Innovative Financing Models for Low Carbon Transitions: Exploring the case for revolving funds for domestic energy efficiency programmes
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Abstract

There is widespread recognition of the need for substantially higher levels of investment in low carbon development if emissions are to be reduced at a rate and to a level that is compatible with avoiding dangerous climate change. Whilst there is a compelling economic case for action at the global scale, it is clear that this does not always translate into a case for private sector investment, and that the opportunities for public sector investment are often constrained, particularly in contexts of austerity. In response, this paper looks at innovative financing arrangements for stimulating and then benefiting from large-scale investments in energy efficiency and low carbon development. The specific focus is on the potential of revolving funds that could either reduce the investment requirements or enhance the impacts of scarce investment funds by recovering and reinvesting some of the savings generated by early investments. Such funds have been discussed before and have been created in various contexts, but as far as we are aware there has never been a formal academic evaluation of the contribution that such funds could make. The paper proposes a generic revolving fund model, and illustrates the contribution it could make to investments in the low carbon transition by applying it using data on the costs and benefits of

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domestic sector retrofit in the UK. The analysis shows that a very extensive

retrofit scheme could essentially be made cost-neutral through the creation of a

revolving fund, albeit with substantial up-front investments that would only pay

for themselves over an extended period of time. It also shows that the initial

investment requirements could be significantly reduced through the creation of

such a fund, and that the savings realized would be sufficient to fund significant

incentives schemes to encourage participation. These findings suggest that

innovative financing arrangements such as revolving funds could enable states

with limited capacities and resources to act in contexts and on issues where

action might otherwise be unlikely. Pragmatically, therefore, it seems that

revolving funds could have significant potential, particularly in an era of

austerity.

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1. Introduction

Tackling climate change undoubtedly represents an enormous challenge, but at the global scale the economic case for tackling it is compelling. Stern famously estimated that the costs of avoiding climate change could be between 1 and 2% of global GDP, but the costs of suffering climate change could amount to between 5 and 20% of GDP per year (Stern, 2007). Even with such a compelling global case for action, however, it is clear that an effective response still requires enormous levels of investment. It is also clear that the general, long term, social case for action on climate change does not always translate into a specific, short term, private case for investment, and that the availability of public funds is frequently constrained in contexts of austerity. Particularly in some settings, these factors have led to levels of financing for low carbon development that are much lower than many estimates of what is necessary. The IPCC (2014) estimated that global investment in climate mitigation and adaptation was in the range of USD 343 to 385 billion per year in the period between 2009 and 2012, and Buchner (2013) suggested that global climate finance flows have plateaued at USD 359 billion. Both of these estimates equate to roughly 0.5% of global GDP; roughly one third of the upper end of the investment needs as estimated by McKinsey (2010), IIASA (2012), WEF (2013), McCullum et al (2013) and IEA (2013a) and one quarter of the upper end of the investment needs as set out in the Stern Review (Stern, 2007).

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The need for an effective response to under-investment in climate mitigation is pressing. As the years pass, decisions are made that will lock the world in to high carbon development paths for years to come, whilst at the same time long lived emissions continue to accumulate in the atmosphere and the opportunity to make investments that will help to avoid dangerous climate change diminishes. Indeed, the IEA (2013a, p3) reported that 'the goal of limiting warming to 2°C is becoming more difficult and more costly with each year that passes'. In assessing the scope to avoid dangerous levels of climate change by limiting atmospheric emissions to no more than 450ppm, a level that is associated with a good chance of avoiding dangerous climate change (IPCC, 2014), the IEA (2013a, p3) finds that 'almost four-fifths of the CO_2 emissions allowable by 2035 are already locked-in by existing power plants, factories, buildings, etc. If action to reduce CO_2 emissions is not taken before 2017, all the allowable CO_2 emissions would be locked-in by energy infrastructure existing at that time.'

But the conditions for investment in low carbon development have hardly been ideal in the last few years. The failure to reach a global agreement on climate change in Copenhagen in 2009 coincided with the financial crisis and the start – in many countries – of a period of instability, uncertainty, recession and austerity. In many settings, for the past few years at least, more emphasis has been placed on these economic and financial issues than on tackling climate change. Indeed, as market instability and policy uncertainty limit private

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investment, and budget deficits and austerity limit public investment, it seems

appropriate to explore some innovative ways of substantially increasing

investment in low carbon development.

With this in mind, this paper explores the case for the creation of an innovative

financing mechanism – the revolving fund – where the savings from investments

in energy efficiency and other forms of low carbon development are captured

and reinvested to either reduce the need for new finance or to increase the

impact of what finance there is. Such funds have been discussed before (EC,

2011; Forum for the Future, 2011; DECC, 2012a, IEA, 2013b) and have been

adopted in different contexts to fulfil a range of objectives including energy

efficiency upgrades, promotion of renewables, provision of clean water and the

clean up of contaminated land. However, as far as we are aware there has never

been a formal academic evaluation of the contribution that such funds can make

either to reducing the cost of achieving particular carbon reduction targets or to

enhancing the impacts of scarce low carbon investment funds. This lack of

academic analysis on the potential of revolving funds to help mitigate climate

change is not unusual – indeed the IPCC (2014) notes that the scientific literature

on investment and finance to address climate change is still very limited and that

knowledge gaps are substantial.

After proposing and describing the generic features of such a revolving fund, the paper considers the ways in which this might stimulate investment in one of the most significant and cost-effective low carbon options; energy efficiency in buildings. Based on the development of a model designed to explore and illuminate the workings of a revolving fund, the paper considers the impacts that this could have on the financing of a large-scale energy efficiency programme for the domestic sector in the UK. Data are drawn from various formal assessments of the costs, performance and scope for deployment of different energy efficiency and low carbon measures that could be adopted across the UK housing stock. In order to test the sensitivity of the model to changes in real world conditions, provision is made to adjust variables including household repayment levels, energy prices, administrative costs, incentives for participation, performance gaps and rebound effects. Results are presented for a number of different scenarios, each with a slightly different design. The findings of the analysis for each specific case are presented before the wider implications for policy and practice are discussed.

