Worth the risk? An evaluation of alternative finance mechanisms for residential retrofit

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Abstract

Improving energy efficiency, de-carbonising heating and cooling, and increasing renewable microgeneration in existing residential buildings, is crucial for meeting social and climate policy objectives. This paper explores the challenges of financing this ‘retrofit’ activity. First, it develops a typology of *finance mechanisms* for residential retrofit highlighting their key design features, including: the *source of capital*; the *financial instrument(s)*; the *project performance* requirements; the *point of sale*; the nature of the *security and underwriting* the *repayment channel* and *customer journey*. Combining information from interviews and documentary sources, the paper explores how these design features influence the success of the finance mechanisms in different contexts. First, it is shown that a low *cost of capital* for retrofit finance is critical to the economic viability of whole-house retrofits. Second, by funding non-energy measures such as general improvement works, finance mechanisms can enable broader *sources of value* that are more highly prized by households. Thirdly, mechanisms that reduce complexity by simplifying the *customer journey* are likely to achieve much higher levels of uptake. Most importantly we discuss how finance alone is unlikely to be a driver of demand for whole-house retrofit, and so instead should be viewed as a necessary component of a much broader retrofit strategy.

Keywords

Energy Efficiency; Finance; Retrofit; Split incentives; Domestic Buildings; Cost of Capital

1. Introduction

CO₂ emissions from energy used in residential buildings result from space and water heating, and electricity used for cooling, lighting and appliances. These emissions constitute a significant

proportion of total emissions in advanced economies (IPCC, 2014). Aside from more efficient appliances and behavioural changes, emissions from the existing building stock can be reduced by the *retrofit* of three main types of measure: improving the energy efficiency (EE) of the building fabric; adopting low carbon heating, ventilation and cooling technologies (HVAC); and building integrated electricity microgeneration, such as solar photovoltaics (PV) (CCC, 2013). Thus, in this paper ‘retrofit’ finance potentially includes funding for all three types of intervention.

The Intergovernmental Panel on Climate Change have set ambitious goals for the retrofit of buildings (50% energy reduction from 2050 baseline scenario (IPCC, 2014)), to keep global temperature rises below 2°C as part of the 2015 Paris agreement. Since 1970 emissions from all buildings have more than doubled and in 2010 constituted around 19% of global carbon emissions (IPCC, 2014). Many retrofit measures deliver net cost savings or are cost effective¹, when compared to other climate mitigation measures (CCC, 2018; IEA, 2017). However, delivering these ambitious targets, will necessitate increasingly comprehensive ‘whole-house’ retrofits, involving multiple integrated building fabric, HVAC, and microgeneration measures (Brown, 2018).

Delivering the 2°C scenario will require an estimated \$31Tn of investment in buildings globally over the next four decades (IEA, 2013). A significant proportion of historical energy efficiency measures has involved self-financing by firms and households (IEA, 2017; Webber et al., 2015). However, an important source of EE investment in recent years in both Europe and North America (12% of total) has come from market based instruments such as supplier obligation policies, paid for by a levy on electricity and gas bills (IEA, 2017). These policies have typically delivered single home retrofit measures (Rosenow, 2012).

¹ The UK’s Committee on Climate Change define the cost-effective path as comprising measures that cost less than the projected carbon price across their lifetimes together with measures that may cost more than the projected carbon price, but are necessary in order to manage costs and risks of meeting the 2050 target (CCC, 2013)

Achieving sufficient ‘whole house’ retrofits through supplier obligations alone could lead to significant increases in household energy bills (Kern et al., 2017), thus having a negative impact on low income households who do not undertake retrofit measures (Rosenow et al., 2013b). Whilst ‘fuel poverty’² objectives could be better achieved through general taxation (Rosenow et al., 2013b), there is a need for effective, repayable *finance mechanisms* for the ‘able-to-pay’ segments (Freehling and Stickles, 2016).

In this paper, finance mechanisms are considered distinct from targeted subsidies, supplier obligations (IEA, 2017), or fiscal incentive schemes such as property tax breaks (Rosenow et al., 2014). A finance mechanism is thus defined as the provision of capital for retrofit measures through equity and/or debt that is repaid to the lender (Leventis et al., 2017). A range of retrofit finance mechanisms have been developed, in the European Union (EU) and USA. The features of and reasons for success of these alternative approaches are the main focus of this study.

A comprehensive study of finance mechanisms for domestic retrofit is largely absent from the academic literature - with most studies published being non-academic, having limited consideration for the specific issues of residential buildings, or involving a different unit of analysis, such as supplier obligations (Rosenow, 2012). Further, an empirical investigation of factors that contribute to household appeal and the cost of capital is presently lacking. The role of different types of financing and their impact on projects remains somewhat of a ‘black box’ in the energy studies field more generally. This paper aims to open up the features of alternative finance mechanisms, and to understand the extent to which they can promote the uptake of whole-house retrofit -drawing on selected examples in Europe and North America.

² The definition of fuel poverty in the UK, is where fuel costs that are above average (the national median level), and these fuel costs leave a residual income that is below the UK’s official poverty line (DECC, 2013)

This paper is structured as follows. Section 2 provides background to the context of residential retrofit and reviews the literature on retrofit finance. Section 3 introduces the conceptual framework for the features of finance mechanisms along with the cost of capital. Section 4 outlines the methodology. Section 5 introduces a new typology of retrofit finance mechanisms, while Section 6 describes how these mechanisms differ according to the framework. Section 7 discusses the findings. Section 8 concludes and provides recommendations for policy and research. A glossary of key financial terminology used in the paper is provided in Table A1 in the Appendix.

2. Background on energy efficiency, residential retrofit and finance

Residential retrofit produces a range of environmental, social and economic benefits, making it an important area for academic and policy research (Kerr et al., 2017). Energy savings from residential retrofit and a shift away from fossil fuel-based heating and cooling have the potential to significantly mitigate anthropogenic climate change. The IPCC (2014) estimate that, through improved EE, energy use from buildings could be stabilised by mid-century, compared to a current baseline where this is set to double. Thus, the EU has set a target of 27% improvement in EE by 2030 (EC, 2014) and the revised Directive for the Energy Performance of Buildings has set a near zero-energy aspiration for the existing building stock (EC, 2018). Residential retrofits have also been shown to improve occupant health and wellbeing (Curl et al., 2015; Willand et al., 2015), reduce fuel poverty (Sovacool, 2015) and lead to job creation and economic growth (EEFIG, 2015; Washan et al., 2014). Retrofit may also produce private benefits to households, including increased property value (Brounen and Kok, 2011; Fuerst et al., 2015), significant savings in energy bills and improved thermal comfort (Aravena et al., 2016; Gillingham et al., 2009). However, much of this potential remains unexploited.

The lack of investment in seemingly cost effective EE measures, is commonly termed the ‘energy efficiency gap’ (Jaffe and Stavins, 1994). Firms, public sector actors and households are seen to underinvest in EE, due to multiple ‘barriers’ that constrain uptake (Kangas et al., 2018; Sorrell et al., 2004) . Although many factors that contribute to a low demand for EE are likely to be outside of what financing alone can achieve (Wilson et al., 2015), tailored financing solutions can make an important contribution to the uptake of retrofit measures (Rezessy and Bertoldi, 2010), particularly in the residential sector (Freehling and Stickles, 2016).

Historically, a large proportion of global investment in residential retrofit has involved either self-financing or energy supplier obligations (IEA, 2017). However, meeting the 2°C target will likely require third-party sources of finance (EEFIG, 2015), particularly as energy suppliers see their market capitalisation shrink and attempt to de-leverage³ their balance sheets due to declining revenues and market share (Blyth et al., 2015; Bolton and Foxon, 2015). Incumbent energy suppliers also lack incentives to fund EE investments, as their current business model relies on increasing throughput sales of energy (Knoeri et al., 2016). Existing financial institutions, such as banks and institutional investors, also remain reticent towards such investment due to an unfamiliarity with the technologies, regulatory risk, short investment horizons, high transaction costs and a lack of suitable finance mechanisms (Bolton and Foxon, 2015; Hall et al., 2015; Stone, 2014).

The United Kingdom’s (UK) ‘Green Deal’ policy provides an interesting case of an innovative finance mechanism, intended to deliver approximately 2 million retrofit installations per year and leverage billions of pounds of investment. The scheme was based on private sector lending to households, paid back through a levy on energy bills—known as ‘on-bill repayment’ (OBR).

³ Leverage involves the use of borrowed money: typically, the use of various forms of debt. Firms or projects may be considered over leveraged when their balance sheets excessive levels of debt compared to equity.

However, the scheme only achieved a fraction of its target, and resulted in a significant loss to UK taxpayers before its premature scrappage in 2015 (Rosenow and Eyre, 2016).

A range of more successful retrofit finance mechanisms, however, provide some important lessons (EEFIG, 2015). Examples include the USA's Property Assisted Clean Energy finance (PACE) programmes (Kim et al., 2012); low cost loans delivered by the German KfW state bank (Schröder et al., 2011); other forms of on-bill-financing and repayment (On-bill) (Zimring et al., 2014a); green mortgages (Ecology Building Society, 2017); and state-backed guarantee funds (Borgeson et al., 2013). In addition, energy service agreements (ESA), where finance for measures is procured upstream by an Energy Service Company (ESCO) as part of an energy saving performance contract have been used in multi-family housing and commercial buildings (Labanca et al., 2014).

Yet, academic studies on alternative approaches to EE finance are largely absent from the energy and climate journals, with leading finance journals largely silent on energy issues in general (Diaz-Rainey et al., 2017). The literature on 'green finance' has tended to focus on high level flows of energy finance (Mazzucato and Semieniuk, 2018), or the challenges of funding large renewable energy projects (Blyth et al., 2015). Hall et al. (2016) also highlight the challenges of financing distributed energy systems, where differing national institutional contexts influence the financial solutions available.

A handful studies have discussed the potential of alternative retrofit finance mechanisms, including potential revolving retrofit funds (Gouldson et al., 2015), the UK's Green Deal (Marchand et al., 2015; Rosenow and Eyre, 2016), and the successful German KfW programme (Rosenow et al., 2013a). Others have explored how energy performance contracts could finance residential retrofit (Winther and Gurigard, 2017) but have not foregrounded the financial component of such models. Bergman and Foxon (2017) discussed the challenges for reorienting finance towards EE in the UK and argue for a re-framing of EE as infrastructure financing. Previous work has also discussed

the potential of novel financing solutions for overcoming the *split incentive* barrier (Bird and Hernández, 2012). But taken together, these studies provide only limited insights into what the features of a successful finance mechanism might be. This paper seeks to address this gap in the literature.

