UNIVERSITY of STRATHCLYDE
CENTRE FOR ENERGY POLICY

Research Briefing

Meeting UK's 2035 energy efficiency goals: Securing greater wider economy benefits through longer-term programmes

Antonios Katris, Karen Turner and Jamie Stewart

Executive Summary

We use an economy-wide computable general equilibrium (CGE) model – UKENVI - to investigate how the implementation of residential energy efficiency programmes over different timeframes, targeted at different low income and/or more 'able to pay' households, may impact employment and GDP across the wider economy depending on the approach to funding. The approach allows us to examine how outcomes in different timeframes are likely to be affected by responses and adjustment in all markets and all sectors of the UK economy. The results should be understood as scenario simulations to isolate the impacts of both enabling (through retrofitting of UK homes) and realising energy efficiency gains (less physical energy required to run people's homes), assuming that nothing else is acting to change activity across the economy. Note that our model database predates the current COVID slump so that near term outcomes in particular may be regarded as conservative in terms of how capacity constraints may impact.

We consider two broad policy approaches to address the question of whether greater GDP and employment gains could be achieved by supporting more substantial, specifically targeted and longer-term retrofitting programmes aimed at fully delivering the UK Government's Clean Growth Strategy aspiration for as many homes as possible to reach EPC Band C by 2035. This involves simulating the impacts of first a 4-year programme involving a total of £4billion of retrofitting spending, then a larger one, £68.5billion, over 15 years (both starting in 2021). In all cases, the CGE modelling approach allows us to consider expansionary processes triggered by **real income gains from reduced energy bills redirected to spending that stimulates other sectors of the economy.** This, in turn, leads to a wider demand driven economic expansion that is reflected in sustained net gains in key variables such as GDP, employment demand and earnings from employment. It **builds on more transitory expansion fuelled by delivering retrofitting projects** to deliver macroeconomic gains that offset initial funding requirements.

Short-term energy efficiency improvement programmes can trigger long-term household income and economy-wide gains

We find that targeting funding support on low-income households would deliver energy bill savings and gains from the wider economic expansion equating to up to an **average of £25.6 per household per year across all of the 20% of UK households with the lowest incomes, with greater gains concentrated in those households actually receiving energy efficiency improvements.** This will trigger a range of wider, indirect and economic and non-economic benefits associated with addressing fuel-poverty, which is one of the main policy priorities in supporting residential energy efficiency. However, where it is also desirable to realise substantial GDP and employment gains, it is important to understand that these are likely to emerge primarily from directing a share of funding to more able-to-pay households. This is simply because the other 80% of households spend more in absolute terms on energy to begin with, with the implication that **more real spending power is freed up if these more able-to-pay households realise efficiency gains in how they heat their homes.**

For example, if we take the extreme case of all £4billion being directed to retrofitting this broader group of more able-to-pay households, this would equate to realising an average efficiency gain of 0.76% (17.2% in 4.42% of these households). Here, even under the most conservative labour market capacity assumptions there is potential for **sustained long term net GDP gains of up to just over £86.7million (0.0049% p/a) and over 1,545 new full-time equivalent (FTE) jobs,** with these gains driven entirely by the permanent gains in the energy efficiency with which households have been enabled to run their homes. In considering the **potential return to any share of the £4billion being directed towards more able-to-pay households**, the key outcome is that such scale of returns equates to **0.39 FTE jobs per £1million spent, or 2,541 FTE jobs per % unit of efficiency gains across the entire UK household stock.** Moreover, if wage cost adjustments do not constrain the expansion of the economy, sustained p/a GDP gains could rise to £300million (0.017% p/a), net FTE job creation of 5,360, or 1.34 jobs per £1million spent (8,816 jobs per % efficiency gain).

The funding option used can lead to a range of transitory impacts

However, these are long-term outcomes, settling only after the economy fully adjusts to the linked 'shocks' of retrofitting spending and realising residential energy efficiency gains. The **shorter-term outcomes, and the transition pathway depends very much on how retrofitting programmes, and the efficiency gains enabled, are funded, and on the impact of the retrofitting activity itself.** Crucially, the choice of funding model affects the timing and both the duration and magnitude of some potential temporary negative impacts that may manifest, particularly during the enabling stage of the programme when the retrofitting activity takes place. Such **temporary losses are largely due to real household spending being dampened by the need to contribute to retrofitting costs combined with impacts arising in other sectors as prices rise in an expanding but constrained economy.** For example, a grants approach obviously addresses the repayment challenge, while eliminating any potential negative changes across all timeframes. Moreover, **net annual GDP and transitory employment gains are maximised at 0.016% and 2,854 FTE jobs in 2027, with 4% of these employment gains concentrated in the UK construction sector.** On the other hand, it does introduce temporary pressure on the government budget during the timeframe grants are paid, but with this is fully recovered over time with a **sustained public budget surplus reflecting the fact that sustained net gains are delivered in a permanently expanded economy.**

In contrast, a regulation approach that forces property owners to retrofit has the potential to cause temporary negative impacts, up to 0.009% negative GDP change by 2023 (year 3), and can place considerable pressure on household incomes while paying for retrofitting, with maximum transitory GDP gains of 0.009%, along with 2,022 FTE job gains, in 2029. **Loans can mitigate or even offset these transitory negative impacts – particularly if they can be offered on a low or no interest basis** - but they extend the payment burden beyond the end of the retrofitting activity, with the implication that any temporary negative impacts associated with repayment burdens on households may be extended too.

Moreover, the transitory negative impacts (at economy-wide and household levels) can be observed under all funding approaches, **crucially where the expansion is constrained by the effects of wage pressures, and even exacerbated if the UK industries are uncertain whether short-term programmes will be refunded.** Underlying all the outcomes discussed so far, we have treated producers as anticipating potential further rounds of retrofitting programmes will roll out (as has been the case under the current ECO programme), particularly given Government's aims to ultimately raise the entire housing stock to EPC C over the next 15 years (to 2035). However, if producers do not anticipate further activity, construction and supply chain firms will begin reallocating resources before the end of the 4-year period with the implication that expansion associated with retrofitting activity will be dampened from the outset, causing temporary GDP contractions to rise to up to -0.036% by year 5 (2025).