2. The Need for Investment in Energy Efficiency in Buildings

In line with many previous assessments (c.f. Pacala and Socolow, 2004; IIASA, 2012), the IPCC (2014) suggested that improvements in energy efficiency should

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be a key part of any mitigation strategy designed to restrict CO2 emissions.

Globally, over one-third of all final energy and half of electricity are consumed in buildings, and buildings are therefore responsible for approximately one-third of global carbon emissions (IEA, 2013b). Energy efficiency in buildings is therefore of critical importance, and many reports highlight the presence of cost-effective opportunities to reduce their energy use (IPCC, 2014). However, the IPCC (2014) noted that many potentially attractive energy efficiency investments do not meet the short-term financial return criteria of businesses, investors, and individuals. As a result, the IEA (2013b) predicted that without a concerted push from policy, two-thirds of the economically viable potential to improve energy efficiency will remain unexploited by 2035.

The reasons for this inertia relate to the presence of strong barriers to change. The IPCC (2014) cited imperfect information, split incentives, lack of awareness, transaction costs, inadequate access to finance, industry fragmentation, the need for new delivery mechanisms and the absence of pipelines of bankable energy efficiency projects as significant barriers. Focusing specifically on the financial barriers, the IEA (2013a) highlighted the importance of up-front costs, levels of risk, issues with interest and discount rates and the inadequacy of traditional financing mechanisms for energy-efficient projects. New forms of policy support, new institutional arrangements, new forms of finance, and new

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business models are therefore required if the energy efficiency opportunities in buildings are to be exploited (IEA, 2013a; IPCC, 2014; DECC, 2012a).

The scale of the challenge is formidable – the IEA (2013b) estimated that over the next four decades USD 31 trillion will be required to promote energy efficiency in buildings at a rate that gives the world a good chance of limiting the temperature increases associated with climate change to 2°C. Whilst the IEA (2013a) suggests that 'it is widely recognised that mobilising huge investment into energy efficiency is essential' it also argues that 'offering advantageous financing mechanisms is likely to require public funds and these may be harder to justify with tighter public budgets' and that as a result mobilising private as well as public sector financing will be essential. In 2008, the IEA argued that one way of doing this might be to establish revolving funds for building refurbishment and retrofit (IEA, 2008).

These issues are particularly relevant in Europe. The European Commission (2011, p8) stated that 'In Europe, the built environment provides low-cost and short-term opportunities to reduce emissions, first and foremost through improvement of the energy performance of buildings … emissions in this area could be reduced by around 90% by 2050'. It also stated that the buildings sector provides the second largest untapped and cost-effective potential for energy savings after the energy sector itself (EC, 2011). Like many others, the EC

recognised the importance of finance and investment if the transition to more energy efficient buildings is to be made. There is recognition that there needs to be a marked improvement in financial incentive structures and that 'Innovative programs will be needed to eliminate information barriers, reduce transaction costs and mobilize investment capital' and that smart financing schemes are needed that can leverage private sector investments (ECF, 2013 p16). Indeed, the European Union has stated that 'Public finance through innovative financing instruments, such as revolving funds, preferential interest rates, guarantee schemes, risk-sharing facilities and blending mechanisms can mobilise and steer the required private finance' (EC, 2013 p11).

Given the level of interest and priority that has been given to this issue, and the fact that in the EU residential buildings need twice the investment needed by the non-residential buildings sector (IEA, 2013a), this paper explores the case for the creation of a revolving fund that could be used to stimulate investment in energy efficient and low carbon buildings.

3. Creating a Basic Revolving Fund Model

Revolving funds could come in many different forms, with different structures, scales, business models and governance arrangements. In this paper, we explore

the case for a large-scale revolving fund that could be adopted – by actors in the public, private or civic sectors on either a for-profit or not-for-profit basis - to fund energy efficiency or low carbon investments in domestic buildings.

- Model Design

The basic structure of the revolving fund assessed in this paper is set out in Figure 1. This figure shows the flows of finance into, around, and out of the revolving fund, and creates the basis for our analysis of different variables within the fund. At the heart of the revolving fund as conceived here is a new entity (here called a Special Purpose Vehicle or SPV) that is established to receive new investment funds from different sources and to invest these in energy efficiency and low carbon measures in households.

Our baseline model calculates the total investment needs associated with the widespread adoption of a range of energy efficiency and low carbon measures in a particular country, region, or city. To enable us to adjust the investment needs to reflect the available investment resources, the model sets a maximum proportion of this total that can be funded each year. Funds – that can be provided by the government, banks, institutional investors, or local communities – are borrowed by the SPV at a real (i.e. after inflation) interest rate. The model then assumes that a proportion of the total capital loaned to the SPV will be

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repaid to the original funders each year. The SPV, after making these repayments and covering its administrative costs, then invests any remaining funds in energy efficiency and low carbon measures.

The SPV then makes money available to fund a wide range of energy efficiency or low carbon measures at the household level. It is assumed that the SPV offers a menu of measures that households could opt to apply, but that the SPC ultimately decides which measures it will invest in. In taking this decision, the SPV has some limited scope for optimizing its investments, and the model allows for measures to be prioritised according to their Net Present Value (NPV), pay-back period, or carbon savings per pound invested. To reflect constraints that may arise due to a limited availability of local installers, for example, the maximum annual deployment potentials of any measure can also be set. Once the maximum available potential of the top priority measure is exploited in any one year, any available funds remaining are diverted to the next highest priority. Allowance is also made for the costs and the profits of the installers.

