large number of professionals untrained, and a reluctance or lack of motivation to achieve some policy targets.

Some authors also cite a lack of trust in installers from households as a prohibiting factor on greater retrofit uptake (Aravena et al., 2016; Curtin et al., 2016). A high level of quality in retrofit supply is identified by Gooding and Gul as an important means of ensuring word of mouth marketing (Gooding & Gul, 2017).

5.2. Policy and the supply side

In the UK, expenditure on non-energy renovation (i.e. general RMI) has been estimated to be around 20 times as much as that on energy renovation (retrofit) (Killip, 2013b). It is perhaps to be expected, therefore, that the professional skills relating to retrofit goods and services might be underdeveloped, with a relatively immature sector in need of support from government policy.

In some national contexts it is thought that retrofit supply-side actors are insufficiently addressed by policy (Gillich, 2013; Owen et al., 2014). In the UK, for example, the expectation has been that the creation of demand will bring forth supply (Gillich et al., 2017b). In their comparison of the Green Deal

in the UK with the BBNP in the USA, Gillich et al. (2017a) found that "the GD did not prioritize the development of the workforce" it was thought that the necessary skills to deliver the GD would be brought about through financial self-interest. The BBNP approach involved "push and pull", simultaneously targeting supply and demand. With respect to the GD, training for the workforce that is both technical and non-technical would have been beneficial. The BBNP's greater conversion rate – rate of households that have a home energy assessment to those that actually carry out an energy retrofit – is considered to be driven by the different ways in which the BBNP engages with homeowners using a variety of 'touch points' and trusted messengers when engaging with both homeowners but also the workforce.

An ex-ante assessment of the Green Deal by Rosenow and Eyre (2013b) found that past experience in the UK had shown that the supply chain *could respond to policy incentives,* citing the large scale uptake of retrofit measures in the UK from the ESOs. The authors, however, warn that the more "sophisticated and expensive" measures incentivised by the GD and associated Energy Company Obligation do not have a well-developed and integrated supply chain. The expected uptake of measures was unrealistic, partly because of the lack of capacity in the supply chain.

5.3. Engaging the supply side

The call to link energy retrofit with general renovations is made regularly (Christensen et al., 2014; Galvin, 2014; Pettifor et al., 2015; Weiss et al., 2012; C Wilson et al., 2015). Owen et al. (2014) outline the importance of installers and advisors from the RMI sector with regard to household decision making regarding low carbon technologies. This group is largely composed of 'micro-enterprises' with three-quarters of firms working on homes in the UK having 3 employees or less. The amount spent on RMI currently dwarves what is spent on energy retrofit – Killip observes figures of around £20 billion spent on home maintenance and repair in 2008 and 2009, compared to £0.9 billion spent on energy efficiency under the main government programme (Killip, 2013b).

Considering that most energy retrofit takes place alongside general renovations and that many households do not distinguish between the practices, installers of renovations are a means of promoting greater energy retrofit uptake. Killip (2013a) estimates that 45% of the RMI market represents a good opportunity for integrating retrofit.

Characterised as financially precarious and risk averse with short work plan horizons these micro-enterprises are "largely beyond the reach of current low carbon policy interventions" (Owen et al., 2014). Critically, the firms are seen as being interested in stability rather than growth and innovation. In order to promote energy retrofit via these actors, policy needs to "provide incentives for the provision of lower carbon advice and solutions that match the installer's motivations for their work."

Communication with supply-side actors on policy is seen as critical. From a set of 23 semi-structured interviews with representatives of the UK retrofit industry in relation to the Green Deal, Gooding and Gul (2017) find that the industry was unprepared to "deal with the expectation of the GD, in terms of business administration and also dealing with the policy itself." They go on to advocate an increased dialogue between policy makers and private businesses to ensure that expectations are in line with reality. Reviewing a wide variety of different retrofit programmes in the USA, Gillich et al (2017b) suggest that the best practice retrofit programmes involved communication strategies engaging with contractors on an ongoing basis.

Gillich et al. (2017b) state that to engage the workforce, policy should explicitly consider the qualitative cost–benefit understanding of the contractor. Those currently involved with RMI renovation "have no

incentive to participate in the programme in and of itself, [so] the programme must ensure the benefits outweigh the perceived costs compared with a business as usual scenario."(Gillich et al., 2017a).