Shifting to more substantial longer-term programmes to meet the 2035 EPC C policy target could increase energy efficiency and wider economy gains

One route to removing any uncertainty over the future of the (here 4-year) short-term programmes is to announce a long-term (here 15-year) plan, for example, one that **guarantees the achievement of the 2035 EPC Grade C goal for residential energy efficiency.** Given the ambition, this naturally equates to a more costly programme over all and per annum, requiring a **£68.5billion plan spanning over 15 years, but which reaches households across all income quintiles, thereby addressing fuel poverty concerns while exploiting the expansionary potential of freeing up spending power in more able-to-pay households.** With a programme of this length and magnitude aimed at fully delivering on the overarching objective, energy savings and the impacts of expanding GDP and employment across the economy mean that **income gains of up to £100.52 per household per year are possible in the lowest income quintile. Gains in the more able-to-pay 80% can reach £271.58 per household per year.** These significant income gains, powered by greater energy efficiency gains, mean that even in the conservative central case scenario (assuming greater capacity constraints than may now be prevalent), **larger sustained GDP gains of £1,285million (0.07% p/a) can be achieved, along with the creation of over 22,545 new sustained FTE jobs.** This equates to **0.33 FTE jobs being created per £million spent or 2,167 FTE jobs per % unit of efficiency improvement of the UK household stock**, metrics that rise to 1.15 and 7,552 respectively if we assume an absence of nominal wage pressures.

Obviously, the challenge with a long-term programme like this is to decide how to distribute the activity over the years. **There is a trade-off in terms of delaying action/slowing the pace of retrofitting action.** This may be justified by a desire to reduce any near-term transitory price pressures (which may in practice be substantially reduced in the current context of the COVID slump) and repayment burdens on households (which could be eased through, for example, longer term loans), where this limits the required building of supply chain capacity. For example, our results show that **the retrofitting programme phase may involve substantial new demand for skilled labour** (here, **over 120,000 additional FTE workers in the 'Construction' sector in 2021 – year 1– in the regulation case, and over 40,000 required for 5 years**) that may not be available at the time. Here later action introduces the risk of lack of funding and/or public support particularly at the late stages of the programme and, crucially, could act to prevent the development of required domestic supply chains. **Steady action leads to more favourable wider-economy impacts but relies on political support and funding over multiple parliamentary terms.**

Contents

1. Introduction and policy context

2019 and 2020 saw a number of key stepping stones for the UK's transition to a net zero economy, and identification of steps that the UK needs to take to achieve its climate change goals. Crucially, the Climate Change Committee's (CCC, 2019) 'Net Zero – The UK's contribution to stopping global warming' provided key advice for the UK Government in becoming the first major economy to legislate to bring all greenhouse gas emissions to net zero by 2050. The CCC has provided subsequent advice to the national and devolved governments through the 2020 'Sixth Carbon Budget', while HMT published its 'Net Zero Review: Interim Report' in late 2020, shortly after HM Government published the "The Ten Point Plan for a Green Industrial Revolution'. One common theme is a growing global consensus that residential energy efficiency is a key component to the transition to net zero. In the UK context, the Clean Growth Strategy states the aim of as many UK homes as possible reaching Energy Performance Certificate (EPC) C by 2035, with particular focus on more able-to-pay households, along with the private rental sector.

Energy efficiency is widely regarded as a cost-effective approach to reduce residential greenhouse gas (GHG) emissions, while reducing the cost delivering heat and other residential energy services, and reducing household energy bills, thereby freeing up real disposable income and spending power. The latter can trigger a sustained expansion in the UK economy leading to gains in GDP, employment opportunities and tax revenues, building on transitory gains delivered by the retrofitting activity required to enable realisation of efficiency improvements. Arguably, enabling residential energy actions constitutes a component of the net zero portfolio that, through energy efficiency and associated real income gains realised, could lead to such actions not only paying for themselves, but delivering a range of both transitory and sustained net gains across the economy. That is, where efficiency gains free up sufficient household spending power, this could trigger wider economy expansionary processes that generate sufficient net gains to offset costs of other measures necessary to enable the wider transition to a net zero economy.

Thus, the discussion becomes less one of a need to promote and support residential energy efficiency action, and more one of just how net gains over different time periods can be maximised through the deployment of different types of programmes targeted in different ways. Currently, most schemes in the UK are relatively short-term in nature, focussing on supporting retrofitting actions in phases, with new schemes coming on line shortly after the completion of existing ones and a key instrument being the Energy Company Obligation (ECO). While ECO has delivered wider economy gains (see our 2020 analysis on 'Funding UK Residential Energy Efficiency: The Economy-wide Impacts of ECO and its Alternatives'),[1] the question arises as to whether setting out longer-term programmes may more effectively secure cost effective retrofitting actions and sustain greater net economic gains through realisation of household efficiency improvements.

Moreover, ECO operates by passing the cost of enabling efficiency improvements through domestic energy bills. As with any funding mechanism, cost recovery does act to partially offset any potential real household income/spending and wider economy gains, at least for some time. However, taken in the wider context of enabling and operating proposed electrification of energy services like heat and transportation, there is a limit on how much of the cost can continue to be passed on through energy bills, and for how long, without losing the source of a range of potential gains and exacerbating issues such as fuel poverty. This motivates consideration of alternative support mechanisms, including (but not limited to) those involving public support (see e.g. Chancellor's July 2020 announcement of Green Homes Grant).

Thus, here we identify and explore two policy facing research questions focussing on the need to improve the enabling and realisation of residential energy efficiency improvements. These are set out below.