Households are encouraged to participate by being offered a share of the savings generated by measures whilst investment costs are being recovered, and all of the savings thereafter for the remainder of the life of the measure. Other inducements to encourage participation, such as cash-back vouchers and government subsidies are also allowed for by the model. We do of course

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recognise that financial incentives alone may not stimulate significant levels of participation and that any scheme will need to be designed and run in ways that raise awareness, minimize risk and disruption and build trust and confidence in the scheme (Dowson et al, 2012; Rosenow and Eyre, 2013). These non-financial aspects are critically important and will determine levels of take-up by households and thus the scale of the investments that can be made and the carbon savings that can be stimulated by the revolving fund.

Where participation can be promoted, households make regular periodic repayments to the SPV that allow it to recoup its financial investment. Repayments are based on a set percentage of the expected cost savings that arise from implementing the carbon efficiency measures after taking into account the impacts of performance gaps and direct rebound effects. Performance gaps reflect the difference between the technical savings that could be generated by a measure and the real savings that are likely to occur in practice with imperfect installation or operation. Direct rebound effects reflect the fact that householders may consume some of the efficiency benefits through increased comfort levels so that the measures achieve lower savings than predicted.

After taking these factors into account, an agreed proportion of the savings realised from each of the different measures funded is recovered and fed back to

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the SPV by the companies that supply energy to the building. The energy companies are paid a small fee for acting in this way. The period over which the payments are made is then determined in a way that ensures that the Internal Rate of Return (IRR) to the SPV from the original investment reaches a pre-determined threshold. This will ensure the financial resilience of the SPV. A consequence of this funding mechanism is that, the more effective the measure, the shorter the time period over which repayments are made (see Table 1). In some cases, the repayment period for a measure is longer than its effective lifetime. In this case, the household makes repayments until the measure is no longer effective, with the SPV then absorbing any financial shortfall. Although the SPV does not achieve the threshold IRR on these economically unviable projects, these measures are still funded because of the carbon savings that they generate.

As some householders may renege upon their financial obligations, the total flow of savings fed back to the SPV also has to be reduced to take defaults into account. Once this has been done, any recovered funds are used to repay the SPVs original funders/investors with interest, and after this any remaining funds are recycled and reinvested in further energy efficiency measures in households. Once all available potential for the deployment of energy efficiency and low carbon measures has been exploited, and all debts to original funders have been

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repaid, the SPV can generate a revenue stream for its owners (who could be central or local government, local communities or private entities). This revenue stream could be taken as income or reinvested in other low carbon initiatives.

- Application and Data Sources

To apply the model of the revolving fund described above, and to make use of available datasets, we focus on the scope for energy efficiency and low carbon measures to be installed in the domestic sector in the UK. We draw input data on the costs, performance and scope for deployment of a range of these measures from a model that was developed by the UK Building Research Establishment for the UK Committee on Climate Change (BRE, 2008). This is the most comprehensive publically available data set that is currently available; in the analysis below some key aspects of it (particularly energy prices, carbon intensities of electricity and levels of subsidy and feed-in-tariffs) are updated to reflect current conditions and the most recent forecasts. We also test the sensitivity of the findings to key assumptions within the data, including performance gaps and rebound effects.

We use input data on 23 energy efficiency and low carbon measures including different levels of loft, cavity, solid wall and floor insulation, improved lighting and appliances and micro-generation from solar photo-voltaics and small wind

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turbines. A full list of the measures – including their estimated lifespans and payback periods – is included in Table 1. Input data on the costs of the different measures takes into account the purchase, installation, running and maintenance costs and the different lifespans of each measure.

To assess the performance of each measure, the input data considers their impact in a standard or 'average' UK house that has already been upgraded to a good standard of energy efficiency. As many UK houses are not yet at this level of efficiency, and as energy prices could be higher than predicted, each measure could have a greater impact than is incorporated in our calibrations. Savings are then calculated using up-to-date energy prices for multiple scenarios integrating low, central and high projections of future energy prices (DECC, 2012b). They are also calculated using the most recent assessments and forecasts of the carbon intensities for electricity generation (DECC, 2012b). The scope for deploying each of the measures in suitable houses across the entire UK housing stock is also assessed in the model, based on data from the UK Committee on Climate Change. This data takes into account the proportion of homes that may be hard to reach, it adjusts for background trends in the take-up of different measures and it has been up-dated to 2012 levels. By considering the total scope for deployment of each measure across the UK, assessments of each individual measure can be scaled up to consider aggregated costs and benefits if all measures are installed in every suitable property in the UK.

- *Default Settings and Variations*

To run the model using the input data described above, we use a series of default settings for each of the key variables. These are presented in Table 2. These default settings are based on a series of assumptions that have been informed by, for example, the UK Green Deal impact assessment (DECC, 2012c) and the adoption of domestic energy efficiency schemes in cities such as the Birmingham Energy Savers scheme (BES, undated) and the Leeds City Region Domestic Energy Efficiency Programme (LCR, undated). We therefore believe that the default settings realistically reflect the conditions under which a large-scale revolving fund might operate in the UK, whether at the national or the city scales.

