Household investment in home energy retrofit – designing effective policy

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Abstract

Home energy retrofit is distinctive as a low carbon policy option due to its requirement for collaboration between private households and public policy in the deeply personal environment of home. While there is an irrefutable case for public investment in retrofit there is also a strong private case and as a result there is often a joint contribution to the cost of retrofit. It involves the use of systematic evidence collection and expert evidence synthesis to address the topic of policy effectiveness with respect to private household investment in retrofit. The review considered how policy can be used to efficiently leverage private household investment in energy efficient retrofit across three key areas: demand-side, supply-side and the overall 'policy mix'. On the demand-side, while private funding levels range from well below 100% of public funding to several multiples of available public funds, levels of policy additionality, positive spill-over and market effects complicate leverage calculations. We find that while subsidised loans offer the greatest example of private to public leverage they are much less widely implemented and are perceived to be less attractive to potentially retrofitting households than one-off payment grants and tax incentives. The reviewed evidence highlights a lack of policy focus on the role of the supply-side within retrofit policy making, with these actors offering opportunities for improved performance and sales. The variables that link households with an interest in retrofit are not consistently reported across international boundaries, with correlations between variables and likelihood to retrofit in one context not existing in another. Thirdly, the paper considers evidence on the effectiveness of the overall policy mix, in terms of whether a stable policy framework is desirable, whether a flexible policy framework is possible and how policy simplicity can be achieved.

1. Introduction

The energy efficient retrofit of domestic buildings typically involves a joint contribution to its costs from public and private funds. Due to its status as a means of mitigating the impacts of climate change, alleviating fuel poverty and addressing a number of other social and economic policy goals (Kerr et al., 2017) there is a clear case for public funding of home energy retrofit. The public case is complimented by the case for investment from the point of view of the household, which incorporates the benefits that apply solely to the house in which the retrofit takes place, e.g. the potential for a warmer, more comfortable home, lower energy bills and various other private benefits.

There are a wide variety of policy options that can be used to encourage retrofit uptake. Policy efforts in many countries have tended to favour a more liberal approach of market mechanisms and information based systems, as opposed to regulations that enforce change (Gillich et al., 2017a; Ricardo-AEA, 2015a).

Considerable increases in energy retrofit have been seen in many countries around the world in recent years. EE programmes have however, routinely been implemented on a cost-effective-first basis (EC, 2010), and as a result the most economically viable retrofit has been prioritised, progressively diminishing the economics of future retrofit opportunities (Galvin, 2010). There are, however, considerable opportunities remaining for energy savings (Rosenow et al., 2017a).

In Scotland, 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, currently available public funding is well below this figure. There is, therefore, a looming investment gap between the available public funds and the investment needed – a gap that could, in theory, be met by private households. In this context, policy can be assessed in terms of how effectively it addresses overall policy objectives, but also in terms of how efficiently it leverages private investment or the extent to which it supports additional retrofit.

The deeply personal and durable nature of a home means that change from energy retrofit requires the consent and collaboration of millions of private households in a way that is distinctive and that presents its own particular challenges. This paper focuses on the contribution of private households to home energy retrofit and the evidence that relates to policy effectiveness and efficiency, of the multiple possible policy instruments in this area. Here, we report the findings of a systematic review of the evidence that considers the relationship between the private and public contributions and how policy can be designed more effectively to improve the private contribution.

Our review considers the question: "How can public policy more effectively encourage private, 'able to pay' households to invest in energy efficient retrofit?" In the process of addressing this question the review assesses evidence on the levels of private household investment in retrofit historically and policy instruments that have been used to facilitate private investment.

2. Methods

The review sought to address the following question - "How can public policy more effectively encourage private, 'able to pay' households to invest in energy efficient retrofit?" The approach relates to a research question which is broader than that conventionally associated with systematic evidence review. The approach was developed specifically for the review question and is distinctive from conventional approaches to evidence review. Evidence was gathered in a systematic process that is familiar to conventional evidence review processes.

2.1. Stage 1: Initial literature review and research question development

The evidence synthesis stage was structured by the identification of a number of themes. These themes were developed during the completion of an initial review of literature related to the research question:

1. Private household investment and public policy
2. Demand-side - policies aimed at households
3. Supply-side – policies aimed at actors involved with the delivery of retrofit
4. Overall policy package dynamics

2.2. Stage 2: Systematic evidence gathering

Evidence collection, analysis and report drafting took place over 6 months. Our approach to evidence gathering builds on 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 review (Kirst and O'Campo, 2012; Papaioannou et al., 2010; Ricardo-AEA, 2015b). For this review we primarily focus on academic, peer-reviewed literature from a defined geography (Europe and North America) and history (2008-2017), partly due to the necessity of placing parameters on the evidence base but also as a means of ensuring maximum relevance. We gathered evidence from the Scopus and Web of Science search engines using the following search terms.

Table 1: Evidence review search terms

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

This process 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. Ultimately 81 articles were given a full reading. The gathered evidence is a mix of original empirical studies on the impact of policy programmes, alongside more 'advocacy' based findings that arise from expert interviews and focus groups.