1. If a programme involving short-term schemes is to be retained, but with a potential replacement of ECO with, in the first instance at least, a 4-year £4billion programme, how might alternative potential funding options impact delivery of net economic gains at UK household and wider economy levels?

- We explore 4 different options to fund efficiency improvements. First, we consider a case where regulations require owners to improve the efficiency of their residencies, without any support from the government. Second, we consider the introduction of government-issued grants specifically for retrofitting purposes, which puts pressure on the government's budget balance. Finally, we simulate the use of interest-free loans with shorter (5 years) or longer (25 years) repayment periods to cover the retrofitting costs.

- Within this we consider the differential nature and magnitude of impacts if (in extreme) the entirety of the funding was directed to supporting the 20% of UK households with the lowest incomes or to the other, more able-to-pay 80%. This highlights a trade-off to be considered in determining the distribution of funds across different household income groups, in that the former will deliver important real income gains to more fuel poor households, while the latter will deliver reductions to higher absolute energy bills and free up more spending power to stimulate the economy.
- In reporting outcomes, we focus on macroeconomic variables commonly reported in a political economy content – i.e. GDP, employment, income from employment and the government budget balance alongside impacts on the real and disposable income of households.
- As part of our analyses we explore how the expected outcomes would vary based on whether economic expansion in the context of an overall constraint on the UK labour supply constraint causes pressure on wage costs faced by firms. Here, our central assumption is that wage determination involves real wage bargaining related to unemployment rates. That is, as unemployment falls, workers have more power to bid up their wages. We explore the impact of this assumption through alternative simulations where we fix the nominal wage. We also consider how outcomes may be expected to vary if the response to short-term schemes involves pessimistic expectations on the part of those UK industries involved (directly or indirectly) in the retrofitting of properties. Crucially, what may happen if these producers are no longer convinced that the completion of one short-term scheme will be followed by another (as has been the case since 2013).

However, ultimately, the UK's commitment is to get the entire household stock to Energy Performance Certificate (EPC) C by 2035. Estimates from our colleagues at the UK's Department for Business, Energy & Industrial Strategy (BEIS) place the total cost of achieving this goal in the region of £68.5billion pounds. Announcing a long-term (here 15-year) programme, which could comprise of multiple shorter confirmed blocks of retrofitting activity, with the aim of delivering on this objective would act to significantly reduce the impact of uncertainties around what will happen after its end. This context informs our second research question.

2. How might development of a longer-term energy efficiency improvement programme to bring the entire UK household stock to EPC C impact delivery of net economic gains to UK households and the wider economy?

- We consider the same funding options, and report the same outcomes, as in the case of short-term programmes. However, now with regulations and government-issued grants and interest-free loans with different (5 years or 25 years) repayment periods set explicitly in the context of full delivery of the transition to EPC C by 2035.
- An important consideration becomes just how any obligations and/or funds are actually allocated over the 15 years. We explore three approaches: one characterised as 'steady', where the allocation is even over the years; another as 'late' where the vast majority of activity happens in the last few years of the programme; finally, 'early' where most of the activity happens in the first years of the programme.

In addressing these two research questions, our objective is to gain a better understanding of the wider economy challenges that the UK Government may face in meeting its climate change and energy efficiency goals. In doing so, we focus on identifying the role that different funding options can play, as well as considering whether a longer-term planning could mitigate any potential negative impacts of a short-term approach and/or introduce new ones.

2. Modelling the residential energy efficiency improvements

The analysis uses the multi-sector economy–wide UKENVI computable general equilibrium (CGE) model for the UK. This approach allows us to study the causal processes (involving a range of market, price and income effects) driving potential impacts across the entire UK economy triggered by the introduction of a new policy action that promotes the improvement of residential energy efficiency. Here we give sufficient non-technical overview of our modelling and scenario simulation approach to facilitate understanding of the results reported, with fuller explanation of the main characteristics of the model and the specifications for each scenario provided in Annex A. A key point to highlight is that our model is using a 2016 Social Accounting Matrix as its basis. Arguably the economic environment was different at the time in the absence of the Covid-19 pandemic. However, these are the more recent data available for our type of analyses.

Key assumptions

There are two fundamental drivers of wider economy impacts triggered by energy efficiency actions. First, enabling energy efficiency gains through retrofitting projects etc. will boost demand for sectors like UK construction and associated supply chains during project timeframes. Second, when households actually realise energy efficiency gains, all other things remaining equal (particularly prices in domestic energy markets) they will enjoy lower bills, freeing up real income to spend on other things. Thus, there are two sources of 'demand-driven' expansion for the wider economy – one transitory and one sustained – with the extent of expansion depending on factors such as whether the presence of any supply constraints on the expanding economy cause price pressures. One obvious and lasting constraint that would cause such pressures, thereby countering the demand boosts of energy efficiency action is our assumption that the UK total labour supply is fixed. While there is some flexibility in labour supply through a small pool of unemployed workers, such a constraint will act to limit the economy's expansionary power in any timeframe.

Several other important assumptions characterise our analysis. First, particularly given the timeframes our scenarios and results relate to (up to 50 years) we assume that market forces determine labour supply, demand and wage rates. This involves bargaining processes between workers and employers, where some degree of 'market power' lies with workers when unemployment is low, and with employers when it is higher. The implication of this assumption, which we will refer to as **wage bargaining**, is that where a growing economy means that excess labour becomes more scarce, labour costs to all firms will increase leading to pressure on the price of output and, particularly where firms export, competitiveness. The feedback on the extent of economic expansion also flows through domestic demand, where higher output prices mitigate increased household demand for goods and services produced in the UK, certainly relative to what may be expected if there was no increase in labour costs. We can examine the implications of this assumption by imposing a **fixed nominal wage**, in which case the labour cost to UK firms is unchanged throughout. In fact, a fixed nominal wage assumption could be seen as more representative of the early post-Covid years where the slump in the economy and the associated increase in unemployment could lead to wages remaining fixed, at least for a short period of time.