3. Features of a finance mechanism and the cost of capital

Access to capital and *split incentives* are a significant barrier to residential retrofit. Often household savings or conventional financing solutions, such as secured and unsecured loans may be unavailable, or unsuitable (Rezessy and Bertoldi, 2010). Many also face split incentives - where the benefits of an investment do not fully accrue to the investor (Bird and Hernández, 2012). The classic example is the pervasive ‘landlord tenant dilemma’, where energy savings accrue to the tenant, with the landlord making the investment. Homeowners may also face split incentives if they move out before their initial investment has been recovered and if the value of that investment cannot be capitalised in the sale price. Thus, many conventional forms of financing⁴ do not address split incentives (Bird and Hernández, 2012). In response, a range of retrofit finance mechanisms have been developed to overcome these barriers (EEFIG, 2015). Figure 1 summarises the conceptual framework of key design features of finance mechanisms, which are described in detail in Table 1.

⁴ Conventional forms of financing such as home equity, credit cards, bank loans or conventional mortgages are excluded from this study. Whilst these approaches may be used to fund retrofit measures they are considered distinct from mechanisms designed to fund energy efficiency specifically - as the latter are designed to utilise the savings generated from the retrofit measures and in many cases to overcome specific barriers such as split incentives.

3.1 The features of a finance mechanism and the customer journey

Figure 1 Process diagram of an EE finance mechanism

Table 1 The key design features of finance mechanisms

Feature	Description
Source of capital	<ul style="list-style-type: none"> Investment in EE may come from single or multiple sources. Banks, institutional investors, firms, governments or even citizens may provide financing. Debt is typically provided by banks and institutional investors, whilst other non-financial corporations may also provide loans (Buchner et al., 2015b). Equity providers tend to be different (although there is often overlap) and can include project developers, ESCOs, co-operatives, private investors/citizens and venture capital funds (Buchner et al., 2015a). Public bodies may provide all of the capital, or provide <i>credit enhancements</i>⁵ including: junior⁶ (high risk) debt with private finance providers providing the senior (low risk) debt (EEFIG, 2015); interest rate reductions (Gouldson et al., 2015); or credit guarantee funds – all with the aim of reducing risk, the cost of capital and leveraging private funding (Zimring, 2014a).
Financial instrument	<ul style="list-style-type: none"> Finance may take the form of debt or equity, or a combination of the two.⁷ Debt finance typically consists of loans provided by financial institutions or equipment providers in the form of leases (Sorrell, 2005). Debt may be issued directly to the homeowner or upstream to energy suppliers, ESCOs or to a special purpose vehicle (SPV)⁸ (Rezessy and Bertoldi, 2010). Securitisation⁹ involves aggregating loans into tradeable ‘securities’, thus drawing in sources of capital who would normally only invest in larger projects (OECD, 2015). Small scale loans to households can be aggregated and <i>securitised</i> and sold into secondary markets¹⁰, often in the form of bonds (Borgeson et al., 2013). Equity takes the form of part ownership or share issues. Stakeholder models such as cooperatives adopt largely equity based approaches (Walker, 2008), although in commercial finance equity tends to be costlier¹¹ than debt (Tapia, 2012), despite its theoretical equivalence (Modigliani and Miller, 1958). The majority of domestic retrofit schemes are debt-financed, although ESCOs may use their own equity to finance projects, as part of energy performance contracts (Leventis et al., 2017).
Project performance	<ul style="list-style-type: none"> The post intervention performance of EE retrofits is of critical importance to both financiers and building occupants. Evaluating the potential of a retrofit

⁵ Credit enhancements are a set of approaches usually offered by public actors, which reduce lender or investor risk by providing some form of protection or guarantee in the event of default, bankruptcy or delinquency.

⁶ Junior Debt is a loan or security that ranks below other loans or securities with regard to claims on assets or earnings. Junior debt is also known as a ‘Subordinated debt’ or subordinated loan. In the case of borrower default, creditors who own subordinated debt won't be paid out until after senior debtholders are paid in full.

⁷ Many retrofit programmes may be partly based on grants or other public subsidies, however the focus of this study is to analyse the dynamics of the finance mechanisms, rather than the influence of grants or subsidy instruments on the underlying economic viability of retrofit measures.

⁸ A special purpose vehicle (SPV) is a company with a specific and often short-term purpose, with a structure and legal status that allows the SPV to fail or go bankrupt without bringing down the wider organisations involved in the transaction. They are designed to isolate risk and allow organisations to finance projects ‘off balance sheet’.

⁹ Securitization is a form of financial engineering where groups of illiquid assets are bundled together, often by aggregating multiple smaller securities, and transforming them into a tradable security in secondary markets.

¹⁰ A secondary market allows for securities (such as loans) to be resold, often in aggregation and are thus second hand.

¹¹ Debt is senior to equity, so in a bankruptcy, the debt holders get paid before the equity holders. Therefore, equity providers (shareholders) require dividends that tend to reflect these higher risks with higher associated rewards and are often linked to project profitability.

	<p>is likely to require an energy model and audit and ideally data on past energy consumption (Rezessy and Bertoldi, 2010).</p> <ul style="list-style-type: none"> • Financiers may place a range of requirements on project performance. This may include requirements that measures are 'cash-flow positive' meaning that finance repayments are less than or equal to energy bill savings – often referred to as <i>energy bill neutrality</i> (Borgeson et al., 2013). • Savings-backed arrangements such as energy performance contracts include requirements for <i>actual</i> energy performance outcomes, such as kWh savings, guaranteed cost reductions or even guaranteed temperatures (Sorrell, 2005). • Financiers may also require projects to be standardised to best practice guidelines (Investor Confidence Project, 2015) or be accredited to industry quality standards (Bonfield, 2016). Alternatively, funders may place less strict requirements on energy performance outcomes, or enable wider non-energy measures to be funded (Borgeson et al., 2013).
Point of sale	<ul style="list-style-type: none"> • The point of sale is the interface through which the customer accesses finance. The nature of this interface has important implications for the <i>customer journey</i>¹² (Norton et al., 2013) for a retrofit project. • In many cases, finance has a separate point of sale from the contractor providing the retrofit measures. This may include the use of the customer's existing bank (Schröder et al., 2011), a special mortgage product (Ecology Building Society, 2017) or an additional third party provider. In other cases the retrofit provider may offer an integrated finance package as part of the retrofit, or as part of an energy performance contract (Borgeson et al., 2013). • Previous studies have shown that the uptake of retrofit schemes is strongly influenced by how information is presented (Hoicka et al., 2014; Long et al., 2015); the nature of the financial rewards (upfront payments or long term savings) (Collins et al., 2018); and the channels through which the scheme is promoted (Mahapatra et al., 2013; Mlecnik et al., 2011).
Security and Underwriting	<ul style="list-style-type: none"> • Mortgages are secured by the financial institution's ability to repossess the home should a customer default on their loan (Borgeson et al., 2013). Other forms of security include property taxes or energy bills, meaning the threat of court proceedings or disconnection can be applied (Zimring, 2014b). • The <i>underwriting</i> process is how financiers determine the underlying credit-worthiness of the asset or borrower. Underwriting may be focussed upon the asset to which finance is secured (i.e. the historic repayments of property taxes or energy bills), or upon the borrower through metrics such as personal credit ratings (Leventis et al., 2017). Publicly funded programmes may place less emphasis on security and underwriting, particularly if they are targeting low-income households (EEFIG, 2015).
Repayment channel	<ul style="list-style-type: none"> • The repayment channel is how funds are repaid to the creditor or shareholders. A range of repayment channels exist for EE projects and are an important area for new policy and legal frameworks (EEFIG, 2015). • Repayments can be made through conventional personal or corporate loan repayments, through energy bills, service charges, collected via property taxes or through rent or mortgage repayments.

¹² The customer journey is defined as the sequence of events that customers experience in order to learn about, purchase and interact with products and services (Norton et al., 2013).

	<ul style="list-style-type: none"> • Equity returns are then distributed through dividends, although these may be contingent on the performance of the asset or company (EEFIG, 2015). Further, equity release models may only require payment once the property is sold (Scottish Government, 2017). Where repayments are linked to the underlying asset such as with property taxes or energy bills, this can enable transferability of the retrofit finance from one occupant to the next, thereby addressing split incentive problems (Borgeson et al., 2013).
<i>Customer Journey</i>	<ul style="list-style-type: none"> • The customer journey is defined as the sequence of events that customers experience to learn about, purchase and interact with products and services (Norton et al., 2013). Although individual elements of a finance mechanism influence the customer journey, the concept summarizes the household's experience of how these elements are integrated. • Complex or lengthy customer journeys have been shown to negatively impact the uptake of residential retrofit finance (O'Keeffe et al., 2016). Specific issues include poor integration with the timing of wider renovations (Fawcett, 2014), complex applications and limited information (Marchand et al., 2015), low trust in the provider (Risholt and Berker, 2013), and a lack of co-ordination with the supply chain (Brown, 2018).

3.2 The cost of capital

The cost of capital is of critical importance for determining the economics of capital-intensive investments, such as retrofit (Donovan et al., 2016). The cost of capital consists of the weighted average cost of debt (e.g. the interest rates attached to a bank loan) and equity (e.g. the returns required by shareholders). Due to the effects of compound interest, the cost of capital has increasing significance for long term, capital-intensive investments (Donovan and Corbishley, 2016).

Figure 2 The impact of the interest rate on borrowing potential, assuming a fixed repayment and term

Figure 2 provides a simple illustration. Assuming a fixed repayment of £100/month and a loan maturity of 20 years, the figure shows the total amount that can be borrowed at 0%, 5% and 10% interest rates respectively. Whilst a household could borrow £24,000 (the principal) at 0%, this reduces to £14,954.65 at 5%, and only £10,216.27 at 10% - where at 10% the total interest is higher than the principal. Consequently, assuming fixed payments and loan term, the cost of capital limits the amount that can be borrowed and in turn the extent of the retrofit measures funded.

Previous studies show that the interest rates on loans can limit the appeal of retrofit finance

mechanisms such as the UK's Green Deal (Marchand et al., 2015; Rosenow and Eyre, 2016), whilst low interest rates were an important success factor in Germany's KfW scheme (Rosenow et al., 2013a; Schröder et al., 2011). This high cost of capital is also likely to significantly limit the feasible range of retrofit measures that can be funded (UKGBC, 2014). However, Borgesson (2014) question the extent to which the cost of capital is a barrier, emphasising how high interest credit card financing for retrofit remains prevalent in the USA.

4. Methods

This study takes a qualitative approach, involving analysis of interviews and secondary data, including a comprehensive review of the 'grey literature' on EE finance. Whilst there are few academic studies on the topic, numerous policy briefs, publicly commissioned studies and consultancy reports exist from a range of public, private and third sector sources. This review identified several texts with recurring descriptions of the key approaches to retrofit finance in both domestic and commercial buildings (EEFIG, 2015; EST, 2011; Investor Confidence Project, 2015; Kats et al., 2011; Kim et al., 2012; Sweatman, 2012; Sweatman and Managan, 2010; The Rockefeller Foundation and DB Climate Change Advisors, 2012; Zimring, 2014b). Examination of this literature led to the development of a typology of six *archetypes* of finance mechanisms used to fund residential retrofit in the EU and USA. For simplicity, some archetypes, such as public guarantee funds and state bank loans were aggregated under a single heading, whilst others, such as leasing, were excluded due to limited examples being available in the residential sector. This typology is summarised in Table 2 and described in detail in Section 5.