The default settings assume that the SPV at the heart of the revolving fund can, in any one year, borrow a maximum of 5% of the total investment required to exploit the full potential of all measures. This is at a real interest rate of 3%. We also assume that the SPV would repay 5% of its existing total borrowing in any year, until the point where all investments would be made when any surplus funds generated through on-going savings are used to clear any remaining debts. We also assume that the SPVs running costs would equate to 3% of its annual level of investment and that its threshold IRR is 4% real. We assume that the SPV

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may, over time, invest the full amount required for the full deployment of all 23 measures included in the assessment. Because of limited availability of installers and limited levels of take-up, we assume that in any year a maximum of 20% of the potential take-up of any one measure can be exploited. We also assume that installers charge 10% of the capital cost of any measure. It is assumed that, as an incentive to participate, householders retain 25% of the savings arising from any measures installed during the repayment period, with the remaining 75% diverted to the SPV. Thereafter, households retain all of the savings. Reflecting the base settings in the model that generated the input data, it is assumed that performance gaps are 41.6% and that rebound effects are 15% - in other words they assume that 56.6% of the technical energy savings potential of any measure is lost. As more recent assessments have found that performance gaps and rebound effects are much lower than these levels (see Webber et al, forthcoming), this means that the model may generate conservative predictions both of the financial viability of the revolving fund and the carbon savings that it might generate. The default settings also assume that 5% of all households default on their financial obligations, but that the SPV is still responsible for repaying any finance provided to these households. Finally, it is assumed that energy companies are paid 0.1% of the savings to pay for the administrative costs associated with collecting repayments and feeding them back to the SPV.

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While these values are adopted in the baseline run of the model, we also examine some of the sensitivities in the analysis to help us to understand the most significant factors shaping these outcomes. Specifically, we examine the effects of altering 5 key variables both individually, whilst holding all other factors constant, and in combination;

1. Increasing (and reducing) energy prices from the central to the high and low energy price forecasts provided by DECC (2012b);

2. Increasing (and reducing) the difference or spread between the SPV's borrowing and threshold IRR to 2% (and 0%);

3. Increasing (and reducing) performance gaps from 41.6% to 50% (and 30%);

4. Increasing (and reducing) the level of savings retained by householders whilst loans to the SPV are being repaid from 25% to 30% (and 20%) of estimated savings; and

5. Increasing (and reducing) the level of household defaults from 5% to 7% (and 3%).

Finally, to explore the potential for the fund to run in different ways, using the default settings we examine the impacts of three key variants in the design and operation of the fund on investment needs, financial viability and on the carbon savings it could achieve.

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The first variant considers the implications of only funding measures with a particular payback period. Rather than funding all of the 23 measures mentioned above, we limit the measures that can be funded to those with 15, 10 and 5 year payback periods. Whilst a fund seeking maximum carbon savings might fund all measures, a fund that seeks to minimize investment needs or maximize payback may focus only on measures with short payback periods.

The second variant considers the impacts of changing the affordability of different inducements to householders. As participation in domestic retrofit schemes may be restricted by short-termism and risk aversity, we consider the implications of a voucher scheme that gives householders 10% of the total costs of the measures installed as 'cash-back' when they agree to participate. This is in addition to the 25% of the value of the energy savings that they are assumed to retain during the repayment period and the 100% of savings that they retain thereafter. To find ways of paying for such inducements, we also consider the implications of asking householders to pay back 10% of the energy savings estimated after the repayment period but for a maximum of ten years from the date of the initial investment.

The third variant considers the implications of assuming that households only pay back the capital that they have received, with no additional financing component. In this case, the government provides a subsidy to cover the

financing costs of the SPV. In each period, government thus pays interest on the outstanding capital component of each measure to the SPV at the threshold IRR rate. The case for such a subsidy comes from the public interest benefits that such investments would realize – for example in helping to reduce fuel poverty, improve public heath and reduce carbon emissions.

4. Results

Under the default settings set out above, the results show that the total funding required to exploit the full realistic potential of all 23 measures shown in Table 1 across the UK would be £33.7 billion. Obviously this is a very substantial level of investment, but critically the results suggest that while £24.8 billion of this total would need to come from new capital, £8.9 billion could come from recycled investment based on savings that were recovered and reinvested. The results show that recycled investment could therefore make up 26.4% of the total investment needs over the lifetime of the fund.

The capital flows associated with this calibration of the model are presented in Figure 2. This shows that investment of £1.5 billion of new capital would be required every year for the first 12 years, but that the savings that these investments generate – that would total over £3 billion from year 5 and for much of the 40 years of its functional life - would allow the proportion of the total

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savings captured and reinvested by the SPV to grow to a peak of nearly £1.2 billion in year 5. Critically, all available opportunities for investment in the 23 energy efficiency and low carbon measures in the domestic sector would be fully exploited within 18 years[1]. After this time, the SPV would not need either any new capital or to retain and reinvest any on-going savings. This would allow it to significantly accelerate its repayments to its original investors and to become debt free after 38 years.

The levels of carbon savings arising from these investments are depicted in Figure 3. The graph shows that these investments would reduce domestic carbon emissions in the UK by up to 9.3 megatonnes (MT) per year, which equates to c6.7% of their 2012 level. This level of reduction would be approached after 12 years when most investments have been made – however it would decline over time as the carbon intensity of electricity falls and as some of the measures reach the end of their operating life; a feature that is particularly evident after 40 years. The results also show that over the lifetime of the investments, total carbon savings of 353 MT would be generated – this is equivalent to 74.5% of the UK's 2012 levels of emissions.

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[1] – Annual savings increase after 15 years once expensive measures such as solid wall insulation have been fully exploited. After this point, investment is diverted to more cost-effective options with more economic rapid paybacks.

The results of the sensitivity analysis described above are set out in Table 3. As can be seen, increasing energy prices, widening the spread between borrowing and the SPV threshold IRR, and lowering performance gaps all result in shorter payback times from the SPV to the investors. These are now 32, 34 and 30 years respectively. However, increasing the threshold IRR may have a significant effect on householder participation. There may therefore be a case for public support for the government to make financial support that enhances the viability of the revolving fund without reducing levels of participation. We consider this further below. Reducing performance gaps has a significant effect on new lending requirements that are reduced by £3 billion and on recycled investment levels that are increased by the same level. In contrast, lowering energy prices, decreasing the spread between borrowing rate and the threshold IRR, or increasing performance gaps all have the effect of leaving the SPV unable to fully repay investors.