The other key set of assumptions is in relation to the expectations of UK industries. This primarily affects the Construction industry and supply chain more directly involved in retrofitting properties, but ultimately, particularly given increased household spending on a range of goods and services, has an impact on how every UK sector responds to the introduction of energy efficiency policies. Our central assumption for the short-term programmes is that the producers (UK industries) expect that there will be a new programme available shortly after the end of the existing one, as has been the case in recent years. This drives them to adjust their production capacity on a year-by-year basis, maintaining a larger share of their capital and labour in expectation that additional retrofitting, and general economic, activity will be available in the years to come. Under this assumption the UK producers are referred to as being **optimistic**. Note that the optimistic assumption (underpinned by a myopic or near-term focus) applies to all the UK production sectors and not just the ones directly involved in retrofitting residential properties.

Alternatively, we also present results where assume that all the UK producers are more **pessimistic**. This emerges from a forward looking/ perfect foresight assumption where the implication is that, from the outset, producers do not expect any further retrofitting activity beyond the end of the announced retrofitting programme. As a result, they start reallocating their production capacity towards activities they view as more profitable much sooner than the optimistic case, and in fact even before the end of the retrofitting programme. An important point to highlight is that we mainly observe the reallocation of resources in those sectors *not* involved with delivering the retrofitting activity. The sectors that deliver projects do maintain sufficient production capacity to fulfil the retrofitting demand until the full energy efficiency improvement programme can be completed as planned. For short-term programmes, whether the expectations of the UK industries will be closer to the optimistic or the pessimistic case depends on the expectation management on behalf of the UK Government. However, for a long-term programme (15 years) of the size considered here, our central assumption regarding expectations changes so that producers do not expect it to be followed by another programme of similar size and/or duration. That is, we assume producers are pessimistic, with the negative implications of this observed in the case of the 4-year case minimised through announcement of a longer term programme, where the difference in outcomes of the pessimistic and optimistic cases is substantially reduced.

Delivering efficiency improvements

We assume that two sectors are involved in the delivery of retrofitting projects. The insulation work, and therefore the majority of the activity is fulfilled by the UK 'Construction' sector. Out of the total value of activity/funding available, 87.2% is directed to this sector. The remaining 12.8% is directed to the 'Manufacture of fabricated metal products, excluding weapons & ammunition' sector. We refer to this as 'Heating System Manufacturing' for simplicity and we use it as a proxy for a number of non-insulation measures, mainly but not limited to heating systems, that may be installed as part of the examined efficiency improvement programmes. The retrofitting activity constitutes what we refer to as **the enabling stage** of the retrofitting programmes.[2] The effects of the enabling stage are temporary and the economy returns to the pre-retrofitting levels shortly after the retrofitting activity, and any related repayment periods, end. In all scenarios, we model the retrofitting activity as an exogenous demand increase for the output of the 'Construction' and 'Heating System Manufacturing' sectors, i.e. there is no direct increase in demand by the households, the government or any other actor in the UK economy.

We assume that the cost to retrofit each property is £4,100 and that each retrofitted household receives an efficiency improvement of 17.2%. For the purpose of our analyses, this means that the same level of comfort can be achieved while using 17.2% less physical energy. However, UKENVI allows us to consider five household income groups (quintiles), each aggregating over 20% of UK households, rather than individual households. Thus, we need to scale the efficiency gains to represent the average efficiency gain accruing to each quintile group as a whole. The scaled outcome depends on the retrofitting activity directed towards each of the different quintiles and is directly linked to the size and the scope of the retrofitting programme under consideration. We detail how the scale is calculated in Annex A. The efficiency gains are considered as permanent and they cumulatively increase as more properties are retrofitting. This constitutes the **realising stage** of the retrofitting programmes and is the driver behind our long-run results.

The different support options

In this work we examine 4 distinct options to promote residential energy efficiency improvements, which are applied to both the short-term and the long-term programmes considered here (see next sub-section).

The first one, which we refer to as **Regulation**, is the introduction of regulations requiring households to bring their properties to EPC C, without financial support in any form. Here, the retrofitting cost is passed directly to the owners of the retrofitted properties. Note that since many households stay in properties that they do not own, we have simulated a scenario (see Annex B) where the retrofitting cost is passed to a different quintile (where the owner is assumed to reside) than the one receiving the efficiency improvement. Households of all income groups may rent a property instead of owning one, but for the purpose of our analysis we only focus on the case where lowest income households reside in properties owned by more able-to-pay households. For the Regulation option, we assume that repaying the retrofitting cost precedes the consumption of any goods and services. The implication is an effective reduction in the household disposable income by an amount equal to the cost of the retrofitting activity, applying for the entire period of the retrofitting programme.

The other option we explore is the provision of government-issued **Grants** to cover the retrofitting cost. We assume that these grants can only be used for a specific purpose, so they do not cause any income effects in the households that receive them. In order to maintain comparability of results across the different funding options, and to consider the impact of providing grants (in the context of any wider economic expansion triggered, which will induce receipts of a range of government revenues), we model the provision of the grants without consideration of how the necessary funds are raised. That is, we model the impacts on the public budget but do not consider what revenue sources may be explored to cover this, or how/if the budget should be balanced in any given timeframe.

As a final option we consider a case where households pay, but with the assistance of interest-free **Loans** with **short (5-year)** or **long (25-year)** repayment periods. We assume that the repayment begins in the year that the retrofitting takes place, meaning that it exceeds the duration of the retrofitting programme. In a similar way to the Regulation case, paying the instalments of the loans is assumed to take precedence over any other goods and services, hence reducing the disposable income of households.