Subsequently, eighteen semi structured interviews were carried out, split into two phases: 'expert scoping' and 'practitioner' interviews. During Spring/Summer 2017, eight prominent experts (Table B1) in the EE finance community were interviewed. Several interviewees were authors in

the key texts described above, notably the European Commission funded Energy Efficiency Finance Group report (EEFIG, 2015), whilst others were selected through personal contacts and snowballing techniques (Yin, 1994). The aim was to understand the key drivers and barriers for residential EE financing; which design features of a finance mechanism are most important; and why certain approaches are more effective. Information was also sought on how the policy and institutional context shapes the preference for and viability of different approaches.

Building on the insights from the expert interviews, a protocol was developed to interview practitioners pertaining to each of the six finance mechanisms in the proposed typology. The aim was to include at least two representatives of each type, with the sample drawn from the EU and the USA. Many of the mechanisms under study, such as PACE, have only been adopted in certain USA states, notably California. Understanding both the mechanism's features and the policy and institutional context in which they operate is therefore important. Questions were designed to probe each of the design features of finance mechanisms (described in Section 3), and the drivers and barriers to the adoption of those mechanisms, including broader contextual factors. During Summer/Autumn 2017, ten semi-structured practitioner interviews (Table A1) were conducted.

Interviews were coded using the NVivo 11™ software, allowing common themes to be identified along with areas for further investigation. This qualitative approach was considered appropriate, given the need to develop a rich understanding of the role and importance of different features of finance mechanisms, and their broader contextual setting (Yin, 1994). The pre-testing of the framework with 'experts' was intended to prevent key approaches and elements being missed, although it is acknowledged this could introduce bias in the selection of interviewees.

5. Typology of retrofit finance mechanisms

Building on the review of grey literature, a number of distinct finance mechanisms can be identified. These approaches are distinguished by variations in the key features identified in

Section 3. The range of approaches to financing residential retrofit was discussed during the expert scoping interviews, leading to the development of a typology of six archetypes of finance mechanism, namely, *public loan/credit enhancement*, *on-bill finance and repayment*, *property assessed clean energy financing*, *green mortgages*, *energy service agreement financing*, and *community financing*. The typology is described in this section and summarised in Table 2. The following types are drawn from prominent contemporary examples and their nomenclature reflects common terminology within the industry. The typology is ordered from the more widespread publicly funded approaches, to the more niche community financing.

Some overlap exists between the different archetypes, with the possibility that hybrid forms may emerge.

Table 2 The key features of six archetypes of finance mechanism for residential retrofit

TYPE OF FINANCE MECHANISM	EXAMPLE SCHEMES	FEATURE OF FINANCE MECHANISM					
		SOURCE OF CAPITAL	FINANCIAL INSTRUMENT	PROJECT PERFORMANCE	POINT OF SALE	SECURITY AND UNDERWRITING	REPAYMENT CHANNEL
PUBLIC LOAN/ CREDIT ENHANCEMENT	HES and HEEPS equity loan (Scotland)	Government spending	Debt	Minimum CO ₂ saving	Third party finance provider	No security - basic credit check	Unsecured Loan/ equity release
	KfW CBRP (Germany)	Public Bank	Debt (bonds)		Retail bank	No security - basic credit check	Unsecured Loan
	JESSICA-> LEEF (EU-> London, UK)	Hybrid – EIB, LEEF & Private lender	Debt		Housing provider	Varies	Revolving phase then full repayment
ON BILL FINANCING/ ON BILL REPAYMENT	UK (OBR) Green Deal	Third party private Sector	Debt	Bill neutrality (Golden rule)	Third party finance provider	Energy meter & bill history	Energy Bills
	USA & Canada (OBF) schemes	Energy Utility & public/ credit enhancements	Debt (some securitised examples)	Often Bill neutrality	Energy utility		
PROPERTY ASSESSED CLEAN ENERGY (PACE)	RE:NEW Financial (US)	Municipal bond -> private capital	Debt (bonds)	None - approved contractor schemes	Contractor	Lien on property & tax bill-based underwriting	Property taxes
GREEN MORTGAGE	EMF Green mortgage project (EU)	Covered Bond market	Mortgage (equity & debt)	EPC improvement	Mortgage provider	Detailed credit check	Mortgage payments
	Ecology Building society (UK)	Member deposits	Equity				
ENERGY SERVICES AGREEMENT	RENESCO (Latvia)	ESCO -> Public Bank	Debt & Equity	Energy Performance Guarantee	Contractor	Based on ESCO	Energy performance contract
	SEA (Italy)	ESCO Institutional investor ->				Based on ESCO & bill payment history	
COMMUNITY FINANCING	BHESCo (Brighton, UK)	Member share issue	Equity	None	Contractor	Credit check	Hire Purchase agreement-> dividends

5.1 Public loan/ credit enhancement

Public retrofit finance mechanisms typically involve low cost loans provided by governments, but may also include a range of credit enhancements to be blended with private capital (EEFIG, 2015). The most prominent example is Germany's CO₂ Building Rehabilitation Programme (CBRP). Germany's state bank, the KfW, provides loans to households arranged through commercial banks. Funds are raised on capital markets¹³, and offered at very low rates of interest (>2%) (Rosenow et al., 2013a). The bank is able to offer these low rates primarily due to its AAA rating; a product of its public status, with additional state funding to further subsidise interest rates (Schröder et al., 2011). In 2007, the CBRP issued €5bn in loans, and the programme is estimated to have reduced carbon emissions from the existing building stock by 24% between 1990 and 2006, with an average of a 59% reduction per property in 2006 (Schröder et al., 2011).

Less well-known schemes are the Home Energy Scotland (HES) loan and Home Energy Efficiency Programme for Scotland (HEEPS) equity loans, funded by the Scottish government. Both programmes offer 0%¹⁴ interest loans. The HEEPS equity loan is repaid upon the sale of the property. However, it is more common for public funded programmes, such as the HES and KfW loans, to be unsecured and linked to the individual rather than the property (Zimring et al., 2014a). Both the CBRP and the HEEPS equity loan schemes allow funding for wider renovation measures (Schröder et al., 2011), with the HEEPS equity loan allowing 45% of the maximum £40,000 to be spent on non-efficiency measures (EST, 2017).

Credit enhancements blend public money with private capital in a single fund. For example, the Joint European Support for Sustainable Investment in City Areas (JESSICA) programme, administered by the European Investment Bank, mobilises grants from European structural

¹³ Generally, these markets involve the trading of longer-term debt and equity instruments, typically with a maturity of a year or more.

¹⁴ A small administration fee and inflation index linking is applied

funds¹⁵ (Rezessy and Bertoldi, 2010). Such mechanisms typically involve the low cost public capital occupying the junior (high risk) tranche¹⁶ of a fund, which is then blended with private sources (Zimring, 2014b). This reduces risk for the private providers, with the public money absorbing the first losses should customers default. A prominent example is the London & Mayors EE Funds (LEEF & MEEF) (LEEF, 2012). Such schemes aim to leverage high ratios of private to public capital for EE investments with LEEF and MEEF raising £100m (50:50 private/public ratio) and £1bn respectively (70:30 private/public ratio) (Amber Infrastructure). Other examples may include loan loss reserve funds and guarantees¹⁷ or direct interest rate subsidies (Zimring, 2014a).

5.2 On-bill finance and repayment (On-bill)

On-bill mechanisms involve the repayment of loans via the energy bill (electricity, gas or dual-fuel). The investment is typically secured by the right to disconnect supply, if left unpaid (Zimring et al., 2014a). These approaches are divided into two types, with different sources of capital. On-bill financing (OBF) involves energy bill-payer or public funds, whilst on-bill repayment (OBR) refers to the use of third party, private capital (Zimring, 2014b). In the USA, UK and Canada over 20 on-bill programmes have provided over \$1.05Bn of financing to households for EE improvements, delivering \$76m in 2014 alone (Zimring et al., 2014a).

The UK's Green Deal is probably the most well-known example of OBR and included requirements for *energy bill neutrality* as part of its 'Golden rule', meaning savings had to be equal to or greater than loan repayments. The Green Deal also precluded non-energy measures from financing (7-11% interest rate). The scheme had very limited uptake. Of the 614,383 assessments

¹⁵ The European Structural Funds are a set of financial tools designed to address inequalities in income, wealth and economic opportunities within the Member states of the European Union.

¹⁶ Tranches are different portions of debt within the capital structure of a fund or project finance structure that are designed to divide risk or group different characteristics such as rewards, maturity and size in ways that are marketable to various classes of investor. This typically includes equity components, junior and senior debt but may also include mezzanine and other hybrid forms of finance.

¹⁷ A loan loss reserve or guarantee sets aside a limited pool of funds from which financial institutions can recover a portion of their losses in the event of borrower defaults. Several examples exist in the US including the MichiganSaves single family loan loss reserve scheme (Zimring, 2014a)

undertaken, only 15,138 households adopted a Green Deal plan by October 2015 (DECC, 2015), far less than the millions of installations that were hoped for (Rosenow and Eyre, 2016). However, in many cases these assessments may have led to self-financing (Webber et al., 2015).

A range of other on-bill programmes in North America have been more successful. Manitoba Hydro's public OBF scheme has funded almost \$300m in efficiency improvements in single-family residences since 2001, although 95 percent of the loans have funded single-measure window, door or furnace replacements (Zimring et al., 2014a). Some smaller scale programmes, such as Clean Energy Works Oregon (CEWO) OBR private finance, have funded whole-house retrofits with loans of up-to \$30,000 (Zimring et al., 2014b). Several of these programmes offer reduced interest rates (0-5%) through public funds and credit enhancements, and have very low rates of default (0-3%) (Zimring et al., 2014a).

5.3 Property assessed clean energy (PACE)

PACE was developed in 2007 and allows municipalities in the USA to fund home and commercial retrofit using land-secured special improvement districts (Kim et al., 2012). These are debt instruments linked to a specific geographical area and secured by land or property. Traditionally they are a means of funding municipal infrastructure investments, through an additional charge on the property tax bill, common in the USA. The assessment districts were devised by Benjamin Franklin in the 17th century as a means to fund improvements that meet a 'valid public purpose'. (Energy Pro). Originally in PACE, local governments funded retrofit measures and attached a tax lien¹⁸ (a form of security that allows claims on tax payments) to properties that benefit from the improvement works. Most PACE funding now comes from the private sector, although still uses the bond issuance and tax collection powers of municipal or local governments (Kim et al., 2012).