2.3. Stage 3: Expert group peer review

The draft evidence review was subject to peer-review from project advisors and topic experts. 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 responding to the 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.

3. Results

3.1. Private and public contributions to the cost of retrofit

3.1.1. Additionality: does public policy encourage 'additional' private investment in retrofit

An important feature of retrofit policy programmes is the degree to which any investment would have occurred anyway 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 a percentage of the total number of retrofit measures, total estimated energy saved or total retrofit investment, in a specific time and place that would not otherwise have occurred.

In the US context the term additionality is not normally used and instead, efficiency programmes distinguish between 'gross' and 'net' energy savings using the term Net-to-Gross (NTG) (de Lovinfosse et al., 2012). There are different approaches to estimating NTG with the possible inclusion of positive spillovers and market effects. Positive spillovers entail retrofit measures that are implemented alongside measures that are subsidised, but which don't receive direct subsidy from the programme. Closely related to this are market effects or non-participant spillover, when a policy programme is thought to have changed the market structure, increasing overall retrofit uptake (PWP, 2017). These direct and indirect effects can be summarised as:

Net savings = gross savings - free rider based savings + positive spillovers + non-participant spillover (Vine et al., 2012)

The following additionality estimates were encountered in this review (additionality is normally measured with respect to energy savings).

Table 2: 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% additionality
(Bard et al., 2011)	Grant	Maine, USA	Various measures	Survey on likelihood to retrofit without grant	86% additionality

(USDOE, 2015)	BBNP in the USA – different policy instruments	USA	Various measures	Self-report survey	94% Net to Gross (NTG) ratio
(Skumatz and Vine, 2010)	USA – different policy instruments	USA	'Home retrofits'	Different methods	50% - 100% NTG ratio

The introduction of any policy instrument e.g. information-based, financial incentive, regulations etc., will likely result in retrofit that is part additional and part not. It will however, also result in positive spillovers of retrofit not directly supported by the programme. It is important to stress that additionality and spillovers are difficult to estimate, and the shortcomings of the assessment methods are widely accepted within additionality estimation research (Giraudet and Finon, 2015; PWP, 2017; Skumatz and Vine, 2010).

Estimation is often carried out via self-report surveys, although econometric methods such as logic/ranking/discrete choice modelling can be used. Econometric approaches are generally considered preferable but are more costly and rely on the existence of appropriate data (PWP, 2017).

The additionality estimates gathered in this review almost all apply to financial incentives. These figures indicate 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. 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 30-40% additionality. In France, Nauleau (2014) finds higher additionality with respect to insulation (walls, roofs etc.), 23-58%, than for windows, 15-39%.

Although the evidence gathered here is limited, 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. 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 and Vine, 2010).

Participant spillover (PS) is thought to be of lesser impact than non-participant spillover (NPS). In a review of energy efficiency programme evaluations in the USA, PS was normally estimated at less than 5%, while NPS estimates ranged from 5% to 100% (PWP, 2017). The Energy Trust in the USA currently apply a 7% value for NPS for programmes relating to existing buildings.

3.1.2. Leverage: relative private and public investment

This section considers the extent to which private household funds have been used alongside public funds within retrofit policy programmes. Similar to additionality, leverage is ordinarily referred to with respect to financial incentives but can be estimated in relation to any policy instrument that uses public funds and stimulates private investment. The ratio of private-to-public funds is often referred to as the *leverage* ratio. As with additionality, leverage is defined in different ways in different analyses. Table 3 contains the leverage estimates that were found in this evidence review.

Table 3: Leverage: examples of public-to-private funding ratios*

Scheme	Leverage (% of private funds relative to public funds	Source
UK, ESO - 2002-2005	79%	(Rohde et al., 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 et al., 2014)

**For further details on these estimates see Kerr and Winskel* (2018)

The studies reviewed here involve only estimates of public funds to cover retrofit's *direct costs* and do not include public funds 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 review 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. As the costs of non-financial incentive schemes do not involve the direct costs being covered the leverage of these policy instruments is not considered here.

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 et al., 2017).

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.

$$\text{Leverage ratio} = \frac{\textbf{\textit{Private household funds}}}{\begin{array}{c}\textbf{\textit{Public funds}}\\ \textit{potentially from multiple public sources i.e. central government funds,}\\ \textit{energy supplier obligation,local authority etc}\end{array}}$$

Despite these limitations, the findings provide an example of the relative contributions to the cost of retrofit that can be made by private and public sources.

3.2. Demand-side: policies aimed at households

3.2.1. Financial incentive options

The evidence here relates to a wide-variety of financial incentives. For the purposes of this section, we will distinguish between 3 forms of financial incentive - *grants*, where funding covers upfront cost and does require repayment, *tax incentives*, the indirect receipt of funding via a reduction in tax obligation that does not require repayment, and *loans*, where funding covers the upfront cost but there is some requirement for repayment. In practice, these are often used in conjunction, often alongside multiple other policy instruments. Their effectiveness as stand-alone policy instruments can, therefore, be difficult to discern.