The short-term and long-term programmes

For our shorter term (4-year) programmes (where our central assumption is of optimistic producers who expect future rounds of retrofitting projects), we assume that the annual value of retrofitting activity is £1billion, leading to £4billion total value of retrofittings. This amount is sufficient to retrofit a total of 975,610 households. If the total retrofitting activity focusses on the lowest income households quintile (HG1), it can make this quintile 3.04% on average more energy efficient (each household actually receiving a retrofit project requires 17.2% less energy to deliver the services it requires, but only 17.7% of HG1 households are targeted by the programme). On the other hand, when the activity is spread evenly across the other 4 quintiles (HG2-5), the average gain in energy efficiency is 0.76% (4.4% of households in each of the HG2-5 quintiles are retrofitted so that they require 17.2% less energy to run their properties).

Our 15-year, long-term, programmes (where assumptions regarding the optimism or pessimism of producers are less important given that this would be the maximum programme length) include a total value of retrofitting activity of approximately £68.5billion. A key difference compared to the short-term programmes is that we explore different ways in which this activity is spread over the duration of the programme. A steady approach leads to an almost even distribution over the years. With a late approach, a very small part of the activity takes place in the early years of the programme, with 50% of the retrofitting activity concentrated in the last three years and 25% in the last year alone. The picture flips under the early approach, with 25% of the retrofitting happening in year 1 (2021) and 50% by year 3 (2023). In terms of the distribution across quintiles, there is a slight variation with the least amount (18%) focussing on HG3 and most of the activity (22%) in HG5.[3] A point to note here is that in our long-term programmes the households covering the retrofitting cost are also the ones receiving the efficiency improvements.

3. Economy-wide impacts of 4-year energy efficiency programmes

The fundamental drivers of outcomes

A key point in considering all the analyses reported here (across both shorter- and longer-term programmes) is that the sustained, (long-run) outcomes of energy efficiency policies are driven by what we refer to as the realising stage – i.e. households actually directly benefiting from efficiency gains in their homes. While the enabling stage – retrofitting projects etc. – will trigger expansionary processes rippling out across the economy (albeit dampened by cost recovery), all gains to employment, GDP and other sectoral and macroeconomic indicators of performance will be transitory, bounded by the programme duration, and affected by the funding model adopted. On the other hand, realising efficiency gains allows households to run their properties using less physical energy and, as long as these are maintained, this will lead to permanent source of reduced energy bills, thereby increasing the real income that households can spend on purchasing other goods and services. The extent of sustained gains is independent of the funding model adopted, though the transition path to long-run outcomes is not, and may involve negative impacts in some timeframes both for households and the wider economy as the costly enabling and more efficient realising stage interact.

Generally, what happens to real household incomes is the key driver of all sustained outcomes, as it is the freeing up of consumer spending that is the fundamental driver of the wider economy expansion. The mechanisms do not vary dependent on which household income groups receive efficiency gains, but the extent of real income and spending gains do (the drivers of the expansion), as will the distribution of income gains realised via the expansion (i.e. lower income households benefit less from growing wage and capital incomes).

The trigger for expansion is real income gains from lower energy bills, and this emerges as the key source of benefits for the lowest income households (here considered within the framing of the lowest income quintile in the UK household sector). In turn, as the economy grows, households will enjoy further real income and consumption gains through growing wage and capital incomes. However, the importance of these gains in funding growing consumption spending varies across different household income groups, where the households in the lowest quintile access relatively limited wage and certainly capital income in a growing economy while those in the highest enjoy both higher rates and levels of return to supplying both capital and labour. Thus, gains to low income households from participating in retrofitting programmes will largely flow from actually realising efficiency gains, with any required contribution to the funding of retrofits potentially having relatively substantial impacts on (more limited) spending power freed up. Higher income households, on the other hand, will gain more from the wider economy impacts of energy efficiency programmes being rolled out, regardless of whether they are direct beneficiaries.

However, given higher absolute spending on energy bills prior to efficiency actions taking place, energy efficiency programmes involving higher income households as direct beneficiaries, involves freeing up of greater spending power which in turns triggers greater expansionary power in the economy, creating something of a 'virtuous circle'. However, the virtuosity is constrained by the fact that when the economy expands in the presence of a lasting labour supply constraint, and only a limited pool of excess/unemployed labour, this will drive increases in prices across the economy – as reflected in the CPI – which will act to 'crowd out' activity particularly in more export-orientated sectors of the economy.

Sustained (long-run) central case outcomes

In considering the case of the shorter-term, 4-year, £4billion programme, we model two extreme scenarios, one where funding is directed only to those least able-to-pay (ATP) and fuel poor households in the lowest 20% income bracket (HG1), the other where it is directed only at the most ATP 80% in HG2-5. These are not intended to be actual policy scenarios, nor with any implication that comparison based purely on wider economy benefits (a secondary focus in energy efficiency policy objectives) is intended. Moreover, the individual funding options examined are not mutually exclusive and could be applied differentially to different household income groups, reflecting varying policy objectives and needs. For instance, Grants may be offered to the lower income HG1 households (with policy focus on increasing real incomes and reducing fuel poverty within that group), while a Regulation approach may be used to promote energy efficiency gains in more able-to-pay households (with secondary policy focus on maximising wider economy and public budget gains to help justify interventions. [4] In the absence of data on what the distribution may be, we model the extremes set out above to consider the how more limited wider economy gains could still be achieved where funding is directed to lower income households, while greater 'returns' could be pursued through potentially alternative forms of intervention in the context of more able-to-pay groups. In practise, it may be useful to consider the outcomes in terms of wider economy 'returns' per £ spent and/or per average percentage gain in energy efficiency realised (the average percentage reduction in physical energy required to run households). Given that greater economy-wide returns are possible where efficiency gains are realised in higher income households, we focus on this scenario in reporting many of the results, again to illustrate a picture of maximum potential gains in different areas of the UK economy.