Each of the other variations has a smaller impact on all outputs, but varying them all together towards a best business case scenario reduces new lending requirements by £6.6 billion, increases recycled investment by the same level, increases peak carbon savings by 2.8 MT per year and reduces the time taken for the SPV to repay all loans to investors by 15 years. Comparative outputs for the worst-case scenario are an increase of £4.6 billion in new capital requirements, a decrease in recycled investment of the same level, a decrease in peak carbon

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savings of 2 MT per year and a failure of the SPV to fully repay its debts to investors. This highlights the need for the adoption of risk mitigation measures, perhaps in the form of government underwriting or the introduction of supporting policies.

After reverting to the default settings, we also examine the impacts of the other changes outlined above. The impacts of these changes are presented in Table 4. As is shown, total investment costs could be reduced if the range of measures that could be funded was restricted to those with paybacks of 15, 10 or 5 years. If the fund only invested in measures with a 5 year payback period or less, total investment costs could be cut from £33.7 bn to £8.8 bn, but the lifetime carbon savings generated would be more than halved from 354 to 175 MT. If a voucher scheme was adopted to encourage participation, total investment costs would increase by £3.4 billion, and new lending needs would increase by £3.8bn, however this increase could be partly offset by asking householders to pay back 10% of the energy savings realized after the repayment period but for a maximum of ten years from the date of the initial loan as this would save £2 billion in new investment needs.

If the government were to fully subsidise the financing requirements of the SPV, this would significantly decrease new lending requirements (by £4.3 bn) whilst increasing recycled investment by an equal amount. The time for the

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householders to repay the SPV would decrease to 24 years, at a cost to the

government of £6.3 bn, as can be seen on Figure 4. However, this would have

unintended consequences for the long-term viability of the fund. This is because

the subsidies from government to the SPV would be conditional on the

repayments from householders to the SPV not including a financing component.

This would shorten payback times and reduce income to the SPV, and this would

alter the cash flow of the SPV to such an extent that it could not cover its debts.

At its lowest level after 24 years, the SPV's outstanding debt would be £7bn. If

this debt was also to be paid by the government, then the total cost of the

subsidy from government would approach £14 bn. This is obviously a very

considerable amount, both in aggregate and as a proportion of the £33.7bn total

investment needed to fund the retrofit scheme in its entirety.

5. Discussion

The results presented above have important implications that relate to the

specific case of revolving funds, to wider discussions about climate change

finance and investment, and to much broader debates on the changing roles and

limited capacities of the state, particularly in an age of austerity.

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Specifically, the analysis has highlighted the need, or alternatively the opportunity, for very significant levels of investment to be undertaken that improve the energy efficiency and reduce the carbon emissions of the UK housing stock. The results show that the total level of funding needed to deploy all 23 measures included in the analysis across the entire UK housing stock is £33.7 billion. Obviously this is a vast amount of money, but it is worth pointing out that it represents 1.4% of the UK's 2012 level of GDP and that the investment could be spread over many years.

Perhaps more importantly, the analysis has shown that with a revolving fund such an extensive domestic sector retrofit scheme could be made essentially cost-neutral, albeit with significant up-front investments that would only pay for themselves over an extended period of time as energy savings come through. It has also shown that the up-front investment costs of such a scheme could be significantly reduced (in this case by £8.9 billion) through the creation of a revolving fund. The analysis has also revealed the extent of the reduction in carbon emissions that could be generated through such investments. Although in this case a 6.7% drop in domestic emissions is a relatively small reduction, it is important to point out that the lifetime savings are very significant as they are equivalent to 74.5% of the UK's total 2012 emissions.

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It is also important to point out that the results are based on figures that assume the financing and deployment of a sub-set of the wider range of energy efficiency and low carbon measures available for the domestic sector and that a large proportion of the savings that are technically achievable from these measures are lost through significant performance gaps and rebound effects. Indeed, we see elsewhere in the analysis that addressing performance gaps can have a very significant effect on the financial viability of the scheme by reducing new investment needs and replacing them with recycled investments. If initiatives to reduce performance gaps were combined with, for example, subsidized lending from the SPV, then the results suggest that further substantial reductions in new investment costs could be achieved but at a very substantial cost to the government.

The results have also highlighted the ways in which the design of a revolving fund could be varied to make it more financially viable and less risky, and to further incentivize participation in such a scheme. We have shown that focusing a fund so that it only invests in measures with short payback periods might make the scheme much more financially attractive, but that this would be achieved at the expense of significant cuts in the carbon savings that can be realised. More positively, the results show that there could be innovative ways of incentivizing householder participation that again could be cost-neutral over time. Other forms of policy support for a revolving fund could also be envisaged;

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governments could enable the emergence and effective operation of revolving funds by underwriting their borrowing to reduce default risk and creating stable policy climates to further reduce levels of uncertainty. They could also establish supporting incentive structures and provide guarantees, assurance and supporting regulations that encourage participation and ensure that public interest objectives are met.

All of these findings are also relevant to broader debates on climate finance and investment in low carbon development. The results suggest that the investment needs and the associated investment gaps discussed at the beginning of this paper might be significantly reduced if revolving funds were widely deployed. However, given the lack of research on climate finance in general and revolving funds in particular, more work needs to be done to consider the contexts in which and the extent to which revolving funds can make a useful contribution. An important issue relates to whether revolving funds have the ability to fund 'deep retrofit' initiatives that deliver much more significant cuts in energy use and carbon emissions than those demonstrated here. There are also questions about whether, how and to what extent revolving funds could be applied to new buildings as well as the retrofit of existing buildings, to commercial and industrial as well as domestic buildings and to other sectors such as energy or transport.