¹⁸ A lien is a legal right granted by the owner of property to a creditor to claim rights to or seize an asset that is the subject of the lien. The lien guarantees the underlying obligation to repay the creditor, such as claims against residential property for repayment of a loan.

The PACE financing is secured as a senior lien on the property and is re-paid along with other municipal charges and assessments, on the property tax bill - which provides investors with robust repayment security¹⁹ (DOE, 2016).

Most residential PACE projects have been concentrated in California, with private providers such as RENEW Financial securitising PACE debt for re-sale to capital markets (RENEW Financial). Residential PACE financing has risen dramatically in recent years, facilitating more than \$4 billion in clean energy investments (Leventis et al., 2017), with RENEW Financial achieving an average 28-27% reduction in home energy use on their projects (RENEW Financial). There is currently no national or state requirement for energy bill neutrality within PACE schemes.

5.4 Green mortgages

Mortgage or home equity financing provides the mainstay of extension and renovation funding to existing homes, usually through a mortgage-extension or re-mortgage. Loans are secured to the property and typically have a duration of 25 years or more. However, some mortgage providers offer a range of Green or EE mortgage products designed to provide lending specifically for retrofit.

Mortgage underwriting is based on the applicant's ability to repay. Whilst a significant proportion of outgoings relate to energy costs, current underwriting methods use arbitrary techniques to determine these costs. Initiatives including the UK LENDERS (2017) and EU EeMAP (2017) projects are seeking to promote actual energy usage data in these underwriting calculations. Thus, lenders may provide increased lending for more efficient properties at reduced interest rates—as the higher disposable income reduces the risk of default (EeMAP, 2017). The LENDERS

¹⁹ “Subject to the structure of a state’s PACE statute...the PACE obligation may result in a property tax lien on the property. If applicable...the failure to pay property taxes, including PACE assessments, could trigger foreclosure and property loss even if the property owner is current on other mortgage lien(s)” (DOE, 2016)

project estimates that monthly savings equivalent to two Energy Performance Certificate (EPC)²⁰ bands, could equate to around £4,000 in additional mortgage finance (LENDERS, 2017). Eventually this may create a modest 'green premium', increasing property values for the most efficient properties (EeMAp, 2017), also providing additional borrowing for retrofit measures.

Whilst mainstream European mortgage lenders are yet to offer EE mortgage products, some specialist lenders such as the UK's Ecology Building Society offer both additional lending for retrofit projects and also interest rate discounts of 0.25% for each EPC improvement level (Ecology Building Society, 2017). In the USA, the Fannie Mae mortgage company's Green financing for multi-family buildings reached \$3.6 billion in 2016, involving preferential interest rates and additional borrowing for energy and water efficiency property improvements (Leventis et al., 2017). The UK government is now looking to promote 'innovative green mortgage products' as part of its Clean Growth Plan (HM Government, 2017).

5.5 Energy Service Agreement (ESA) financing

Energy service agreements (ESAs) are a form of financing to fund energy performance contracts. In a traditional energy performance contract²¹, the ESCO implements a retrofit and provides an energy performance guarantee and a commitment to maintain the assets under the contract for a given period. Energy performance contracts have been most common in the public sector, where public actors can access cheap capital and, thus, ESCOs typically provide engineering services without any financial component (Nolden and Sorrell, 2016). Recently energy performance contract and ESCO models have been growing in the small commercial and residential sectors (Labanca et al., 2014). Under an ESA, a finance provider will arrange financing directly with the ESCO or SPV (typically 7-10% interest), with the end user or household paying

²⁰ EPCs are a measure of a buildings energy efficiency and running costs, based on a standardised assessment procedure. Most EU member states employ some form of EPC and they are typically rated from A to G, with A being an exemplary dwelling.

²¹ In an energy performance contract without a financing package from the ESCO, the client will need to find other forms of capital to fund the retrofit. Therefore, this model is not considered a standalone finance mechanism and is not included in the study.

for measured performance improvements - usually derived from a baseline of past consumption (Kim et al., 2012). This effectively shifts the financing upstream from the household to provide an integrated offer of finance and measures through an energy service charge. In some models the ESCO will initially use its own funds and then sell on the cash flows or 'receivables' of proven projects to a third-party financier in a process known as 'factoring'²² (EEFIG, 2015). In a pure ESA, the third-party financier will fund projects from the beginning, usually via an SPV, where projects are aggregated and sold into secondary markets to institutional investors (SUSI Partners 2017).

Although in 2014, over \$150m of USA ESCO revenues were generated through projects in public housing, most this was funded using working capital from the housing provider rather than an ESA structure. However, since 2011 PosiGen have offered an ESA for residential solar and EE and completed 8,400 projects in the USA (Leventis et al., 2017). The model has also been gaining traction in Europe in the multi-family sector. RENESCO provide an ESA for the deep retrofit and renovation of dilapidated eastern European housing, while Servizi Energia Ambiente (SEA) offers ESAs and energy performance contracts to the Italian multi-family market. RENESCO have invested over €4m in 15 Soviet-era blocks and are developing a factoring fund with the European Bank for Reconstruction and Development (EBRD) (RENESCO 2015). SEA are currently negotiating to refinance several projects, with financing partners (SUSI Partners, 2017). Several large investment funds are now beginning to become involved in the ESA market, including the UK's Green Investment Group (2017).

5.6 Community Financing

Community financing mechanisms use equity capital from multiple individuals, each providing a

²² Invoice Factoring involves the sale of project accounts and revenues (receivables) to a third party at a discount. This allows the issuing company to shift these projects with corresponding debt and future cash flows off their balance sheet - enabling them to deleverage and take on additional projects

small component of funding for a project. Often this involves groups organised around a local geographical area, adopting ‘co-operative type’ legal structures. Typically the number of shares (and votes) an individual can hold is limited (Yildiz, 2014). Projects are funded through a share issue. However, often these shares cannot be easily sold on, requiring long term commitment from project investors, who may value wider community benefits (Yildiz, 2014).

Community finance mechanisms are common for renewable energy, where in Germany, over 500 energy co-operatives with 80,000+ members have invested up to €800 million in solar PV (EEFIG, 2015). Yet, there are a growing number of examples of this being used to fund residential EE projects. The Brighton and Hove Energy Services Co-op (BHESCo) in the UK use a co-operative approach and a low-cost financing offer (5%) to fund retrofits, based on issuing shares to the local community with an annual return of 5% (BHESCo). A number of examples also exist in Germany (EEFIG, 2015).

6. Key features of retrofit finance mechanisms

The following section outlines the key findings from both sets of stakeholder interviews in relation to the *features* of these finance mechanisms as outlined in Section 3. The discussion draws upon insights from each of the *archetypes* of finance mechanisms described in the previous section, with the aim of identifying some more generalizable findings. A summary of relevant interview quotes for each feature of is provided in Table A2 in the Appendix.

6.1 Source of capital

Two interviewees felt that government should be the primary source of capital for residential retrofit. It was argued that the multiple social and environmental benefits of retrofits are ‘public goods’, justifying state financing. Equally, government bodies typically have the lowest cost of borrowing and are able to offer the longest term, lowest interest loans to the widest range of customers. It was emphasised that governments already absorbed significant risk in other areas,

providing credit guarantees and low-cost loans for a range of sectors from infrastructure to first time house purchases.

However, most interviewees (eleven out of eighteen) considered that the required investment (~\$1.3 trillion to 2035 in the EU (EEFIG, 2015)) could not be met from public sources alone. Indeed, whilst many small publicly funded programmes utilised day-to-day government spending, (such as the HES and HEEPS loans in Scotland), scaling this up could be a challenge. Therefore, many stressed the need to bring in low-cost institutional capital²³. The only scheme to have achieved this at significant scale has been PACE in California, with ESA models being better developed in the commercial sector. Crucial to accessing these sources of capital is project standardisation and the use of aggregation or securitisation techniques discussed in the following sections.

Aside from PACE, leveraging significant private capital for residential retrofit has involved public co-financing and credit enhancement approaches. Programmes such as LEEF/MEEF and some on-bill schemes in the USA use public money to reduce risk for private investors. Through provision of the 'at risk' or junior tranche of a fund or project finance structure, these approaches are able to leverage significant sums of private capital and achieve high ratios of private to public investment.

Germany's CBRP programme is able to overcome the constraints on day-to-day public spending through the use of the borrowing powers of the KfW state bank. Thus, the programme is able to access large amounts of low-cost funding via the capital markets. However, five interviewees described how this approach owes a lot to the specific institutional context in Germany and similar approaches would require significant institutional change in countries such as the USA or UK, where no equivalent banks exist.

²³ Institutional investors are a class of investor who trade in securities of sufficient scale and quantity that they qualify for preferential treatment and lower commissions. Typical institutional investors include pension funds and life insurance companies.

6.2 Financial instruments & secondary markets

Most of those interviewed agreed that the long term, low yield nature of retrofit investments lends itself to debt financing. However, BHESCo co-operative emphasised that community equity finance mechanisms could also play an important role in empowering citizens to engage in retrofit at a local level. Community shareholders may also accept lower returns in exchange for local community and environmental benefits.

EnergyPro in particular emphasised that accessing institutional investor capital is likely to require aggregated financial instruments, such as bonds enabling small loans to be pooled and traded in capital markets. Unlike central governments, state banks such as KfW are less constrained by national fiscal policy and deficit reduction as they are able to issue bonds directly into capital markets (Schröder et al., 2011). Equally EE mortgages can utilise the well-established 'covered bonds' ²⁴ markets, which are used for trading mortgage securities (European Mortgage Federation). Private sector PACE programmes in the USA, have successfully aggregated multiple retrofit loans through securitisation and sold them as PACE bonds into the asset-backed securities market (RENEW Financial).

Achieving sufficient *scale* was described by six respondents as the key challenge in accessing these secondary markets. Most institutional investors require minimum investments of at least £2m. Several examples of the ESA/energy performance contract approach have successfully sold on project receivables, often by aggregating several projects once the revenue streams or cash flows had been proven. Therefore, ESA models are an attractive means of bringing in institutional investors, although these models have so far only been used for the non-residential and multi-family markets. To appeal to institutional investors, achieving standardised projects, that can be aggregated and securitised was identified a key challenge by both Energy Pro and the European

²⁴ Covered bonds are backed both by the issuer -usually a bank and the portfolio of projects -typically mortgages. Unlike asset backed securities they remain on the balance sheet of the issuer and are thus considered very secure.

Mortgage Federation. Ensuring and demonstrating project quality is therefore important for reassuring both investors and households, mitigating the issues associated with the securitisations of sub-prime mortgages during the 2008 financial crisis.