Given that real household income gains drive the type of wider economy expansion associated with residential energy efficiency programmes, let us consider these first for scenarios focussing on a **4-year programme involving £4billion of spending.** In the analyses reported here, we find that, **when only those 20% of UK household with the lowest income households (the quintile labelled HG1) retrofit their properties, over time these households will enjoy an average sustained annual income boost of £25.58 per household.** Note that we report the average income boost across *all* HG1 households because our model identifies household quintile groups rather than individual households. Thus, we need to scale the efficiency gains that trigger expansion and report average outcomes. In practise, income gains driven directly by the efficiency gains will be concentrated in the households that retrofitted their properties, with the remaining households in the quintile receiving small indirect real income gains as a result of the wider economy expansion. Similarly, where efficiency actions are concentrated in HG1, households in the remaining quintiles HG2-5 also receive relatively small indirect real income gains, linked entirely to the wider economic expansion triggered, and ranging between £1.56 per household per year (HG2 households) and £4.85 per household per year (HG5 households).

On the other hand, **when the retrofitting activity is evenly distributed across HG2-5**, the households of these quintiles experience sustained average income gains **between £10.36 per household per year (HG2) and £19.3 (HG5).** While this triggers greater expansionary power across the wider economy (see below), it delivers relatively limited indirect income gains for HG1 households equating to an average of £1.47 per household per year. This is not just because they do not receive any efficiency installations, but because they enjoy more limited and lower wage rate employment. Note that, while the real income gains in each quintile are smaller compared to the case where HG1 households are retrofitted, here the same volume of retrofitting activity is spread across more household quintiles. If the entire volume of activity was concentrated only on one of the ATP quintiles, or if there were £4billion of retrofitting activity in each of the HG2-5 quintiles, the income gains in beneficiary quintiles would have been larger.

So what does this wider economic expansion look like? As explained above, real household income gains delivered through lower energy bills fuel further household consumption, triggering demand-driven economic expansion across the economy. This contrasts to the impacts of retrofitting activity (enabling stage), the transitory effects of which are presented below in considering the evolution of wider economy impact. Rather, the impact of increased household consumption spending is driven by realising permanent efficiency gains, with sustained real income gains that trigger expansionary processes that underpin the long-run results reported here.

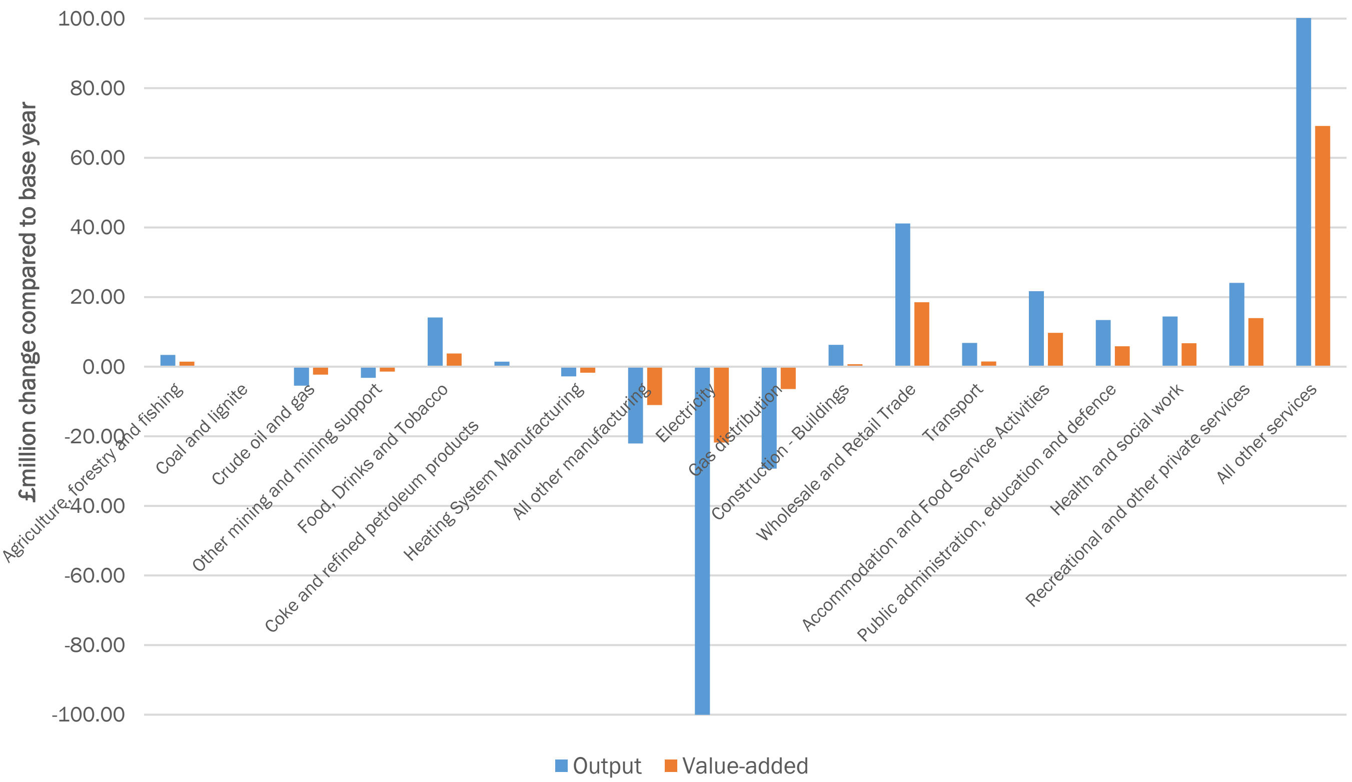
In the extreme, if combining energy efficiency gains with driving sustained expansion across the economy were the sole policy objectives, the best long-run outcomes are enabled when £4billion are used to retrofit HG2-5, 'able to pay' (ATP) households. Here the real income gains set out above are associated with **sustained GDP gains of £86.7million (0.0049% p/a) along with a 1,545 (0.0053%) net increase in new full-time equivalent (FTE) jobs.**[5] At the other extreme, if the whole £4billion were directed towards enabling efficiency gains HG1 households – including most of those classified as fuel-poor (FP) – the greater real income gains for that group (the average £25.58 per annum reported above) are associated with more restricted sustained macroeconomic gains. These amount to sustained per annum GDP gains of £63.4million (0.0036%), and a net boost to employment of 957 FTE jobs (0.0033%). To reiterate, the difference in long-run results across these two extreme cases stems from the difference in the extent of real household spending power freed up. In both cases the same total number of households are retrofitted. However, when those households are located in quintiles HG2-5, this means that they experience the same percentage efficiency gains over larger bills (in absolute terms) compared to HG1 households so that more real income is freed-up leading to a greater consumption demand increase and, thus, greater GDP and employment gains.