Grants are probably the most widespread policy instrument for energy retrofit support internationally (Curtin, et al., 2016; Rosenow *et al.*, 2016). Their simplicity is a key factor in their appeal (Curtin et al., 2016). Tax incentives are another popular form of financial incentive for retrofit, with the saliency of the tax of critical importance (Murphy et al., 2012). As not all households pay all taxes, tax incentives suffer from not being applicable to all households. Unlike grants, tax incentives are ordinarily received after the retrofit investment has bene made and thus do not address the barrier of a prohibitive upfront investment cost (Crandall-Hollick and Sherlock, 2016). Grants or tax incentives linked to the energy saving performance are found to be less appealing to households than a fixed incentive in one study (Hoicka et al., 2014).

Loans have a variety of features that can be altered to make them preferable e.g. lower interest rates or favourable lengths of repayment (Kempa and Moslener (2017). Government options here 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.

It is regularly observed that loans are less attractive to households than incentives which do not involve repayment i.e. grants or tax-incentives (e.g. Curtin et al., 2016; Gillich, 2013; Zhao et al., 2012). Whilst incentives that do not involve repayment might be popular with households there is also some evidence that they offer lower leverage efficiency than loans.

A common means of administering financial incentives is via the use of energy supplier obligations (ESO). An important issue with respect to ESOs is their emphasis on implementing the most cost-effective measures (Moser, 2013; Rosenow and Eyre, 2013; Schlomann et al., 2013). This approach 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. 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 highlights the important dynamic between leverage and additionality, in terms of the tension between policy efficiency and overall effectiveness. Obligated Parties seeking to achieve their obligations with minimum expenditure 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.

3.2.2. Information-based policy options: convincing household to retrofit

One of the primary policy mechanisms for providing information on retrofit and its benefits is that of Energy Performance Certificates (EPCs). An online survey of roughly 700 respondents on the usefulness of EPCs in Denmark (Christensen et al., 2014) 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 as households may find the detail in EPCs too general and superficial – the "usability of the recommendations" should be improved 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''.

Energy assessments are distinct from EPCs on account of their "face-to-face element" (Murphy, 2014). 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. No demonstrable impact was found, 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). They find some increase in energy retrofit after households have an assessment, but also that there is substantial diversity in how homeowners respond to assessments and that the effect of an assessment may not always be positive – information can lead a household switching 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 by a credible source.

3.2.3. Policy package design

3.2.3.1. Regulations

Several sources make reference to the importance of regulations with a need for "both carrots and sticks" in an overall policy mix (Murphy et al., 2012; Rosenow et al., 2017b, 2016). 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) suggests 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 on the supply-side.

3.2.3.2. Overall policy mix

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. For example

Rosenow et al. (2016) conclude that information measures, energy labelling schemes and standards can reinforce the effectiveness of *all* other instruments, while 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. In a further paper Rosenow et al. (2017) highlight the likelihood that households will desire different retrofit support at different times and thus a comprehensive policy package that offers support for households at different stages, in different ways is necessary.

3.2.3.3. Trigger points

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 due to the Danish scheme encouraging support at a renewal point in the regular maintenance cycle – a trigger point. Weiss et al. (2012) highlight the point of general home renovation is "the most opportune moment to make relatively inexpensive energy efficiency improvements". Galvin (2014), Bundgaard et al. (2013) and Weiss et al. (2012) argue that if retrofit takes place alongside general renovation its overall economic viability can be improved. Weiss et al. highlight the point of transfer of ownership as a potential trigger, while Caputo and Pasetti (2017) point to the repair of a failure or obsolete component as an appropriate opportunity. The potential of linking energy retrofit with general refurbishment and routine maintenance is made in multiple UK based studies (Pettifor et al., 2015; Simpson et al., 2015; Wilson et al., 2013).

3.2.3.4. Whole-house or over time approach to retrofit

Some experts support the idea of whole house retrofit projects in principle, due to the potential for cost-efficiency and the overall minimisation of hassle (Desogus et al., 2013; Murphy et al., 2011). 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. 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.

3.3. 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.

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

Several studies highlighted that when considering the actors involved with the supply of energy retrofit, it is important to include those involved with *supplying general renovations or refurbishment*, so called 'repair, maintenance and improvement' (RMI) (Owen et al., 2014; Pettifor et al., 2015; Wilson et al., 2015). The vast majority of retrofit in the UK and USA takes place alongside general renovations (Wilson et al., 2015), and seeing retrofit as distinct artificially decontextualises it for many households. 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).

The supply of retrofit and RMI involves multiple micro-firms which frequently operate in "temporary multi-firm configurations" (Dunphy, 2016). The sector has a reputation for being conservative and risk averse (Dunphy, 2016; Gooding and Gul, 2017; Killip, 2013b, 2013c; Owen et al., 2014) with low margins instilling conservatism and impeding innovation (Dunphy, 2016).

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

3.3.2. Policy and the supply-side

In some national contexts it is thought that retrofit supply-side actors are overlooked by policy (Gillich, 2013; Owen et al., 2014). In the UK the expectation has largely been that the creation of demand will bring forth supply (Gillich et al., 2017a), while in the USA, policy involved "push and pull", simultaneously targeting supply and demand. Policy in the USA engages with homeowners and supply-side actors using a variety of 'touch points' and trusted messengers, as a means of boosting the conversion rate – from assessments to actual retrofit.