6.3 Project performance

Long-term performance contracts as part of ESA financing structures provide a clear revenue stream that can appeal to investors in a similar way to power purchase agreements for renewable generation. Whilst it was recognised that energy performance guarantees could also be a key driver for households, Joule Assets Europe emphasised, this alone would not be sufficient to reassure private investors. Therefore, standardised procurement and quality assurance frameworks, such as the Investor Confidence Project (2015) for commercial buildings, were seen as important for attracting finance into residential retrofit.

However, requirements for energy bill neutrality such as the Green Deal's 'Golden Rule' was criticised by several interviewees. Such requirements prevent non-energy measures from being funded and obstruct deeper retrofits, particularly at high interest rates (Figure 2). For example, measures such as solid wall insulation could not be funded under the Green Deal. Restricting the focus to carbon and energy savings was also seen as a major constraint on household demand. Since customers value funding for general renovation work and aesthetic improvements, restricting funding to efficiency measures alone limits the appeal of the finance package. Mechanisms, such as the CBRP and the HEEPS equity loan and PACE to a lesser extent, allow for wider renovation measures to be funded. These schemes also do not impose strict requirements for energy bill neutrality. However, it was noted that this needs to be balanced against affordability concerns for repayments significantly above current energy bills.

6.4 Point of sale

The point of sale for finance, and the ease and availability of procuring financing alongside the

retrofit was viewed as critical by all interviewees. The analogy of the purchase of a car or mobile phone was used by several interviewees. In these mature sectors, suppliers provide a financing package as part of their offer to customers, whereas many retrofit programmes, require a separate interface, involving a long and complex application process. This is also usually separated from the process of actually procuring the retrofit measures.

The complexity of schemes such as the Green Deal, with a separate point of sale, is considered to be a major barrier. The success of PACE is partly attributed to the fact that approved contractors can offer financing through the scheme at the point of sale of the retrofit. This means that customers are able to procure the retrofit measures and financing on the same day and from the same person. This simplicity can dramatically increase uptake, although it requires a streamlined underwriting and approval process from the PACE loan provider, usually initially over the telephone. However, challenges remain with contractors' lack of literacy in financing, and financiers' lack of literacy in energy efficiency. Equally, Energy Programmes Consortium (USA) emphasised that whilst USA contractors are able to promote certain financing packages, UK contractors must be accredited with the Financial Conduct Authority before they can provide such advice. Similar arrangements exist in other EU countries. These findings highlight the importance of the presentation of the finance offering to prospective households, the levels of trust in the finance provider and quality of information provided.

6.5 Security and underwriting

Different mechanisms require different forms of security and underwriting processes, whilst most public mechanisms are unsecured. Although there are some examples of private unsecured lending, this typically involves a high cost of capital for what is perceived as a high-risk loan without collateral. Both PACE and on-bill approaches involve novel forms of security, tied to the property tax regime and energy bills respectively. Theoretically this leads to streamlined underwriting and draws in people with lower credit ratings - as the debt is secured to the

underlying asset, rather than the individual. However, this is not always the case, with one interviewee describing how it could take up to 60 days to get a Green Deal loan. Rapid underwriting and unconventional security can also raise concerns about the appropriateness of offering finance to vulnerable households who would otherwise not qualify for credit. EE mortgage models also require the inclusion of EPCs as part of the underwriting, although is unlikely to add a significant burden on already extensive mortgage eligibility assessments.

Thus, private sector funded mechanisms are likely to require a robust form of security or collateral in order to provide lending at lower interest rates (<10%). Publicly funded approaches offer greater flexibility on both underwriting and repayment terms so could therefore provide a good option for those in rented accommodation, on low incomes, with a poor credit history, or some combination thereof.

6.6 Repayment channel

The use of an existing repayment channel was viewed as a key benefit of the PACE, on-bill and mortgage-based approaches. Thus, adopting an existing bill that customers are unable to partially pay or refuse to pay the retrofit component of.

Both PACE and on-bill approaches are theoretically transferable to the new occupier of a property, addressing the split incentive issue - although currently PACE finance is only available to homeowners. Equally, mortgage or equity-release approaches such as HEEPS in Scotland, see the remaining debt resolved once the property is sold, through the equity share. Therefore, finance for measures that add value to the property strengthens the case for using mortgage-based financing. However, case studies from the USA have shown that the debt from PACE and On-bill schemes is transferred to the new occupant only about 50% of the time, thus requiring the outstanding payment on sale (Leventis et al., 2017). Further, both Energy Pro and PACE Nation

highlighted how the PACE approach would be particularly challenging for the UK given its different system of property taxation and municipal finance.

7. Discussion

This paper introduced a typology of six financing mechanisms currently adopted for residential retrofit across the EU and USA. Developing a novel framework, the paper has further identified six key features of these mechanisms and shown how these contribute to the success or failure of the mechanism. The following section discusses the findings in the context of the literature on residential retrofit and EE finance. It is shown how the six features influence three outcomes that are critical for the successful uptake of residential retrofit: *cost of capital*, *source of value* and *customer journey*. The paper then discusses how the institutional and policy context of different states is likely to shape the viability of these approaches and the policy solutions required.

7.1 Cost of capital

The stakeholder interviews explored the significance of the cost of capital for the financing of residential retrofit projects, particular for more expensive, ‘whole house’ approaches. The impact of the interest rate on household appeal has previously been highlighted by several studies on retrofit finance (Marchand et al., 2015; Rosenow and Eyre, 2016). Typically, deeper retrofits require capital expenditure of at least £15-20,000 (BEIS, 2017) and have payback periods of 20 years or more. Thus, in combination with requirements for energy bill neutrality, higher interest rates may prevent deeper (but ultimately necessary) measures like solid wall insulation from being financed. Although those with sufficient access to capital, or other forms of household borrowing may continue to self-finance retrofits (Webber et al., 2015), a lack of access to low cost finance remains a key barrier the uptake of residential retrofit. These higher costs may be offset by private benefits such as higher house prices (Brounen and Kok, 2011). However, the findings presented here suggest the customer journey and source of value have a greater impact on household

appeal.

The results support the view that the state's ability to borrow cheaply, absorb risks and deliver social and environmental benefits, provides a strong justification for public funding of investments such as residential retrofit (Stiglitz, 1993). However, given the scale of investment required, the extent to which day-to-day government spending alone can deliver this may be limited (Blyth et al., 2015). Therefore, countries such as Germany have funded large scale investment through public banks, offering very low interest rates and favourable loan terms. This builds on previous research on the market-creating and shaping role that state investment banks can play (Mazzucato and Penna, 2016), particularly where such investments are seen as high risk by private finance (Mazzucato and Semieniuk, 2018).

However, in countries without state investment banks, more 'market led' solutions are often favoured (Hall et al., 2016). This paper has described several examples of using public money to leverage significant private finance and reduce the cost of capital through tools such as credit enhancements (see Zimring, (2014a)). These approaches can also bring in customers who would otherwise not qualify for credit (Zimring et al., 2014c). Whilst this may leverage limited public funds and reduce the cost of capital, some argue that this represents a public subsidy to private capital (Bergman and Foxon, 2017) or a socialisation of risk and a privatisation of rewards (Mazzucato, 2011). However, some form of public support is likely to be required for those with difficulty in accessing low-cost capital or in rented accommodation and fuel poverty (Sovacool, 2015).

Privately funded mechanisms are likely to require robust forms of security or collateral such as mortgage eligibility and repossession (EE Mortgages), property tax default (PACE) and energy disconnection (On-bill). These findings support work such as Blyth et al., (2015) and Hall et al., (2015) on the potential role of institutional investors, such as pension funds in the energy system. Securitisation enables small loans to be pooled and sold through financial instruments such as PACE bonds in capital markets. However, this requires sufficient scale and standardised project

performance protocols currently only widespread in the PACE market and ESA's in the non-residential sector. Therefore, widespread institutional financing of EE retrofit remains largely aspirational at present (Hall et al., 2015).

7.2 Customer journey

In interpreting the findings, this paper draws on the concept of the *customer journey* (Norton et al., 2013). Whilst the previous section largely concerned with how the features of finance mechanisms affect their appeal to investors, this research suggests the nature of customer journey has a greater impact on household appeal.

A key finding is that the success of schemes such as PACE and KfW's CBRP owe a lot to the ease of the customer journey in procuring retrofit financing. PACE loans are often sold by the contractor, at the point of sale of the retrofit. The streamlined underwriting of PACE programmes has enabled loans to be approved over the telephone, during the contractor's sales visit. Equally EE mortgages utilise a well-established process, which is usually essential when purchasing a property, whilst the KfW approach uses the customers' existing bank and support from accredited project managers. This simplicity is often valued ahead of a low cost of capital by households – helping to explain why expensive credit card retrofit financing remains prevalent (Zimring et al., 2014a).

These findings support previous critiques of the UK's Green Deal which involved a complex vetting and application process, requiring a separate interface with a third-party provider (O'Keeffe et al., 2016; Rosenow and Eyre, 2016). This complexity may be further compounded when additional policy measures interact with retrofit programs, such as the smart meter rollout (McCoy and Lyons, 2017) reducing household uptake. This supports arguments for *integrated business models* for residential retrofit (Brown, 2018), including a financing offer to households alongside retrofit measures (Mahapatra et al., 2013). In an ESA, financing is fully integrated into the energy

performance contract, effectively upstream of the client (Brown, 2018).

An important dimension of the customer journey relates to how the information is presented to households and by whom. This research identifies the point of sale as the critical juncture in the customer journey in which to promote both the retrofit measures and the financing package in a clear and compelling way to households. This supports previous research which identifies the significance of how costs and benefits of retrofit are presented to households (Hoicka et al., 2014) and the importance of a trusted and competent advisor in disseminating this information (O’Keeffe et al., 2016; Risholt and Berker, 2013). Our findings therefore suggest that schemes are most successful, when the technical and financial elements of the customer offering are integrated by a single competent advisor - as is the case in the German KfW scheme (Rosenow et al., 2013a).

Adopting a repayment channel, and form of security that is tied to the underlying asset, theoretically enables PACE, on-bill and Green mortgage/equity release approaches to address split incentive barriers (Bird and Hernández, 2012). However, only on-bill mechanisms address the landlord-tenant dilemma. Yet, in many examples from the USA this has not been the case. Outstanding debt on properties with PACE or on-bill loans may need to be settled when homes change hands (Zimring et al., 2014a), although can be partially offset by increased property values (Sayce and Haggett, 2016). The latter, in turn, requires credible labelling schemes to allow the energy efficiency properties to be identified by potential buyers, together with more widespread appreciation of the benefits of energy efficiency for mortgage repayments.

7.3 Source of value

The study demonstrates how successful retrofit finance mechanisms typically involve funding for wider renovation and enabling works as part of the finance package. This builds on contemporary research on residential retrofit, where broader motivations such as environmental concerns, improved comfort and living standards, property longevity and aesthetics are often valued more

highly than cost savings (Fawcett and Killip, 2014), or at least act as important drivers for retrofit projects (Kivimaa and Martiskainen, 2018). Thus, in many cases, financing provides a means of ‘addressing a problem’, such as a broken boiler or low levels of thermal comfort. Whilst the desire to save money is often a driver (Marchand et al., 2015), households may be willing to spend more to finance these broader sources of value.