Adequate training of those potentially involved with retrofit installation is seen as a key barrier to uptake in the UK (Fylan et al., 2016; Killip, 2013b), Italy (Pollo, 2017) and across the EU (Tuominen et al., 2012). In research that considered the barriers to retrofitting 'fuel poor' households in the UK (but with relevance to all retrofit) the training of installers (especially on the details of external wall insulation) was highlighted by providers and housing associations as a central problem (Fylan et al., 2016).

Alongside training there should be greater levels of inspection throughout the installation process, and not just at the end. Killip (2013b) highlights the importance of an intermediary or 'integrator' as a means of ensuring retrofit projects are implemented properly with the most appropriate, accredited workforce. In interviews with UK supply-side actors Killip cites the examples of Building Control Officers who are viewed as "practical and helpful" in contrast with "powerful and unaccountable" Planning Officers. Gillich (2017b) highlights the effectiveness of 'energy advisors' in USA retrofit programmes, who act as intermediaries between suppliers and households. Such an approach is linked to the Community Based Social Marketing (CBSM) of retrofit that is seen as effective in the USA.

In a review of the barriers to energy retrofit in the Italian building stock, Pollo (2017) suggests that policy that addresses the supply side should be a priority. He argues for the joint training of designers, contractors, craftsmen and material suppliers, with workshops and demonstrations to experiment with solutions. While in their interviews with experts in 10 EU member states Tuominen et al. (2012) observe that "it is noteworthy that not many mentioned any specific training efforts to improve the skills of the people implementing the energy efficiency improvements, even though the lack of skills was a commonly cited barrier to further improvements. This seems like a clear avenue for development."

In a review of EU policy for energy efficiency in buildings, Visscher et al. (2016) draw attention to the fact that there are performance gaps between modelled energy savings and what is achieved in reality. They suggest that to reduce the gap, "stricter demands must be set for the knowledge and skills of the building professionals (designers, engineers, installers, constructors, etc.)." In the UK, a recent review of the home energy efficiency supply sector advocated the introduction of a single readily recognisable 'Quality Mark' as a means of improving standards (Bonfield, 2016).

Training is not just seen as important to the practice of installation but also with regard to "heightened customer service … increasing client trust and property performance levels" (Gooding & Gul, 2017). Sales training for retrofit installers in Maine, USA was found to have a considerable impact on persuading households that have energy assessments to actually carry out retrofit: sales training led to an increase from 10% to 60% of conversion rates for customers moving from initial assessments to purchasing the recommended retrofit measures (Gillich, 2013). In retrofit programmes perceived as effective, the workforce are critical actors in driving demand and selling upgrades to interested homeowners (Gillich et al., 2017b).

Gooding and Gul (2017) believe that improved qualifications are needed to tackle complex problems, with a suggestion that better qualified project managers may be needed for retrofit projects. Ultimately a focus on training of retrofit installers would permit improved customer service, client trust and property performance levels. Alongside Rosenow and Eyre (2012) they advocate improved accreditation of installers as a means of building trust in the supply chain.

From data gathered from semi-structured interviews with and the shadowing of heating installers, Wade et al. (2016a) highlight the importance of ensuring that supply-side actors are able to preserve their "hard earned expert identity" while also learning about the installation of new energy saving or low carbon technologies. Citing the work of Janda and Parag (2013), the authors stress that policy needs to consider how these vital actors can 're-orient' themselves, to give greater consideration to energy issues.

One possible means of tackling the lack of trust in the supply side is addressed by Tonn et al. (2013). They gather qualitative data on the effectiveness of the Home Performance with Energy Star Program (HPwES) in the USA, which applies the well-known Energy Star marketing label (more commonly seen on appliances) to high-quality, whole house energy efficiency services. Via a review of programme documentation and interviews with the schemes administrators and retrofit contractors the authors record that the use of previously well-recognised branding is valued highly by all those involved with the scheme. It is seen as inspiring contractors to improve both the quality of their work and their communications with customers. The study does not, however, gather the views of households with respect to the logo.

Caputo and Pasetti (2017) argue that the most effective means of connecting demand and supply is at the local rather than the national level. They advocate Local Energy Plans devised by Local Authorities that set out the opportunities for energy retrofit of the private building stock. This "helps to create a market, by anticipating the needs of the owners in renovating their buildings and finding work opportunities for companies". This highlight the use of intermediaries such as an 'Energy Advisors' to "build and structure the demand" and 'Energy Scouts' that inform and help the supply.