3.3.3. 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; 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. Killip (2013a) estimates that 45% of the RMI market represents a good opportunity for integrating retrofit.

Firms are often seen as being interested in stability rather than growth and innovation, and as being financially precarious and risk averse (Owen et al., 2014). In order to promote energy retrofit via these actors, policy needs to provide incentives and solutions that match the installer's motivations for work. Gooding and Gul (2017) advocate an increased dialogue between policy makers and private businesses to ensure that expectations are in line with reality. Gillich et al (2017b) suggest the best programmes in the USA involved communication strategies engaging with contractors on an ongoing basis. Policy should explicitly consider the qualitative cost–benefit understanding of RMI contractors and ensure that the benefits outweigh the perceived costs compared with a business as usual scenario (Gillich et al., 2017b).

Training and the inspection of work throughout the installation process are seen as critical in various European countries (Fylan et al., 2016; Killip, 2013b; Pollo, 2017; Tuominen et al., 2012; Visscher et al., 2016). Killip (2013b) highlights the importance of an intermediary or 'integrator' as a means of ensuring retrofit projects are implemented properly while 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 and the effective use of multiple 'touch points' in USA policy. Improved accreditation is seen as a means of building trust in the supply chain (Gooding and Gul, 2017; Rosenow and Eyre, 2013; Tonn et al., 2013). Training is not just seen as important to the practice of installation but also with regard to "heightened customer service" (Gooding and Gul, 2017) and in driving demand and selling upgrades to interested homeowners (Gillich et al., 2017a).

Wade et al. (2016a) highlight the importance of ensuring that supply-side actors are able to preserve their "hard earned expert identity"; citing the work of Janda and Parag (2013), the authors stress that policy needs to consider how these actors can 're-orient' themselves, to give greater consideration to energy issues. Alongside Owen et al (2014), in another paper, Wade et al. (2016)

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.

3.4. 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

3.4.1. Policy stability

A major theme to emerge from the review is the importance of policy stability for policy effectiveness (Curtin et al., 2016; Fylan et al., 2016; Gillich et al., 2017a; Gouldson et al., 2015; Kern et al., 2017; Tuominen et al., 2012). Kern et al. (2017) highlight that the excessive 'churn' in UK energy retrofit policy in the period 2000-2014, has increased uncertainty for stakeholders and households. Murphy et al. (2011) highlight the benefit of short-term cycles for targets for retrofit activity within long term stability, allowing for improvements and adjustments.

Policy stability is seen as a critical factor with respect to *supply side,* as much as the demand side. Gooding and Gul (2017) report that UK supply-side actors need to shift away from a pattern of 'boom and bust', and a long term outlook is needed to make retrofit businesses or careers more attractive, thus helping to address some of the issues with the quality of supply. Gillich et al. (2017a, 2017b) also highlight that contractors are unlikely to change their business models unless there are clear long term benefits. Kern et al. (2017) 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.

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. 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. 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.

Whilst some degree of policy change is inevitable (and desirable), 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 consistently available funding, such as through the use of a dedicated fund for retrofit. In Germany, Weiss et al. (2012) highlight the potential benefits of a stand-alone energy efficiency fund helping to ensure the continuation of subsidy programmes and thus improving programme saliency and coordination. Gouldson et al.'s (2015) model of a revolving fund that is replenished via the receipt of a portion of forecast energy bill savings could help to depoliticise public expenditure, and further ensure stability.

3.4.2. 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 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 capacity within government, 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.

3.4.3. 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.”

4. Discussion and policy implications

This evidence review considered how policy can be more effectively designed to increase the uptake of retrofit and address policy objectives for carbon emission reduction and ameliorating fuel poverty. It also considered various different forms of policy efficiency, in terms of the degree to which public funds can *leverage* private investment and the extent to which policy support facilitates *additional* retrofit.

The review first addressed the issue of how private household investment in retrofit should be quantified. How much additional retrofit that policy facilitates is difficult to measure accurately with methods such as ex-post, self-report surveys, subject to well-recognised flaws. Despite the difficulties in measurement, it is likely that a significant portion of retrofit that receives public funding support will not be additional i.e. it would have occurred anyway. Although policy is unlikely to facilitate entirely 'additional' retrofit it will also entail some positive spillover effects in the form of participants in the scheme implementing non-subsidised retrofit alongside the subsidised retrofit, and the stimulus that is provided to non-participants in the overall retrofit market.

Although there will be a trade-off between the appeal of the policy incentive to households and the relative level of private to public leverage there are policy design options that can help to mitigate the level of trade-off. The review presents some evidence that policy incentives that are applied to *supplementary* retrofit e.g. new insulation, are likely to entail higher levels of additionality than those that are applied to *replacement* retrofit of existing components of a property e.g. windows, doors etc. Consequently, the additionality of policy is likely to be maximised if public funds are only used to subsidise supplementary retrofit. While public funds used in this way might more efficiently create additional retrofit, such incentives are (once more) likely to be less appealing to households.