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More generally, the broad finding that revolving funds could enable major public interest programmes to be undertaken in ways that both significantly reduce the need for new investment and that even render substantial programmes cost-neutral over time could be of great importance. This finding suggests that innovative financing arrangements such as revolving funds could enable states with limited capacities and resources to act in contexts and on issues where action might otherwise be impossible. Pragmatically, therefore, it seems that revolving funds could have massive potential, particularly in an era of austerity.

The model presented here allows us to start to consider the potential contribution of different sources and types of finance. For example, if the revolving fund is financed by the private sector, this is likely to require the interest rate to be higher than if the capital was provided by the public sector and it may also require the capital to be repaid over a shorter period (Sullivan *et. al*, 2013). In relation to this latter point, we note that there is significant institutional investor interest in long-term (20+ years) investment structures and opportunities (see, for example, OECD, 2013), and so there may be good alignment between these investors' timeframes and the investment and repayment periods of such a fund. Similarly, when we look at the role of government funding, the model allows us to explore how different funding interventions may be deployed. For example, government funding could be used to provide some level of insurance against defaults, to reduce the cost of capital,

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to reduce the level of capital required (through debt or equity financing), to provide direct incentives to households, or to cover some of the setup and transaction costs for the SPV or the installers. In each case, the effect of these on the revolving fund's cash flows, revenues, profits and repayments can be explicitly modelled and assessed. It also enables the financial impacts on the other actors involved, which may include central and local government, capital providers, energy providers and service companies, businesses and households, to be assessed. Finally, the model enables the effect of transaction costs, e.g. SPV fees, set up costs, on investment returns and capital deployment to be evaluated.

Returning to our earlier comment about the financing of energy efficiency in an era of austerity, the analysis presented here suggests that central government can help stimulate these investments in a whole host of ways and at much lower cost than central government looking to actually fund such investments directly. It suggests that governments can encourage and provide practical support to local authorities, community groups or other bodies looking to invest in energy efficiency within their areas, and that government can help address some of the key investment risks associated with these investments (see Sullivan, 2011, Sullivan *et al,* 2013) and thereby encourage the private sector to invest in energy efficiency. Within this, it is important to recognize that many investment risks relate to, or are informed by, investors' views on the dependability of public

policy measures such as carbon taxes and their views on governments' long-term commitment to action on climate change and energy efficiency. The fact that central and/or local government provides some level of financial support for the revolving fund is, in itself, likely to be seen as mitigating some of the financial risks and, in turn, may see private investors being happy to receive lower rates of return on their investments.

While the broad case for using revolving funds to support the financing of energy efficiency is clear, they also raise profound questions around governance, accountability and legitimacy. Some of these issues are critically important in public policy debates: measures to mitigate financial risks may be seen as effectively being a form of subsidy to the private sector; a limited focus on economically attractive options may mean that governments do not achieve their wider climate change commitments; the involvement of central government or of the private sector may limit the autonomy of local government or community groups to develop funds that deliver on wider local priorities and concerns.

More generally, there is also what many would see as a danger that revolving funds – and the greater involvement of non-state actors in providing the capital needed for the delivery of public goods benefits such as reducing greenhouse gas emissions or improving energy efficiency and strengthening energy security and

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resilience - could be used by some to argue for the further curtailment of the powers of the state. This is particularly relevant in contexts where, in a climate of austerity or neoliberalism, many governments are moving away from being the provider of public goods and instead acting as facilitators or enablers for other private or civic actors to deliver these public goods (Gouldson and Sullivan, forthcoming). Whether or not this is a desirable outcome is, of course, a question of politics. One of the contributions of this article is that it enables the financial costs and benefits and the public goods outcomes (in terms of energy savings or greenhouse gas emission reductions) to be explicitly identified and assessed, thereby enabling a more informed debate on the costs, benefits and implications of this type of innovative financing mechanism to be had.

6. Conclusions

There is broad agreement that climate change is both a pressing issue and an incredibly complex challenge and that new capacities need to be developed if it is to be effectively addressed. Although there is a strong economic case for climate action at the global scale, in many settings the ability of both public and private actors to invest in low carbon development has been curtailed in recent years. Globally, levels of investment fall a long way short of those required if dangerous climate change is to be avoided. There is therefore a pressing need to

explore the potential of innovative financing arrangements that might stimulate flows of capital into, and ideally also reduce the costs of, climate action.

This paper has explored the contribution that revolving funds might make in this respect. The paper has illustrated the contribution that the creation of a revolving fund might make to investment in an extensive domestic sector energy efficiency programme in the UK. This is obviously an individual case, and although the wider body of research on this topic is limited, the analysis does suggest that revolving funds could have a very significant role to play, particularly in an era of austerity where the capacities of the state to act on climate change are often seen to be more limited. However, the paper also points to a number of important research questions where further work is needed. The experience to date with revolving funds is limited, and there is therefore a need to strengthen the evidence base on how they function, on the costs and benefits, and on the financial risk management and mitigation measures that may be adopted and how these affect the financial and energy saving outcomes that are seen. There is also a need to look much more explicitly at the governance of these funds and the associated delivery vehicles, at both the macro level (i.e. do they accelerate the withdrawal of the state from certain types of public good provision) and at the local level (i.e. how do they affect local needs and interests, how do they affect local governance). These factors deserve urgent attention given the apparent potential of revolving funds to close the climate finance gap

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and to enable intensified and accelerated action on climate change, even in an era of austerity.