Wade et al. (2016) consider a different type of intermediary by looking at the influence that actors within supply chains have on the installation or low carbon technologies. Alongside Owen et al (2014) they highlight that supply chain actors such as plumbing and building merchants may provide a useful point of contact with the disparate supply-side actors in the sector. With a view to promoting more low carbon technologies such as heat pumps the authors suggest policy addresses how information about the benefits of new technologies is disseminated through these supply chain networks.

5.4. Summary

Retrofit policy in many countries around the world is criticised for not adequately addressing the actors either currently or potentially involved with the supply of retrofit. Retrofit policy is also regularly identified as a means of supporting 'green jobs' (see Blyth et al, 2014). Retrofit and general, non-energy, home renovations are often not viewed by households and supply-side actors, as distinctive, separate practices. Although there is considerably more non-energy renovation than energy renovation at present, several authors suggest that the promotion of retrofit alongside other forms of renovation – new kitchens and bathrooms etc. – is a potentially effective means of increasing uptake. Policy should seek to better consult and communicate with potential supply-side actors. The technical training of installers is seen as important for alleviating the performance gaps associated with installed retrofit, increasing energy savings and comfort levels, whilst sales training for both energy and non-energy renovation installers could improve overall household interest in retrofit.

6. Policy stability, flexibility and simplicity: the ideal policy package

This section considers some of the macro, cross-policy programme characteristics that are identified as influencing overall policy effectiveness. From the reviewed evidence we highlight the importance of a policy package that is considered stable from the point of view of demand and supply actors. The review also highlights that whilst stability is critical it is also important to be flexible enough to adapt over time and in different contexts and for policy to be simple enough to engage with the relevant audience.

6.1. Policy stability

Another major theme to emerge from the review is the importance of policy stability (Curtin et al., 2016; Fylan et al., 2016; Gillich et al., 2017b; Gouldson et al., 2015; Kern et al., 2017; Tuominen et al., 2012). In this section we will consider the relevant evidence, outlining what is meant by policy stability and why it is seen as important.

In their comparative analysis of energy efficiency policy packages in the UK and Finland, Kern et al. (2017) suggest that there has been excessive 'churn' in UK energy retrofit policy in the period 2000-2014, with some schemes replaced by very similar schemes with different names: a policy culture thought to increase uncertainty for stakeholders and households. The frequently changing title (but essentially similar role) energy supplier obligation schemes is the primary example. The authors also draw attention to the proliferation of policy mechanisms in the UK, noting that this "increases the challenge of ensuring consistency". In contrast, Finland offered a more stable policy environment, in which new policies have not radically altered the mix.

The UK has not always had a reputation for policy churn. In an article published 6 years prior to the Kern et al. analysis, Murphy et al. (2011) outline the approaches of the perceived national 'front-runners' in retrofit policy. The energy supplier obligation scheme in the UK at this time (i.e. Carbon Emission Reduction Targets - CERT), was seen as a good example of a long-term approach. Murphy et al. highlight the benefit of short-term cycles for targets for retrofit activity within long term stability, allowing for improvements and adjustments. Tuominen et al. (2012) identify frequent regulatory changes as one of the most commonly cited barriers in achieving energy savings in existing buildings. They did not, however, consider this to be a particular barrier at this time in the UK.

6.1.1. Policy stability and the supply side

While reference is made to the importance of stability in improving *demand* for energy retrofit, it is more often seen as a critical factor with respect to *supply side* actors. Reporting on their series of interviews connected to the UK Green Deal, Gooding and Gul (2017) highlight that, a detachment from policy was seen as critical if a sustainable business was to be created. A consistent message from the interviews "was the need to step away from 'boom and bust' strategies in relation to differing policy schemes and incentives" (Gooding & Gul, 2017). A long term policy outlook was needed to make a long term retrofit business or career more attractive, helping to address some of the issues with the quality of supply (see Section 5).

In their comparison of the GD with retrofit policy in the USA, Gillich et al. (2017a, 2017b) highlight that the conversion rate – from energy assessments to actual retrofit - was relatively stable in the USA

programmes, but fluctuated in relation to changing funding in the UK. They state that contractors are unlikely to change their business models unless there are "clear long term benefits" – an observation repeated in other studies (Gooding & Gul, 2017). It is suggested that those designing policy should carefully consider the cost-benefit balance of the relevant workforce (Gillich et al., 2017a). One example of policy support to improve the cost-benefit case of the supply side is given from a retrofit programme in Colorado, where public funding was used to create energy advisors who interacted with retrofit supply-side actors as well as households. (Gillich et al., 2017b).