The overall level of extra retrofit relates to a policy's additionality but also its scale. A programme that has 100% additionality but is applied to a small number of homes, may be efficient in terms of additionality but be relatively ineffective in terms of overall retrofit implementation. Whilst it could be more efficient in terms of additionality to subsidise supplementary retrofit, such an approach may be detrimental to overall policy effectiveness i.e. take up of retrofit. If public funds are used to subsidise supplementary retrofit and not replacement retrofit, there is also the issue of how this would affect the level of replacement retrofit. If public funds are used exclusively to fund supplementary retrofit, replacement retrofit could be regulated with minimum energy performance standards at the point of replacement, an approach that is seen with the replacement of boilers and windows in some countries.

A variety of different leverage ratios are encountered in the evidence compiled for this review. Although, these levels are largely dependent on the approach of the policy i.e. whether it utilises loans or grants/tax incentives and whether the policy applies universally to all households or whether incentives are targeted at households deemed unable to pay, they give an impression of the degree of private to public contribution that can be expected.

As would be expected higher levels of private leverage were found with loan programmes than with non-repayment subsidies like grants and tax-incentives. While loans are more often seen as covering retrofit of higher cost and complexity (Rosenow et al., 2017b), grants often involve a portion of funds being ring-fenced for more vulnerable households that are less able to contribute to retrofit's costs. Loans are regularly highlighted as being less appealing to households than non-repayable subsidies. This finding again highlights the potential tension in retrofit policy between overall effectiveness and efficiency i.e. that policy instruments with higher levels of private to public funding are less appealing to households and thus may result in less uptake and retrofit implementation. A similar tension between overall effectiveness and efficiency is seen in the study of Hoicka et al. (2014) where households are less likely to take up incentives that are performance based than those that are fixed, but that performance-based incentives provide more efficient levels of energy saving to public funds.

It is important to observe that loans, grants and tax-incentives are routinely used in conjunction. The relative weight of non-repayable subsidy (grant, tax incentive) to repayable subsidy (loan) in a particular financial incentive programme will influence the leverage ratio and the relative appeal of the incentive, and ultimately the level of retrofit installed.

Various sources make reference to how policy should make use of the potential trigger points that exist in relation to retrofit. A commonly cited opportunity for retrofit triggering is that of RMI renovation. The RMI market is reported as currently being many times larger than the retrofit market and with households not normally distinguishing between RMI and retrofit this is seen as a key opportunity for retrofit policy to apply.

A related theme of the reviewed evidence is the importance of policy to go beyond relatively narrow assessments of leverage and additionality, and to situate effectiveness assessment in a broader context of retrofit demand and supply. The review highlights that the nature of the renovation and retrofit industry i.e. highly distributed, micro-enterprises that operate on low economic margins and can have conservative attitudes to change, means that engaging it with the potential level of change required is difficult. For industry to engage with the potential for retrofit change, policy should involve a dialogue with supply side actors and explicitly consider the costs and benefits to their business of implementing more retrofit. Policy that properly engages with the supply-side could also work to improve training and thus improve the performance of newly installed retrofit.

On the demand-side a lack of information about home energy efficiency opportunities or home energy use more generally, is regarded as a principle reason for a lack of investment. Information based policy mechanisms, are however, perceived as having merely a supportive role (although still necessary) in overall policy.

Alongside policy that seeks to persuade demand and supply side actors to engage with retrofit there are a variety of options for policy makers that mandate retrofit. As highlighted, replacement retrofit could be subject to mandatory minimum energy performance standards as can be seen with new windows in some regions. Further incremental introduction of regulations including retrofit at the point of other home renovations may be a necessary feature of future retrofit policy.

We also highlighted the need for a policy package that is considered stable from the point of view of demand and supply actors. 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. The evidence that relates to overall policy dynamics reveals further tensions within retrofit policy. While policy stability is desired, the complexity of facilitating wide scale change to the embedded, private environment of home means that policy lessons will inevitably be learned in the lengthy transition period, and policy change and flexibility are necessary evils. Flexibility is also called for in a wide-ranging policy package that ranges across varied types of housing and occupants. Aligning this need for variability with simple and salient measures will require considerable policy design expertise.

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References

Alberini, A., Bigano, A., Boeri, M., 2014. Looking for free riding : energy efficiency incentives and Italian homeowners. Energy Effic. 571–590. https://doi.org/10.1007/s12053-013-9241-7

Aravena, C., Riquelme, A., Denny, E., 2016. Money , Comfort or Environment? Priorities and Determinants of Energy Efficiency Investments in Irish Households. J. Consum. Policy 39, 159–186. https://doi.org/10.1007/s10603-016-9311-2

Bard, A., Korn, D., Winch, C., Cook, R., Carollo, A., Donohue, S., Seiver, M., 2011. Efficiency Maine Trust Home Energy Savings Program Final Evaluation Report. The Cadmus Group, Inc.

Bundgaard, S.S., Dyhr-mikkelsen, K., Kjærbye, V.H., Togeby, M., Sommer, T., Larsen, A.E., 2013. Spending to save : evaluation of the energy efficiency obligation in Denmark, in: 2013 Eceee Summer Study. European Council for an Energy Efficient Economy.