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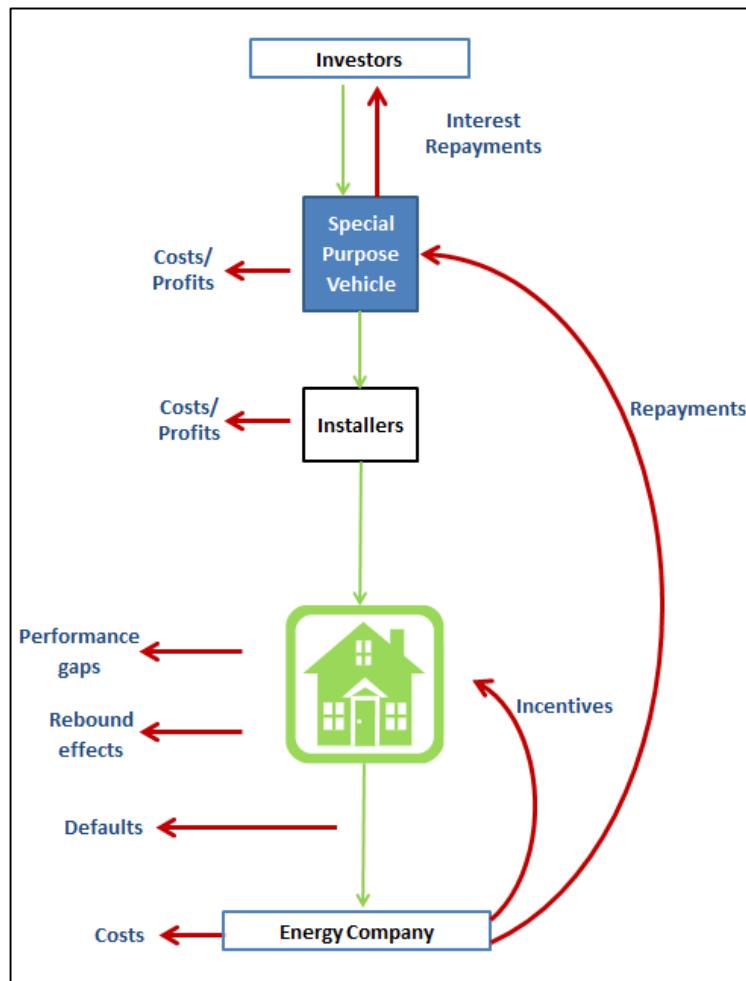
Figure 1 – The Basic Structure of the Revolving Fund

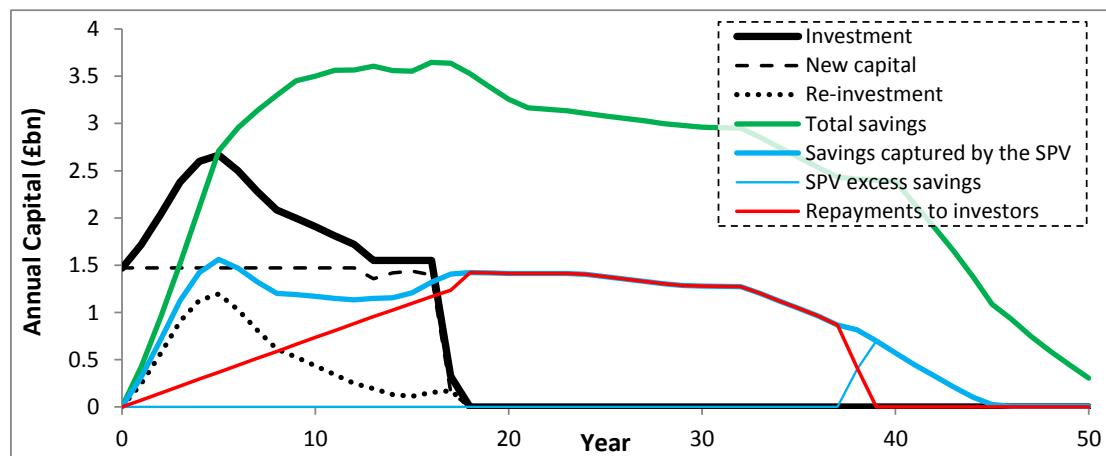Figure 2 – Profile of Investments and Savings with Default Settings

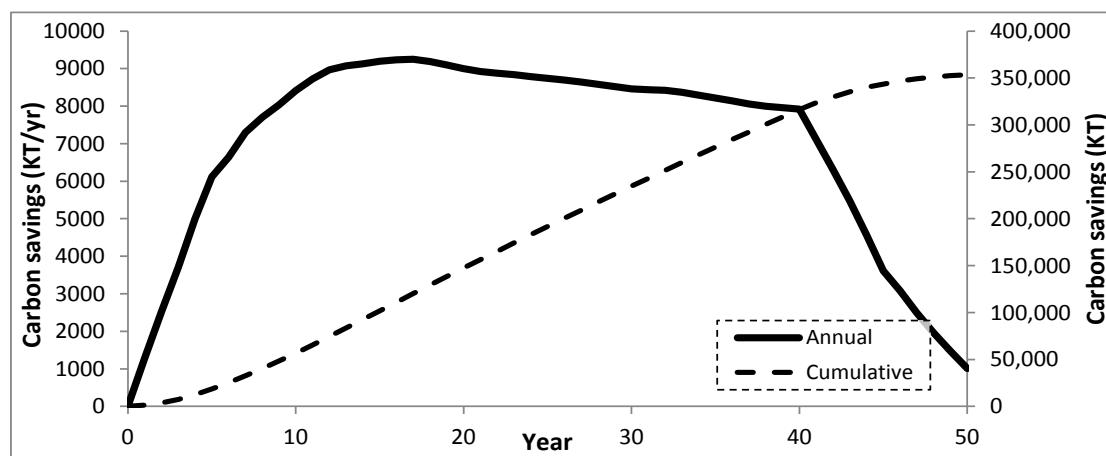Figure 3 – Profile of Annual and Accumulated Carbon Savings with Default Settings