In practice, where some distribution across both less and more able-to-pay households is likely to be desirable, it is useful to consider the societal returns of, for example, the employment outcomes in terms of FTE jobs created/supported per £million spend and/or per % unit of efficiency gains realised. Here, the results reported above map to outcomes where **retrofitting HG2-5 properties leads to a maximum societal return of 0.39 FTE jobs per £million spent**, which is, as would be expected greater than the potential **0.24 FTE jobs per £million spent when only HG1 properties are retrofitted**. Alternatively, employment returns can be stated in terms of the efficiency gains funded, here returning **between 1,574 and 2,541 FTE jobs per % unit of efficiency gains** through funding of projects in fuel poor HG1 and ATP HG2-5 respectively. The increased employment opportunities, especially in labour intensive sectors like retail trade and accommodation services (where households spend a large share of disposable income), drive an increase of the earnings from employment across the UK economy. When ATP HG2-5 households are retrofitted, we observe a maximum 0.015% increase in real earnings from employment. Even if only HG1 were retrofitted, a sustained net gain of 0.009% per annum is possible.

However, while real wages gains are important in powering the household spending driven expansion, it is important to understand that, in the presence of what is a lasting total labour supply constraint in the UK economy, these are associated with nominal wage increases that affect the cost of labour in all sectors. In our scenario simulations, wage pressures in the constrained labour market emerge through wage bargaining processes where the power of workers to 'bid up' their wages is inversely related to the unemployment rate (i.e. the extent to which the labour supply constraint 'bites'). Here the outcome is reflected in what happens to the UK CPI, which is observed to increase by up to 0.011% over time. Underlying this is the fact that increases in nominal wage rates are the driver of sustained competitiveness loss in some sectors (pressure on capital prices relieves over time through investment activity), with the biggest impacts felt in the majority of the export-oriented manufacturing industries. This, in turn, leads to a shift in the composition of expanding UK economic activity, and reflected in the changes in both total output and value-added generated by the UK sectors.

Focussing on the scenario where the £4billion supports the ATP HG2-5 households, as an extreme scenario where macroeconomic gains are more likely to be required to justify support, Figure 1 reflects significant potential gains across the different services sectors, like 'Wholesale and Retail Trade', which, on balance, benefit more from increased domestic spending (by UK households). On the other hand, the biggest losses associated with competitiveness loss are observed in the 'All Other Manufacturing' sectors where household demands for things like food and drink, and fuel/energy are less directly or indirectly important in supporting production activity. However, the biggest net sectoral losses are actually observed in the 'Electricity' sector,[6] driven by the shift in household consumption associate with energy efficiency gains, rather than competitiveness loss. [See table A.2 in Annex A for a full list of the composition of sectors in our model]. Please note that a switch towards specific alternative technologies, which we do not model here, could change the picture we see in Figure 1. For instance, extensive use of heat pumps would lead to differences in the demand for electricity. However, in the current simulations we do not specify switching from gas to electricity as a heating fuel, where identifying the differences driven by the adoption of any specific technology will require in-depth further research.[7]

Figure 1: Long-run sectoral output and value-added generated changes due to residential energy efficiency improvements in HG2-5 of UK households



Despite gross losses in some production sectors, the long-run outcomes discussed above demonstrate that the net impact of enabling and realising the energy efficiency improvements is a positive one for the UK households and by extension to a number of important economy-wide variables like GDP, employment and earnings, even in the presence of a lasting labour supply constraint. Crucially, there are also sustained government budget savings (which, in the case of grants would contribute to the delivery of programmes). We find that there are sustained budget savings of £8.8million in the first extreme case when HG1 households are retrofitted, expanding to £13.3million in the other, where only HG2-5 are retrofitted. As with all the long-run results, the government budget savings depend on the households that are retrofitted but not on the funding mechanism used.

Of course, this does not necessarily imply that budget savings are achieved in all timeframes and for all funding mechanisms. A key driver of the impact to government budget balance, and in particular government expenditure, is related to what happens to UK prices. In our model, government expenditure includes a number of transfers to households, which are a significant source of income for HG1 households, and these are adjusted for the CPI so that households receiving them can maintain their purchasing power. Thus, increases in the CPI require a consequent adjustment in government expenditure, with the net outcome depending on whether the additional government revenue achieved due to the increased consumption and the expansion of the economy is sufficient to offset and negate. Our findings indicate that in the long-run this is the case. We examine the government budget impacts under different spending models throughout the timeframe studies below.

Examining the importance of wage pressures on wider economy outcomes

One of our central assumptions is that the total UK labour supply is fixed, with limited flexibility provided through a small pool of unemployed labour (given by ONS data in constructing our base year dataset). Thus, when labour demand increases in an expanding economy, there will be upward pressure on the nominal wage rate, determined in our model through a wage bargaining function where worker bargaining power is inversely related to the unemployment rate. In the long-run results reported above, the nominal wage is permanently increased by up to 0.023%, which, in turn, puts additional pressure on the price of UK goods and services across all sectors. To understand the importance of the labour cost in determining the outcomes of the energy efficiency improvement programme we explore an alternative assumption where the nominal wage, and therefore the cost of labour, remains fixed across all timeframes.