Consequently, mechanisms that have requirements for energy bill neutrality, or only fund energy measures are likely to undermine these motivations. Many of those interviewed regarded the ‘Golden Rule’ element of the Green Deal as a mistake and pointed out that no such requirements are in place for other forms of consumer finance. Equally the narrow focus on energy measures alone, may leave a finance gap for important enabling works. However, there is a need to balance these issues with concerns over affordability (Leventis et al., 2017). Other forms of project performance guarantees such as energy performance contracts, or warranties are however, likely to be valued by both households and finance providers. This supports recent work on the potential for energy performance contracts to be a demand driver for residential retrofit (Brown, 2018; Winther and Gurigard, 2017).

Critically, all those interviewed agreed that barriers for retrofit financing were of secondary importance for driving demand for residential retrofit. Indeed Borgeson et al. (2014) describe: *‘lack of financing is seldom the primary reason that efficiency projects do not happen.’* Thus, financing should be seen as an *enabler* rather than a driver of demand, with the analogy that in the Green Deal *‘people were sold the loan instead of the car’* (Rosenow and Eyre, 2016).

8. Conclusions and policy implications

This paper presented a typology of finance mechanisms for residential retrofit, including examples that are delivering at scale. The paper develops a novel framework to understand the features of these mechanisms, including; the *source of capital; financial instrument(s), project performance;*

point of sale; security and underwriting and the repayment channel.

These features are shown to implicate three outcomes that affect the success of these finance mechanisms. Firstly, it is shown that a low *cost of capital* is key to the current economic viability of whole-house retrofits, such as those involving solid wall insulation. This can be achieved through public finance through state investment banks, municipal authorities or the blending of public and private sources through a range of credit enhancements. Alternatively, low cost private financing is likely to require robust forms of security, standardised project performance protocols and access to secondary markets through the aggregation of multiple projects into trade-able financial instruments. Secondly, and perhaps more significantly, mechanisms that reduce complexity by simplifying the *customer journey* are likely to achieve much higher levels of uptake. Thirdly, by enabling non-energy measures such as general improvement works, schemes can appeal to broader *sources of value* that are more highly valued by households, often ‘addressing a problem’, such as broken boiler or low levels of comfort.

Most importantly, the paper outlines how the finance mechanism alone is unlikely to be a driver of demand for whole-house retrofit, and so instead should be viewed as a necessary *enabler* of a much broader strategy. Thus, integrated business models that enable the wider benefits of whole-house retrofits, alongside a range of up-front incentives and minimum standards are likely to be pre-requisites of a successful, ambitious retrofit programme. Consequently, a review of different retrofit incentives and investigation of how policy can support business model innovation, seem important avenues for further research.

This paper has emphasised the scale and importance of financing the low carbon retrofit of residential buildings. Different countries and regions may adopt different approaches based on their specific institutional context, with different approaches serving certain market segments. However, this goal is unlikely to be achieved without a broad strategy to promote demand and build supply chain capacity - only then requiring appropriate financing solutions. This paper

presents a template of how this can be done effectively and provides lessons from where it has not.

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9. References

- Aravena, C., Riquelme, A., Denny, E., Denny 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>
- Bergman, N., Foxon, T.J., 2017. Reorienting Finance Towards Energy Efficiency in the UK. *eccee 2017 Summer Study Proc.* January, 1–11.
- Bird, S., Hernández, D., 2012. Policy options for the split incentive: Increasing energy efficiency for low-income renters. *Energy Policy* 48, 506–514. <https://doi.org/10.1016/j.enpol.2012.05.053>
- Blyth, W.W., McCarthy, R., Gross, R., 2015. Financing the UK power sector: Is the money available? *Energy Policy* 87, 607–622. <https://doi.org/10.1016/j.enpol.2015.08.028>
- Bolton, R., Foxon, T.J., 2015. A socio-technical perspective on low carbon investment challenges - Insights for UK energy policy. *Environ. Innov. Soc. Transitions* 14, 165–181. <https://doi.org/10.1016/j.eist.2014.07.005>
- Bonfield, P., 2016. Each Home Counts - An Independent Review of Consumer Advice, Protection, Standards and Enforcement for Energy Efficiency and Renewable Energy. Department for Business, Energy and Industrial Strategy (BEIS) and Department for Communities and Local Government (DCLG).
- Borgeson, M., Todd, A., Goldman, C., 2013. Getting the Biggest Bang for the Buck Exploring the Rationales and Design Options for Energy Efficiency Financing Programs.
- Borgeson, M., Zimring, M., Goldman, C., 2014. The Limits of Financing for Energy Efficiency.
- Brounen, D., Kok, N., 2011. On the economics of energy labels in the housing market \$. <https://doi.org/10.1016/j.jeem.2010.11.006>

- Brown, D., 2018. Business models for residential retrofit in the UK: a critical assessment of five key archetypes. *Energy Effic.* <https://doi.org/10.1007/s12053-018-9629-5>
- CCC, 2018. Reducing UK emissions – 2018 Progress Report to Parliament.
- CCC, 2013. Committee on Climate Change. Fourth Carbon Budget Review – part 2.
- Collins, M., Dempsey, S., Curtis, J., 2018. Householder preferences for the design of an energy efficiency retrofit subsidy in Ireland. *Econ. Soc. Rev. (Irel)*. 49, 145–172.
- Curl, A., Kearns, A., Mason, P., 2015. Physical and mental health outcomes following housing improvements: evidence from the GoWell study. *J Epidemiol Community Heal.* 69, 12–19. <https://doi.org/10.1136/jech-2014-204064>
- DECC, 2015. Domestic Green Deal and Energy Company Obligation in Great Britain, Headline Report.
- DECC, 2013. Fuel Poverty: a Framework for Future Action.
- Diaz-Rainey, I., Robertson, B., Wilson, C., 2017. Stranded research? Leading finance journals are silent on climate change. *Clim. Change* 143, 243–260.
- DOE, 2016. Best Practice Guidelines for Residential PACE Financing Programs DOE Best Practice Guidelines for Residential PACE Financing Programs.
- EC, 2018. Directive (EU) 2018/ of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency, Official Journal of the European Union.
- EC, 2014. A policy framework for climate and energy in the period from 2020 to 2030. Communication from the Commission to the European Parliament, the Council, the European economic and social Committee and the Committee of the Regions, Publication

- Office of the European Union. <https://doi.org/10.1017/CBO9781107415324.004>
- Ecology Building Society, 2017. C-Change Mortgage Discounts | Ecology Building Society [WWW Document]. URL <https://www.ecology.co.uk/mortgages/c-change-discounts/> (accessed 6.15.17).
- EEFIG, 2015. Energy Efficiency – the first fuel for the EU Economy. <https://doi.org/10.1021/ja982781y>
- EeMAP, 2017. Energy Efficient Mortgages Action Plan (Eemap) Initiative Eemap Energy Efficiency (EE) Financing: Emerging Analysis. Brussels.
- EST, 2017. HEEPS Equity Loan | Energy Saving Trust [WWW Document]. URL <http://www.energysavingtrust.org.uk/scotland/grants-loans/heeps/heeps-equity-loan-scheme> (accessed 12.21.17).
- EST, 2011. Local Authority Large Scale Retrofit: A Review of Finance Models.
- Fawcett, T., 2014. Exploring the time dimension of low carbon retrofit: owner-occupied housing. *Build. Res. Inf.* 42, 477–488. <https://doi.org/10.1080/09613218.2013.804769>
- Fawcett, T., Killip, G., 2014. Anatomy of low carbon retrofits: evidence from owner-occupied Superhomes. *Build. Res. Inf.* 42, 434–445. <https://doi.org/10.1080/09613218.2014.893162>
- Freehling, J., Stickles, B., 2016. Energy Efficiency Finance: A Market Reassessment (An ACEE White Paper).
- Fuerst, F., McAllister, P., Nanda, A., Wyatt, P., 2015. Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England. *Energy Econ.* 48. <https://doi.org/10.1016/j.eneco.2014.12.012>
- Gillingham, K., Newell, R.G., Palmer, K., 2009. *Energy Efficiency Economics and Policy*.

<https://doi.org/10.1146/annurev.resource.102308.124234>

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, 739–748.

<https://doi.org/10.1016/j.enpol.2015.08.012>

Green Investment Group, 2017. Energy Solutions - Making energy work harder, in: SEAF Investor Forum.

Hall, S., Foxon, T.J., Bolton, R., 2016. Financing the civic energy sector: How financial institutions affect ownership models in Germany and the United Kingdom. *Energy Res. Soc. Sci.* 12, 5–15. <https://doi.org/10.1016/j.erss.2015.11.004>

Hall, S., Foxon, T.J., Bolton, R., 2015. Investing in low-carbon transitions: energy finance as an adaptive market. *Clim. Policy* 3062, 1–19. <https://doi.org/10.1080/14693062.2015.1094731>

HM Government, 2017. The Clean Growth Strategy Leading the way to a low carbon future.

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>

IEA, 2017. Market-based Instruments for Energy Efficiency.

IEA, 2013. Transition to sustainable buildings: Strategies and opportunities to 2050, OECD.
<https://doi.org/10.1787/9789264202955-en>

Investor Confidence Project, 2015. Fueling investment in energy efficiency.