Figure 4: Profile of Investments and Savings with Government Paying Interest
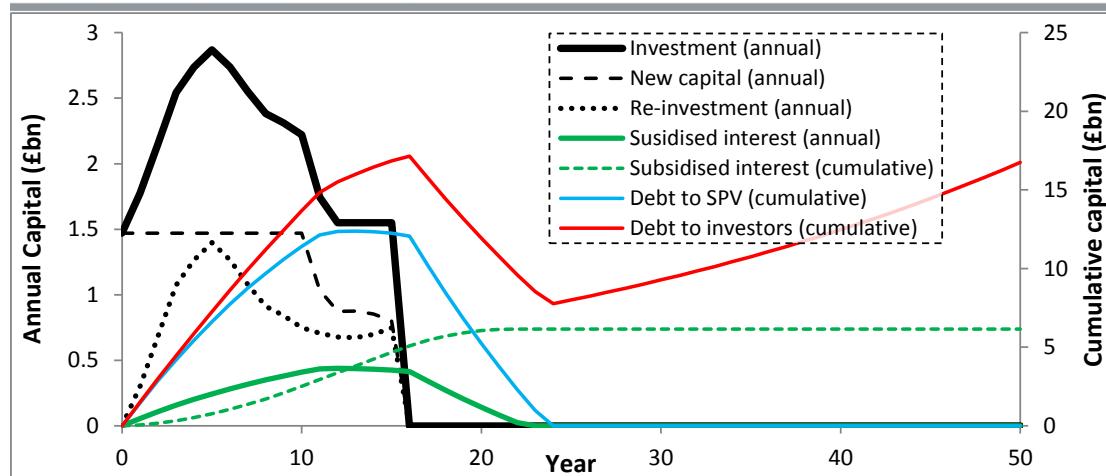
Table 1 – List of Energy Efficiency and Low Carbon Measures Assessed

Measure	Lifetime (years)	Payback period for measures installed in 2014 (years)
Loft insulation from 0 - 270mm	40	2.4
Loft insulation from 25 - 270mm	40	4.2
Loft insulation from 50 - 270mm	40	6.4
Loft insulation from 75 - 270mm	40	8.0
Loft insulation from 100 - 270mm	40	22.3
Cavity wall insulation for homes built before 1976	40	3.6
Cavity wall insulation for homes built between 1976 and 1983	40	7.4
Cavity wall insulation for homes built after 1983	40	15.8
DIY floor insulation for suspended timber floors	40	4.1
Solid wall insulation	40	33.6
Paper type solid wall insulation	40	176.1
Best practice standard windows	25	28.7
Uninsulated hot water cylinder to high performance cylinder	20	4.7
Modestly insulated hot water cylinder to high performance cylinder	20	51.0
Primary pipework insulation	15	4.1
Improve airtightness	25	6.3
Thermostatic radiator valves	15	15.1
Room thermostats	15	6.1

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Hot water cylinder thermostat	15	176.1
Efficient lighting	10	3.2
Photovoltaic generation with FIT	20	20.4
Micro wind turbines (1kW) with FIT	10	16.9
Mini wind turbines (5kw) with FIT	15	9.1

Table 2 – Default Settings

Variable	Default Setting
SPV Maximum Borrowing Level from external sources (as % of total investment need)	5%
SPV Borrowing Rate (real)	3%
SPV Annual Repayment of Loan (as % of total loan)	5%
SPV Running Costs (as % of overall investment)	3%
SPV Required Internal Rate of Return (real)	4%
Measures considered	All
Maximum exploitation of any measure in any year	20%
Installer costs	10%
Household repayment to SPV as proportion of total savings during repayment period	75%
Performance gaps	41.6%
Direct rebound effects	15%
Household default levels	5%
Cost recovery administration cost	0.1%

Table 3 – Sensitivities and Impacts of Changing Key Variables

	Total Investment (£bn)	New Lending (£bn)	Recycled Investment (£bn)	Peak Carbon Savings (MT)	Lifetime Carbon Savings (MT)	Time for SPV to become debt free (yrs)
Default settings	33.7	24.8	8.9	9.3	353	38
High (low) energy prices	33.7	22.5 (27)	11.2 (6.7)	9.4 (9.2)	354 (353)	32 (-)
Increasing (reducing) spread to 2% (0%)	33.7	24.5 (25.1)	9.2 (8.6)	9.3 (9.3)	353 (353)	34 (-)
Reducing (increasing) performance gaps to 30% (50%)	33.7	21.8 (27.2)	11.9 (6.5)	11.9 (7.4)	448 (284)	30 (-)
Reducing (increasing) incentives to 20% (30%)	33.7	24.2 (25.7)	9.5 (8)	9.3 (9.3)	354 (353)	35 (42)
Reducing (increasing) defaults to 3% (7%)	33.7	24.4 (25.5)	9.3 (8.2)	9.3 (9.3)	353 (353)	36 (41)
Overall best (worst) case scenario	33.7	18.2 (29.4)	15.5 (4.3)	12.1 (7.3)	449 (283)	23 (-)

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Table 4 – Variations in Programme Design

	Total Investment (£bn)	New Lending (£bn)	Recycled Investment (£bn)	Peak Carbon Savings (MT)	Lifetime Carbon Savings (MT)	Time for SPV to become debt free (yrs)
Default settings	33.7	24.9	8.8	9.2	354	38
Payback < 15yrs	32.7	22.9	9.8	9.2	345	40
Payback < 10yrs	15	7.9	7.1	5.7	186	33
Payback < 5yrs	8.8	3.9	4.9	5.2	175	20
Voucher scheme	37.1	28.7	8.4	9	352	45
Voucher scheme plus 10yr 10% payback	37.1	26.7	10.4	9.1	353	41
Government subsidised interest (cost to Govt. is £6.2bn)	33.7	20.6	13.1	9.4	354	24