Finally, Kern et al. (2017) also observe that previous research has shown that a "rapidly fluctuating policy environment" can hinder innovation, with companies preferring stability for their investment decisions and that "innovation processes can take decades" (see Section 5.1).

6.1.2. Policy stability and the demand side

In their qualitative analysis of existing energy retrofit policy in Germany, Weiss et al. (2012) state that to engage households not currently interested in retrofit it is important to have funding schemes that are stable and predictable. This is in part because refurbishment is ordinarily carried out "one step at a time" and support should be predictable over the long term (see Section 4.3.6). In the Gooding and Gul analysis (2017) a longer term outlook of policy is associated with improving public awareness of the benefits of energy retrofit and potentially strengthening the link between home energy performance and house prices (see Section 4.3.4). In her analysis of tax credit policy in France, Nauleau (2014) concludes that consistency needs to exist alongside simplicity in policy incentives, and that these need to be accompanied by good communication (see Section 6.3).

6.1.3. Achieving stability

Some degree of policy change with respect to an emerging activity such as energy retrofit is inevitable. Relatively generous subsidy schemes can be necessary to kick start interest and to establish a market (Gillich, 2013) but can be unsustainable in the long term (Curtin et al., 2016). Whilst some policy change is inevitable, studies highlight the importance of having a long term strategy (Murphy et al., 2012). Kempa and Moslener (2017) note that a long term strategy has the potential to give rise to innovative practises and cost reductions, as seen in other sectors of the energy industry.

One important feature of credible, long term policy is available funding, such as through the use of a specific energy retrofit fund or revolving fund. The ability of energy retrofit to reduce energy bills and thus potentially generate returns on investment is the basis for Gouldson et al.'s (2015) modelling of the operation of a revolving fund for energy retrofit in the UK. The fund is replenished via the receipt of a portion of forecast energy bill savings, and the authors predict that such a model could reduce the overall investment needed for a UK wide retrofit programme by 26%. A non-profit re-financing model that uses the returns from energy savings can depoliticise public expenditure, helping to ensure stability and thus help to build public awareness.

In their policy recommendations for improving retrofit rates in Germany, Weiss et al. (2012) also highlight the potential benefits of a stand-alone energy efficiency fund, suggesting it could ensure "the continuation of subsidy programmes and lead to their improved coordination and communication". The most obvious stumbling block for self-sufficient funds such as these is the need to attract participants willing to pay back the fund with a portion of their forecast savings.

Gillich et al. (2017b) argue that if retrofit policy is designed for the long term "e.g. as part of a long term infrastructure renewal programme", then natural market forces are more likely to influence retrofit uptake.

6.2. Policy flexibility

Whilst the desirability of stable and credible support for both the retrofit supply industry and households is repeatedly mentioned in research, a degree of policy flexibility is also called for; there is no value in policy stability if the overall package is ineffective. Policy flexibility is advocated both with respect to revising the approach of existing retrofit programmes, as well as implementing policy packages that are flexible enough to cater for differences in households and regions.

Interviews with supply-side actors from Gooding and Gul (2017) suggest that the UK Green Deal may have performed better if it was able to adopt innovations. Gillich et al. (2017a) suggest that the BBNPs in the USA were allowed more flexibility, helping to explain their greater effectiveness. The GD and BBNP programmes had similarly stated objectives, and their different outcomes "offers a measure of the extent to which such flexibility is useful for a loan programme."