IPCC, 2014. Climate Change 2014: Mitigation of Climate Change. Summary for Policymakers and Technical Summary, Climate Change 2014: Mitigation of Climate Change. Part of the

- Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. <https://doi.org/10.1017/CBO9781107415416.005>
- Jaffe, A.B., Stavins, R.N., 1994. The energy-efficiency gap What does it mean? *Energy Policy* 22, 804–810. [https://doi.org/10.1016/0301-4215\(94\)90138-4](https://doi.org/10.1016/0301-4215(94)90138-4)
- Kangas, H.-L., Lazarevic, D., Kivimaa, P., 2018. Technical skills, disinterest and non-functional regulation: Barriers to building energy efficiency in Finland viewed by energy service companies. *Energy Policy* 114, 63–76. <https://doi.org/10.1016/j.enpol.2017.11.060>
- Kats, G., Menkin, A., Domm, J., Debold, M., 2011. *Energy Efficiency Financing -Models and Strategies, Capital E.*
- Kern, F., Kivimaa, P., Martiskainen, M., 2017. Policy packaging or policy patching? The development of complex energy efficiency policy mixes. *Energy Res. 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*. <https://doi.org/10.1016/j.enpol.2017.03.053>
- Kim, C., O'Connor, R., Bodden, K., 2012. *Innovations and Opportunities in Energy Efficiency Finance*, Wilson Sonsini Goodrich & Rosati.
- Kivimaa, P., Martiskainen, M., 2018. Innovation, low energy buildings and intermediaries in Europe: systematic case study review. *Energy Effic.* 11, 31–51. <https://doi.org/10.1007/s12053-017-9547-y>
- Knoeri, C., Steinberger, J.K., Roelich, K., 2016. End-user centred infrastructure operation: Towards integrated end-use service delivery. *J. Clean. Prod.* 132, 229–239. <https://doi.org/10.1016/j.jclepro.2015.08.079>

- Labanca, N., Suerkemper, F., Bertoldi, P., Irrek, W., Duplessis, B., 2014. Energy efficiency services for residential buildings: Market situation and existing potentials in the European Union. *J. Clean. Prod.* 109, 284–295. <https://doi.org/10.1016/j.jclepro.2015.02.077>
- LEEF, 2012. Introduction to the London Energy Efficiency Fund (LEEF).
- LENDERS, 2017. Lenders-Improving energy costs in mortgages- Promoting energy efficiency in homes. <https://doi.org/10.1089/obe.2005.1.166>
- Leventis, G., Kramer, C., Schwartz, L., Zetterberg, J., Ludwig, V., 2017. Energy Efficiency Financing for Low-and Moderate-Income Households: Current State of the Market, Issues, and Opportunities Financing Solutions Working Group FOR MORE INFORMATION.
- Long, T.B., Young, W., Webber, P., Gouldson, A., Harwatt, H., 2015. The impact of domestic energy efficiency retrofit schemes on householder attitudes and behaviours. *J. Environ. Plan. Manag.* 58, 1853–1876. <https://doi.org/10.1080/09640568.2014.965299>
- Mahapatra, K., Gustavsson, L., Haavik, T., Aabrekk, S., Svendsen, S., Vanhoutteghem, L., Paiho, S., Ala-Juusela, M., 2013. Business models for full service energy renovation of single-family houses in Nordic countries. *Appl. Energy* 112, 1558–1565. <https://doi.org/10.1016/j.apenergy.2013.01.010>
- Marchand, R.D., Koh, S.C.L.L., Morris, J.C., 2015. Delivering energy efficiency and carbon reduction schemes in England: Lessons from Green Deal Pioneer Places. *Energy Policy* 84, 96–106. <https://doi.org/10.1016/j.enpol.2015.04.035>
- Mazzucato, M., 2011. The entrepreneurial state. *Soundings* 49, 131–142. <https://doi.org/10.3898/136266211798411183>
- Mazzucato, M., Penna, C.C.R., 2016. Beyond market failures: the market creating and shaping roles of state investment banks. *J. Econ. Policy Reform* 19, 305–326.

<https://doi.org/10.1080/17487870.2016.1216416>

Mazzucato, M., Semieniuk, G., 2018. Financing renewable energy: Who is financing what and why it matters. *Technol. Forecast. Soc. Change* 127, 8–22.

<https://doi.org/10.1016/j.techfore.2017.05.021>

McCoy, D., Lyons, S., 2017. Unintended outcomes of electricity smart-metering: trading-off consumption and investment behaviour. *Energy Effic.* 10, 299–318.

<https://doi.org/10.1007/s12053-016-9452-9>

Mlecnik, E., Paiho, S., Cré, J., Stenlund, O., Vrijders, J., Haavik, T., Synnove, A., Vanhoutteghem, L., Hansen, S., 2011. Web Platforms Integrating Supply and Demand for Energy Renovations 1–8.

Modigliani, F., Miller, M.H., 1958. The Cost of Capital, Corporation Finance and the Theory of Investment. *Am. Econ. Rev.* 48, 261–297. <https://doi.org/10.4013/base.20082.07>

Nolden, C., Sorrell, S., 2016. The UK market for energy service contracts in 2014-2015. *Energy Effic.* 1–16. <https://doi.org/10.1007/s12053-016-9430-2>

Norton, D.W., Joseph, B., Li, P., 2013. Using the customer journey to road test and refine the business model. <https://doi.org/10.1108/10878571311318196>

O’Keeffe, J.M., Gilmour, D., Simpson, E., 2016. A network approach to overcoming barriers to market engagement for SMEs in energy efficiency initiatives such as the Green Deal. *Energy Policy* 97, 582–590. <https://doi.org/10.1016/j.enpol.2016.08.006>

OECD, 2015. Infrastructure Financing Instruments and Incentives.

Rezessy, S., Bertoldi, P., 2010. Financing Energy Efficiency: Forging the link between financing and project implementation. *Environ. Plan. A* 41, 1072–1089.

- Risholt, B., Berker, T., 2013. Success for energy efficient renovation of dwellings - Learning from private homeowners. *Energy Policy* 61, 1022–1030.
<https://doi.org/10.1016/j.enpol.2013.06.011>
- Rosenow, J., 2012. Energy savings obligations in the UK-A history of change. *Energy Policy* 49, 373–382. <https://doi.org/10.1016/j.enpol.2012.06.052>
- Rosenow, J., Eyre, N., 2016. A post mortem of the Green Deal: Austerity, energy efficiency, and failure in British energy policy. *Energy Res. Soc. Sci.* 21, 141–144.
<https://doi.org/10.1016/j.erss.2016.07.005>
- Rosenow, J., Eyre, N., Bürger, V., Rohde, C., 2013a. Overcoming the Upfront Investment Barrier: Comparing the German CO2 Building Rehabilitation Programme and the British Green Deal. *Energy Environ.* 24, 83–104. <https://doi.org/10.1260/0958-305X.24.1-2.83>
- 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>
- Rosenow, J., Platt, R., Flanagan, B., 2013b. Fuel poverty and energy efficiency obligations - A critical assessment of the supplier obligation in the UK. *Energy Policy* 62, 1194–1203.
<https://doi.org/10.1016/j.enpol.2013.07.103>
- Sayce, S., Haggett, F., 2016. Re-Value : Assessing the Value of Energy Efficient Properties in the Residential Sector.
- Schröder, M., Ekins, P., Power, A., Zulauf, M., Lowe, R., 2011. The KfW experience in the reduction of energy use in and CO2 emissions from buildings : operation , impacts and lessons for the UK, Energy.
- Scottish Government, 2017. Energy Strategy – Scotland's Energy Efficiency Programme

(Seep).

Sorrell, S., 2005. The contribution of energy service contracting to a low carbon economy to a low carbon economy. Tyndall Cent. Tech. Rep. No. 37 Novemb. 2005 1–114.

Sorrell, S., Schleich, J., O'Malley, E., Scott, S., 2004. The Economics of Energy Efficiency: Barriers to Cost-Effective Investment., Books. Edward Elgar, Cheltenham.

Sovacool, B.K., 2015. Fuel poverty, affordability, and energy justice in England: Policy insights from the Warm Front Program. *Energy* 93, 361–371.
<https://doi.org/10.1016/j.energy.2015.09.016>

Stiglitz, J.E., 1993. The role of the state in financial markets. *World Bank Econ. Rev.* 7, 19–62.
<https://doi.org/10.1142/S0219091508001337>

Stone, H.B.J., 2014. Market Development Objectives for the Energy Performance Contracting Sector in the UK.

SUSI Partners, 2017. SUSI Energy Efficiency Fund SUSI Energy Efficiency Fund SUSI Energy Efficiency Fund SUSI Addresses the Three Main Pillars of Energy Infrastructure.

Sweatman, P., 2012. Financing Mechanisms for Europe's Buildings Renovation: Assessment and Structuring Recommendations for Funding European 2020 Retrofit Targets 1–11.

Sweatman, P., Managan, K., 2010. Financing Energy Efficiency Building Retrofits International Policy and Business Model Review and Regulatory Alternatives for Spain, Climate Strategy and Partners. Madrid.

The Rockefeller Foundation, DB Climate Change Advisors, 2012. United States Building Energy Efficiency Retrofits Market Sizing and Financing Models.

Washan, P., Stenning, J., Goodman, M., 2014. Building the Future: The economic and fiscal

impacts of making homes energy efficient.

Webber, P., Gouldson, A., Kerr, N., 2015. The impacts of household retrofit and domestic energy efficiency schemes: A large scale, ex post evaluation. *Energy Policy* 84, 35–43.

<https://doi.org/10.1016/j.enpol.2015.04.020>

Willand, N., Ridley, I., Maller, C., 2015. Towards explaining the health impacts of residential energy efficiency interventions - A realist review. Part 1: Pathways. *Soc. Sci. Med.* 133,

191–201. <https://doi.org/10.1016/j.socscimed.2015.02.005>

Wilson, C., Crane, L., Chrysoschoidis, 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>

Winther, T., Gurigard, K., 2017. Energy performance contracting (EPC): a suitable mechanism for achieving energy savings in housing cooperatives? Results from a Norwegian pilot

project. *Energy Effic.* 10, 577–596. <https://doi.org/10.1007/s12053-016-9477-0>

Yildiz, Ö., 2014. Financing renewable energy infrastructures via financial citizen participation - The case of Germany. *Renew. Energy* 68, 677–685.

<https://doi.org/10.1016/j.renene.2014.02.038>

Yin, R.K., 1994. *Case Study Research—Design and Methods*, Sage Publications.

Zimring, M., 2014a. Credit Enhancement Overview Guide.

Zimring, M., 2014b. Energy Efficiency Financing Program Implementation Primer [WWW Document]. URL

https://www4.eere.energy.gov/seeaction/system/files/documents/financing_primer_0.pdf
(accessed 11.14.17).

Zimring, M., Leventis, G., Borgeson, M., Thompson, P., Hoffman, I., Goldman, C., 2014a.

Financing Energy Improvements on Utility Bills : Market Updates and Key Program Design
Considerations for Policymakers and Administrators.

Zimring, M., Leventis, G., Borgeson, M., Thompson, P., Hoffman, I., Goldman, C., 2014b.

Financing Energy Improvements on Utility Bills: Technical Appendix — Case Studies.

Zimring, M., Leventis, G., Goldman, C., Borgeson, M., Thompson, P., Hoffman, I., 2014c. On-
Bill Finance: From Policy to Promise to Practice 1.

Appendix

Table A1 Glossary of financial terms

Asset backed securities

Securities issued by a special purpose company that holds a package of low-risk assets whose cash flows are sufficient to service the bonds. Unlike covered bonds they do not remain on the balance sheet of the issuer.

Bill neutrality

Finance for energy efficiency measures who's repayments are less to or equal than the project cost savings from those measures

Capital markets

A financial market in which longer-term debt (generally with maturity of longer than one year) and equity instruments are traded

Cash flows or 'receivables'

Accounts receivable, based on future sources of income from a contract or finance repayments¹

Covered bonds

Unlike asset backed securities covered bonds are "covered" by both the issuer (usually a bank) and the reference portfolio of projects (assets, usually mortgages). Remaining on the balance sheet of the issuer

Credit enhancements

Broadly defined, credit enhancements are a class of tools that reduce lender or investor risk by delivering these capital providers with a level of protection against losses in the event of borrower default or delinquency

Credit rating (i.e. AAA)

Credit rating agencies typically assign letter grades to indicate ratings. These rating scale ranging from AAA (excellent) and AA+ to C and D. A debt instrument with a rating below BBB- is considered to be speculative grade or a 'junk bond', which means it is more likely to default on loans.