Caputo, P., Pasetti, G., 2017. Boosting the energy renovation rate of the private building stock in Italy : Policies and innovative GIS-based tools. Sustain. Cities Soc. 34, 394–404. https://doi.org/10.1016/j.scs.2017.07.002

Christensen, T.H., Gram-Hanssen, K., Best-Waldhober, M. De, Adjei, A., 2014. Energy retrofits of Danish homes : is the Energy Performance Certificate useful? Build. Res. Inf. 42, 489–500. https://doi.org/10.1080/09613218.2014.908265

Crandall-Hollick, M.L., Sherlock, M.F., 2016. Residential Energy Tax Credits : Overview and Analysis. Congressional Research Service, USA.

Curtin, J., Mcinerney, C., Gallachóir, B.Ó., 2016. Financial incentives to mobilise local citizens as investors in low-carbon technologies: A systematic literature review. Renew. Sustain. Energy Rev. 75, 534–547. https://doi.org/10.1016/j.rser.2016.11.020

de Lovinfosse, I., Janeiro, L., Blok, K., Larkin, J., 2012. Measurement , Verification and Additionality of Electricity Demand Reductions. ECOFYS, London.

Desogus, G., Di Pilla, L., Mura, S., Pisano, G.L., Ricciu, R., 2013. Economic efficiency of social housing thermal upgrade in Mediterranean climate. Energy Build. 57, 354–360. https://doi.org/10.1016/j.enbuild.2012.11.016

Dunphy, N., 2016. Developing a Sustainable Housing Marketplace: New business models to optimize value generation from retrofit. Int. J. Hous. Sci. its Appl. 40, 211–221.

EC, 2010. Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings. Brussels.

Fawcett, T., 2014. Exploring the time dimension of low carbon retrofit: owner-occupied housing. Build. Res. Inf. 42. https://doi.org/10.1080/09613218.2013.804769

Frondel, M., Vance, C., 2013. Heterogeneity in the Effect of Home Energy Audits: Theory and Evidence. Environ. Resour. Econ. 55, 407–418. https://doi.org/10.1007/s10640-013-9632-4

Fylan, F., Glew, D., Smith, M., Johnston, D., Brooke-Peat, M., Miles-Shenton, D., Fletcher, M., Aloise-Young, P., Gorse, C., 2016. Reflections on retrofits: Overcoming barriers to energy efficiency among the fuel poor in the United Kingdom. Energy Res. Soc. Sci. 21, 190–198. https://doi.org/10.1016/j.erss.2016.08.002

Galvin, R., 2014. Why German homeowners are reluctant to retrofit. Build. Res. Inf. 42, 398–408. https://doi.org/10.1080/09613218.2014.882738

Galvin, R., 2010. Thermal upgrades of existing homes in Germany: The building code, subsidies, and economic efficiency. Energy Build. 42, 834–844. https://doi.org/10.1016/j.enbuild.2009.12.004

Gillich, A., 2013. Grants versus Financing for Domestic Retrofits: A Case Study from Efficiency Maine. Sustainability 5, 2827–2839. https://doi.org/10.3390/su5062827

Gillich, A., Sunikka-Blank, M., Ford, A., 2017a. Lessons for the UK Green Deal from the US BBNP. Build. Environ. 45, 384–395. https://doi.org/10.1080/09613218.2016.1159500

Gillich, A., Sunikka-Blank, M., Ford, A., 2017b. Designing an " optimal " domestic retrofit programme Designing an " optimal " domestic retrofit programme. Build. Res. Inf. https://doi.org/10.1080/09613218.2017.1368235

Giraudet, L.-G., Finon, D., 2015. European experiences with white certificate obligations: A critical review of existing evaluations. Econ. Energy Environ. Policy 4.

Gooding, L., Gul, M.S., 2017. Achieving growth within the UK â€™ s Domestic Energy E ffi ciency Retro fi tting Services sector , practitioner experiences and strategies moving forward. Energy Policy 105, 173–182. https://doi.org/10.1016/j.enpol.2017.02.042

Gouldson, A., Kerr, N., Millward-Hopkins, J., Freeman, M.C., Topi, C., Sullivan, R., 2015. Innovative financing models for low carbon transitions: Exploring the case for revolving funds for domestic energy efficiency programmes. Energy Policy 86. https://doi.org/10.1016/j.enpol.2015.08.012

Gram-Hanssen, K., Bartiaux, F., Jensen, O.M., Cantaert, M., 2007. "Do homeowners use energy labels ? A comparison between Denmark and Belgium." Energy Policy 35, 2879–2888. https://doi.org/10.1016/j.enpol.2006.10.017

Hoicka, C.E., Parker, P., Andrey, J., 2014. Residential energy efficiency retrofits: How program design affects participation and outcomes. Energy Policy 65, 594–607. https://doi.org/10.1016/j.enpol.2013.10.053

Hor, K., Rahmat, M.K., 2017. Analysis and recommendations for building energy efficiency financing in Malaysia. Energy Effic. https://doi.org/10.1007/s12053-017-9551-2

Janda, K.B., Parag, Y., 2013. A middle-out approach for improving energy performance in buildings. Build. Res. Inf. 41, 39–50. https://doi.org/10.1080/09613218.2013.743396

Kastner, I., Stern, P.C., 2015. Examining the decision-making processes behind household energy investments : A review. Energy Res. Soc. Sci. 10, 72–89.