The importance of a more local perspective on policy implementation is highlighted in Section 4.3.5. The nature of the retrofit industry i.e. highly distributed, small scale actors, may mean that regionally flexible policy implementation is appropriate. Hoicka et al. (2014) conclude that different households respond differently to different programme designs and suggest designing policy that targets particular subsets of the household population. They conclude that "one size fits all programmes" should be avoided and that policy designers should identify sub-sets of the population and then target them to achieve the desired outcomes. Market segmentation analyses are advocated by others (e.g. Gillich et al., 2017b) but designing specific policies for specific population sub-sets may put pressure on institutional capacity, as well as being at odds with calls for policy simplicity and consistency, and risk creating 'post-code lotteries', in terms of access to public funding and policy support

6.3. Policy simplicity

Curtin et al. (2016) find several studies suggesting that the administrative burden of applying for grants can be off-putting, and other studies that conclude that the *simplicity* of the application process for grants is a "key success factor". Simplicity within the application process was also noted by Weiss et al. (2012) with respect to policy in Germany and the applications for loans at local banks, especially for households currently expressing little interest in energy conservation issues. In an analysis of a broad set of energy efficiency policies in Malaysia, Hor and Rahmat (2017) suggest that a tax incentives scheme for residential and commercial buildings received only a small number of applications because of "its lengthy and cumbersome incentive approval process."

6.4. Summary

Policy support for retrofit that is considered stable – by both supply and demand side stakeholders – but also flexible enough to respond to policy assessments, is important for effective retrofit policy. Stability relates not just to policy content, but also to programme name and branding, with little benefit from changing names if the approach remains similar. Flexibility applies to the ability of a policy mechanism to be adapted if it is considered ineffective, although adaptations should be carefully considered with reference to stability concerns. Finally, simplicity within the application process for public funding support is important, particularly with respect to encouraging those not currently interested in retrofit.

7. Conclusion

The energy efficient retrofit of residential buildings has contributed to falling energy demand and carbon emission levels in Scotland, the UK, and many other countries around the world. Ambitious climate change mitigation strategies mean that there is the potential for substantial, additional levels of home energy retrofit throughout the residential building stock. However, the historical priority on cost-effective retrofit means that remaining options are often more expensive and more disruptive. The leverage of private household investment in retrofit is therefore critical to the future of effective energy efficiency policy.

A wide variety of policy options, with varying levels of public funding, can be used to encourage private household investment in retrofit. This evidence review found that the ratio of private-to-public direct investment in retrofit programmes can vary substantially between schemes, from some in which private investment is less than public investment, to others where private investment is four times the public level. The review also highlighted the importance of *additionality* – the extent to which policy increases the overall uptake of retrofit, or whether it supports retrofit that would have taken place anyway – as well as wider positive spillover effects. The difficulty of measuring additionality and positive spillovers is a good example of the difficulty of assessing policy effectiveness in the energy sector in general, where policy often applies at a macro scale to millions of small embedded actors.

Although there is a limited amount of evidence on the overall effectiveness of policy instruments, the review identifies some possible tensions and trade-offs between overall policy effectiveness and policy efficiency. Low interest loans, while likely to achieve the highest levels of private-to-public investment, may struggle to attract the same levels of household interest as financial incentives that do not require repayment such as grants and tax incentives. As a result, loans may generate lower levels of energy and carbon saving, the key criteria in overall policy effectiveness. There is a similar efficiency–effectiveness tension between additionality and leverage, with policy programmes that support retrofit likely to occur anyway – i.e. low additionality – also having the potential to leverage large amounts of private investment relative to the available public subsidy – i.e. high leverage. Perhaps the key overall public policy challenge in this area is reconciling, over time, overall policy *effectiveness* with *efficiency* concerns.

While it is often reported that households lack the necessary information on the benefits of home energy retrofit, the main information based policy tools considered in this review show very limited effectiveness, and are instead best viewed as supportive of other policy instruments. While the review found that energy savings and comfort are reported to be the most commonly identified benefits of retrofit, there was some agreement that retrofit is often too overtly framed as a narrowly financial undertaking and that its lifestyle benefits should be more heavily emphasised.

While the review has considered policy measures that directly address household demand for retrofit, it also reviewed evidence on the more indirect options that relate to the policy review question. Using mainly evidence from expert or stakeholder interviews, this highlighted the importance of supply-side aspects, and noted that these often attracted inadequate policy support. A key opportunity for higher household retrofit investment is through the installers of general, non-energy home renovations.

Finally, the review highlighted the importance of a coherent overall policy package with a range of policy instruments. While a whole house approach to retrofit is unlikely to be feasible in many cases, it is important to consider a long-term, ‘over time’ plan for properties. Regulations affecting home alteration can also play an important role in transforming the retrofit market. Specific policy instruments also need to be considered in terms of the overall stability, flexibility and simplicity of the

policy package. Although these dynamics can be difficult to reconcile they are critical to long-term policy effectiveness.

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