Factoring

Invoice Factoring is a financial transaction and a type of debt finance in which a business sells its accounts receivable (invoices) to a third party (factoring company) at a discount.

Institutional investor

Institutional investors are financial institutions that manage savings collectively on behalf of other investors such as pensions, insurance and private wealth funds. These liabilities are typically long term, and so these investors may be interested in correspondingly long-term investments.

Lien

A lien is a legal right granted by the owner of property, by a law or otherwise acquired by a creditor. A lien serves to guarantee an underlying obligation, such as the repayment of a loan. If the underlying obligation is not satisfied, the creditor may be able to seize the asset that is the subject of the lien

Liquidity

Liquidity describes the degree to which an asset or security can be quickly bought or sold in the market without affecting the asset's price.

Principal

Principal refers to the original sum of money borrowed in a loan, or put into an investment. Similarly can also refer to the face value of a bond.

Project finance

Project finance is the financing of long-term infrastructure, industrial projects and public services based upon a non-recourse or limited recourse financial structure, in which project debt and equity used to finance the project are paid back from the cash flow generated by the project.

Secondary markets

A financial market in which securities that have been previously issued (and are thus second hand) can be resold

Securitization

Securitization is the process of taking an illiquid asset, or group of assets, and through financial engineering, transforming it (or them) into a security.

Security'

A security is a fungible, negotiable financial instrument that holds some type of monetary value. It represents an ownership position in a publicly-traded corporation (via stock), a creditor relationship with a governmental body or a corporation (represented by owning that entity's bond), or rights to ownership as represented by an option.

Senior debt

Senior debt is borrowed money that a company or project must repay first if it goes out of business. In this sense its repayment is senior to the junior or junior comp

Special purpose vehicle (SPV)

A special purpose vehicle) is a subsidiary company with an asset/liability structure and legal status that makes its obligations secure even if the parent company goes bankrupt. They are often used to finance projects 'off balance sheet' of the participating firms.

Structural Funds

The Structural Funds and the Cohesion Fund are financial tools set up to implement the regional policy of the European Union. They aim to reduce regional disparities in income, wealth and opportunities. ... The Structural Funds are made up of the European Regional Development Fund (ERDF) and the European Social Fund (ESF)

Subordinated Debt

Junior Debt is a loan or security that ranks below other loans or securities with regard to claims on assets or earnings. Junior debt is also known as a 'junior security' or junior loan. In the case of borrower default, creditors who own junior debt won't be paid out until after senior debtholders are paid in full.

Subprime mortgage

A subprime mortgage is a type of mortgage that is normally issued by a lending institution to borrowers with low credit ratings. As a result of the borrower's lower credit rating, a conventional mortgage is not offered because the lender views the borrower as having a larger-than-average risk of defaulting on the loan.

Tranches

Tranches are portions of debt or securities that are structured to divide risk or group characteristics in ways that are marketable to various investors. Each portion, or tranche, is one of several related securities such as senior or junior tranches with different risks, rewards and maturities to appeal to different types of investors.

Underwriting

Involves research and assessment of the risk an application for finance presents. This helps to create the market for securities by accurately pricing risk and setting fair rates that adequately cover the true cost of lending money or providing insurance. If a specific applicant's risk is deemed too high, underwriters may refuse the offer.

Table B1 Interview details

Finance Mechanism	Organisation
Expert Scoping	
All	Climate Strategy and Partners
	United Kingdom Green Building Council (UKGBC)
	Building Research Establishment (BRE)
	Energy Programmes Consortium (USA)
	Climate Bonds Initiative
	Marksman Consulting LLP
	Energy Pro Ltd
Practitioner	
Public/credit enhancement	Energy Saving Trust Home Energy Efficiency Programme Scotland (EST-HEEPS)
	Amber Infrastructure (LEEF/MEEF)
OBF&R	National Conference of State Legislatures (NCSL)
	Business Energy and Industrial Strategy (BEIS)
ESA	Servizi Energia Ambiente (SEA)
	Joule Assets Europe
	RENESCO – Riga, Latvia
PACE	RENEW Financial
	PACE Nation
EE Mortgage	European Mortgage Federation (EeMAP)
Community Finance	Brighton and Hove Energy Services Company (BHESCo)

Table B2 interview quotations

<p>Source of capital</p>	<p><i>'this is something that should be financed by the state... i think this is the state's responsibility...by definition the state is the cheapest borrower, nobody can borrow cheaper than the state' (RENESCO)</i></p> <p><i>'actually, that's considerably less risk than the government is absolutely willing bar falling over itself to take in other parts in other areas of its portfolio.'</i> (Climate Strategy and Partners)</p> <p><i>'looking at something that might need to be scaled up....I guess there are other options that the government would need to look at...what budget might be necessary, where they might come from, how the government might be able to raise that kind of funding etcetera.'</i> (EST - HEEPS)</p> <p><i>'PACE [is] bundled together in a way that large scale, long term investors can buy it, under the certain rules...So the vast majority of what we've done has ultimately—its funded long term by pension funds, insurance companies and money managers' (RENEW Financial)</i></p> <p><i>'Look at the problem develop a solution and bring in the institutional capital ready to invest at the right time. And that would take a very small amount of public money relative to the investment'</i> (Energy Pro)</p> <p><i>'If you went out in the market and said, "I've got social-housing retrofit with external wall insulation"...most people would run a mile. So, we're there to alleviate that'(Amber Infrastructure).</i></p>
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Financial Instrument	<p><i>'One of the problems at the moment is that we've got too much equity coming in, so the equity guys want 10-15% return, the debt guys want 2-10%, the more we can make it like debt and secure it the lower the cost of the money'</i> (Marksman Consulting).</p> <p><i>'We can't nationalise the industry anymore, it would be way too expensive. Cooperatives represent a way of creating social enterprise for the energy industry'</i> (BHESCO)</p> <p><i>'Every several months...we bundle everything that we've financed using that line of credit...and we then do a rated securitization where we sell the cash flows...as a bond into the asset backed securities market'</i> (RENEW Financial)</p> <p><i>'When you go in residential, first is really difficult to find big, big projects'</i> (SEA-ESCO).</p> <p><i>'I start to feel from investment funds [they are] interested in buildings because what they have learned from experience is that energy performance contract has a really low risk from a long payment point of view'</i> (SEA-ESCO).</p>
Project performance	<p><i>'[Energy performance guarantees] have the potential to make a huge difference on... [consumer] confidence.'</i> (Energy Programmes Consortium)</p> <p><i>'Investors aren't going to accept an ESCO's performance guarantee at face value. They need to understand how the savings were calculated and this needs to be backed by strong financial modelling. They also need to know</i></p>

	<p><i>that the client is financially healthy, and possibly that the performance and savings are insurable.’ (Joule Assets Europe)</i></p> <p><i>‘One you need standardisation. And that’s where the Investor Confidence Project...comes in...standardisation of everything. The whole process has to be really standardised’. (Energy Pro)</i></p> <p><i>‘In the US PACE market, there is no requirement that a project reaches a savings to investment ratio greater than one. Some projects do not meet this test and still go ahead with financing" (PACE Nation)</i></p> <p><i>‘anecdotally from one of the downsides we heard from industry is that actually really big-ticket stuff [doesn’t happen] because of the Golden Rule cap’ (Policy Manager - BEIS).</i></p> <p><i>‘It is about selling health and well-being it is about creating better internal environment where people have the opportunities to live in a warmer, dryer stable building. But the mechanism is EE and carbon - it is never going to work...It is a flawed matrix for success’ (Director - BRE).</i></p>
Point of sale	<p><i>‘If you need to buy a car, you don't need \$30,000. You just go in... You pay a couple thousand dollars down. You drive out with the car. You're billed every month. So, you solved this upfront cost issue in like virtually every other category of things. But until...we've solved it in this residential energy sector, it's impossible to get people to do these types of projects and scale.’ (RENEW Financial)</i></p> <p><i>‘it was actually kind of a pain in the ass to get a Green Deal loan ... So, I'm like well then why the hell would you pay 9% for it. You know you're not</i></p>

	<p><i>gaining anything you know from that programme' (Energy Programmes Consortium)</i></p> <p><i>'That meant that literally while the [PACE] contractors was there he can get the customer approved on an iPad. And go ahead ... same day. Huge deal.'</i> (Energy Programmes Consortium)</p> <p><i>'the need for an integrated business model, the need for a mechanism that fits into that hand in glove. And then at the very end we then fill that with the appropriate financial instrument' (Climate Strategy and Partners)</i></p>
Security and underwriting	<p><i>'most commercial lenders want a lot more security as you'd expect. So, we're able to look at a non-secure position. Especially if ... we're more comfortable with the entity, just put it that way, like a major housing association or local authority' (Amber Infrastructure)</i></p> <p><i>'(In PACE) we get kind of pulled into that whole regime which means it's very secure. And if you don't pay your property taxes over time, really, really bad things happen, right?' (RENEW Financial)</i></p> <p><i>'if a household or an applicant stops making their repayment...it may be possible in certain situations, for there to be some flexibility for example, reducing monthly repayments based on the householder's affordability, or providing a repayment holiday.' (EST - HEEPS)</i></p> <p><i>'Contractors are the original points of contact for homeowners. Typically, a contractor can conduct a simple eligibility check 'over-the-kitchen-counter' and determine whether a project can go ahead or not. This can be done using PACE provider's software on a tablet. Then the contractor can guide</i></p>

	<p><i>a homeowner through the necessary improvements. The homeowner will receive a phone call from a PACE provider to confirm the project and go over the terms and conditions of PACE financing' (PACE Nation)</i></p> <p><i>'I spoke with people who used to run [Green Deal], and with people who analysed at it at Brussels level...and you know, had to boil it down to one example is that, sometimes it took up to 60 days for people to get the financing, and I think that's just insanity.'</i> (PACE Nation)</p>
Repayment channel	<p><i>'That's what makes it. So, when you take PACE, you get a new line item on your property tax bill ...And that is collected in the same time and in exactly the same manner with exactly all of the same rules and laws in all other parts of your property tax bill. And you can't partially pay'</i></p> <p><i>'Something such as on bill or a performance contract can help clarify the repayment terms by adding simplicity, by including the information on a bill or combining it with energy savings as well.'</i> (Energy Policy Specialist - NCSL)</p> <p><i>'So, based on the equity that house holders have in their own property, they need to be left with at least 30% equity after the loan value has been taken off' (EST-HEEPS)</i></p>