Kempa, K., Moslener, U., 2017. Climate Policy with the Chequebook - An economic analysis of climate investment support. Econ. Energy adn Environ. Policy 6, 111–129. https://doi.org/https://doi.org/10.5547/2160-5890.6.1.kkem

Kern, F., Kivimaa, P., Martiskainen, M., 2017. Policy packaging or policy patching? The development of complex energy efficiency policy mixes. Energy Reserach Soc. Sci. 23, 11–25. https://doi.org/10.1016/j.erss.2016.11.002

Kerr, N., Gouldson, A., Barrett, J., 2017. The rationale for energy efficiency policy: Assessing the recognition of the multiple benefits of energy efficiency retrofit policy. Energy Policy 106, 212–221. https://doi.org/10.1016/j.enpol.2017.03.053

Kerr, N., Winskel, M., 2018. Private household investment in home energy retrofit – reviewing the evidence and designing effective public policy. ClimateXChange, Edinburgh.

Killip, G., 2013a. Products, practices and processes: Exploring the innovation potential for low-carbon housing refurbishment among small and medium-sized enterprises (SMEs) in the UK construction industry. Energy Policy 62, 522–530. https://doi.org/10.1016/j.enpol.2013.06.024

Killip, G., 2013b. Transition management using a market transformation approach: lessons for theory, research, and practice from the case of low-carbon housing refurbishment in the UK. Environ. Plan. C Gov. Policy 31, 876–892. https://doi.org/10.1068/c11336

Killip, G., 2013c. Products, practices and processes: Exploring the innovation potential for low-carbon housing refurbishment among small and medium-sized enterprises (SMEs) in the UK construction industry. Energy Policy 62, 522–530. https://doi.org/10.1016/j.enpol.2013.06.024

Kirst, M., O'Campo, P., 2012. Realist Review Methods for Complex Health Problems, in: O'Campo, P., Dunn, J.R. (Eds.), Rethinking Social Epidemiology. Springer, Netherlands, pp. 231–245. https://doi.org/10.1007/978-94-007-2138-8

Moser, S., 2013. Poor energy poor : Energy saving obligations , distributional effects , and the malfunction of the priority group. Energy Policy 61, 1003–1010. https://doi.org/10.1016/j.enpol.2013.06.021

Murphy, L., 2014. The influence of energy audits on the energy ef fi ciency investments of private owner-occupied households in the Netherlands. Energy Policy 65, 398–407. https://doi.org/10.1016/j.enpol.2013.10.016

Murphy, L., Meijer, F., Visscher, H., 2012. A qualitative evaluation of policy instruments used to improve energy performance of existing private dwellings in the Netherlands. Energy Policy 45, 459–468. https://doi.org/10.1016/j.enpol.2012.02.056

Murphy, L., Meijer, F., Visscher, H., 2011. Effective National Energy Performance Instruments for Existing Dwellings? Lessons from Front-Runners 1–13.

Nauleau, M., 2014. Free-riding on tax credits for home insulation in France : An econometric assessment using panel data. Energy Econ. 46, 78–92. https://doi.org/10.1016/j.eneco.2014.08.011

Owen, A., Mitchell, G., Gouldson, A., 2014. Unseen influence — The role of low carbon retrofit advisers and installers in the adoption and use of domestic energy technology. Energy Policy 73, 169–179. https://doi.org/10.1016/j.enpol.2014.06.013

Papaioannou, D., Sutton, A., Carroll, C., Booth, A., Wong, R., 2010. Literature searching for social science systematic reviews: Consideration of a range of search techniques. Health Info. Libr. J. 27, 114–122. https://doi.org/10.1111/j.1471-1842.2009.00863.x

Pettifor, H., Wilson, C., Chryssochoidis, G., 2015. The appeal of the green deal : Empirical evidence for the influence of energy efficiency policy on renovating homeowners. Energy Policy 79, 161–176. https://doi.org/10.1016/j.enpol.2015.01.015

Pollo, R., 2017. The Housing Retrofit Market in Italy: Constraints and Barriers to Development, in: Mediterranean Green Buildings & Renewable Energy. pp. 765–772. https://doi.org/10.1007/978-3-319-30746-6

PWP, 2017. Current Methods in Free Ridership and Spillover Policy and Estimation. PWP and Evergreen Economics.

Ricardo-AEA, 2015a. A Comparative Review of Housing Energy Efficiency Interventions. Glasgow.

Ricardo-AEA, 2015b. SPLiCE Phase 1 A methodology for Rapid Evidence Assessments. Oxford, Riccardo-AEA.

Rohde, C., Rosenow, J., Eyre, N., Giraudet, L., 2014. Energy saving obligations — cutting the Gordian

Knot of leverage? Energy Effic. 8, 129–140. https://doi.org/10.1007/s12053-014-9279-1

Rosenow, J., Eyre, N., 2013. The Green Deal and the Energy Company Obligation. Energy 166, 127–136. https://doi.org/http://dx.doi.org/10.1680/ener.13.00001

Rosenow, J., Eyre, N., Sorrell, S., Guertler, P., 2017a. Policy briefing: Unlocking Britain's First Fuel: The potential for energy savings in UK housing. UK Energy Research Centre and CIED.

Rosenow, J., Fawcett, T., Eyre, N., Oikonomou, V., 2016. Energy efficiency and the policy mix. Build. Res. Inf. 44, 562–574. https://doi.org/10.1080/09613218.2016.1138803

Rosenow, J., Kern, F., Rogge, K., 2017b. The need for comprehensive and well targeted instrument mixes to stimulate energy transitions: The case of energy efficiency policy. Energy Res. Soc. Sci. 33, 95–104. https://doi.org/10.1016/j.erss.2017.09.013

Rosenow, J., Platt, R., Demurtas, A., 2014. Fiscal impacts of energy efficiency programmes-The example of solid wall insulation investment in the UK. Energy Policy 74, 610–620. https://doi.org/10.1016/j.enpol.2014.08.007

Schlomann, B., Rohde, C., Eichhammer, W., Bürger, V., Becker, D., 2013. Which role for market-oriented instruments for achieving energy effciiency targets in Germany? Energy Environ. 24, 27–55. https://doi.org/https://doi.org/10.1260/0958-305X.24.1-2.27

Simpson, S., Banfill, P., Haines, V., Mallaband, B., Mitchell, V., 2015. Energy-led domestic retrofit: impact of the intervention sequence. Build. Res. Inf. 44, 97–115. https://doi.org/10.1080/09613218.2014.996360

Skumatz, L.A., Vine, E., 2010. A National Review of Best Practices and Issues in Attribution and Net-to-Gross : Results of the SERA / CIEE White Paper Project Introduction / Context, in: 2010 ACEEE Summer Study on Energy Efficiency in Buildings. pp. 347–361.

Tonn, B., Hawkins, B., Schweitzer, M., Eisenberg, J., 2013. Process evaluation of the home performance with ENERGY STAR Program. Energy Policy 56, 371–381. https://doi.org/10.1016/j.enpol.2012.12.076

Tuominen, P., Klobut, K., Tolman, A., Adjei, A., Best-waldhober, M. De, 2012. Energy savings potential in buildings and overcoming market barriers in member states of the European Union. Energy Build. 51, 48–55. https://doi.org/10.1016/j.enbuild.2012.04.015

USDOE, 2015. Evaluation of the Better Buildings Neighborhood Program Final Synthesis Report , Volume 1 American Recovery and Reinvestment Act of 2009. U.S. Department of Energy Office of Energy Efficiency and Renewable Energy.

Vine, E., Hall, N., Keating, K.M., Kushler, M., Prahl, R., 2012. Emerging issues in the evaluation of energy-efficiency programs: The US experience. Energy Effic. 5, 5–17. https://doi.org/10.1007/s12053-010-9101-7

Vine, E., Hamrin, J., 2008. Energy savings certificates: A market-based tool for reducing greenhouse gas emissions. Energy Policy 36, 467–476. https://doi.org/10.1016/j.enpol.2007.10.001

Visscher, H., Meijer, F., Majcen, D., Itard, L., 2016. Improved governance for energy efficiency in housing Improved governance for energy e ⁄ ciency in housing. Build. Res. Inf. 44, 552–561. https://doi.org/10.1080/09613218.2016.1180808

Wade, F., Hitchings, R., Shipworth, M., 2016a. Understanding the missing middlemen of domestic heating: Installers as a community of professional practice in the United Kingdom. Energy Res. Soc. Sci. 19, 39–47. https://doi.org/10.1016/j.erss.2016.05.007

Wade, F., Shipworth, M., Hitchings, R., 2016b. Influencing the central heating technologies installed in homes: The role of social capital in supply chain networks. Energy Policy 95, 52–60. https://doi.org/10.1016/j.enpol.2016.04.033

Weiss, J., Dunkelberg, E., Vogelpohl, T., 2012. Improving policy instruments to better tap into homeowner refurbishment potential : Lessons learned from a case study in Germany. Energy Policy 44, 406–415. https://doi.org/10.1016/j.enpol.2012.02.006

Wilson, C., Chryssochoidis, G., Pettifor, H., 2013. Understanding Homeowners ' Renovation Decisions : Findings of the VERD Project. UK Energy Research Centre.

Wilson, C., Crane, L., Chryssochoidis, G., 2015. Why do homeowners renovate energy efficiently ? Contrasting perspectives and implications for policy. Energy Res. Soc. Sci. 7, 12–22. https://doi.org/10.1016/j.erss.2015.03.002

Zhao, T., Bell, L., Horner, M.W., Sulik, J., Zhang, J., 2012. Consumer responses towards home energy financial incentives : A survey-based study. Energy Policy 47, 291–297. https://doi.org/10.1016/j.enpol.2012.04.070