Our analyses with fixed nominal wage reveal that the gains across the majority of the areas we explore above are significantly greater. For example, sustained **GDP gains can reach £300million (0.018%) with 5,360 new sustained FTE jobs** when HG2-5 households are retrofitted, again regardless of the funding mechanism used. From a societal return perspective, without additional labour costs up to **1.34 FTE jobs can be created per £million spent or 8,816 FTE jobs per % unit of efficiency gains**. The key difference is that with fixed labour cost there is no long-term increase in the price of goods and services, facilitating a substantially greater increase in household consumption. Furthermore, the lack of price increases overall averts export losses and through that losses in value-added, employment and government revenue in the exporting sectors. These differences combined lead to the significantly greater GDP and employment gains under a fixed nominal wage assumption. Moreover, with no sustained increase in the CPI, government does not need to adjust its transfers which keeps government spending fixed while revenue increases. As a result, with a fixed nominal wage the same £4billion retrofitting programme can enable **sustained government savings of up to £73.5million**.

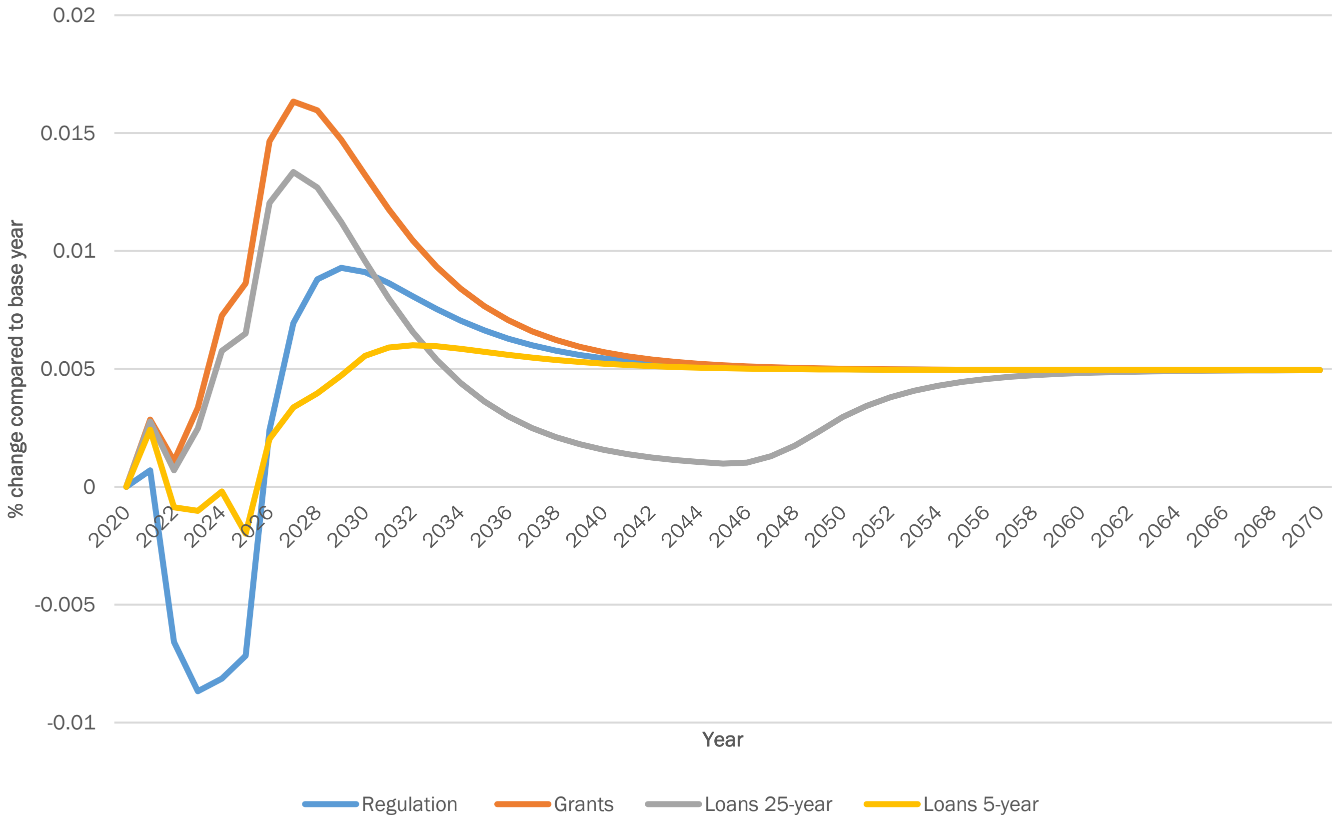
Furthermore, even without real wages rising through increased demand for labour, households still enjoy greater real income gains. In the case where retrofitting is entirely targeted on the lowest income (HG1) households, the average sustained income gains for the households of this quintile are £25.92 per household per year under a fixed nominal wage, slightly more than reported above. This is due to these households being heavily reliant on transfers from the government, and less affected by changes in employment opportunities. On the other hand, where retrofitting is concentrated in higher income households (HG2-5), a higher range of real income gains (between £10.9 and £21.6 per household per year) is explained by the more extensive expansion of the economy.

How does the economy adjust over time (through both enabling and realising stages)?

Let us return to our central case scenarios (wage bargaining assumption). While the sustained long-run results above are driven by the magnitude and targeting of efficiency gains, the impacts of alternative funding approaches are mainly observed within the timeframe of the enabling/retrofitting stage, where additional demand-driven expansionary power is triggered by the spending programme itself. The key differences in adjustment pathways are driven by nature of the funding model. Figure 2 shows the evolution of GDP for each option, for the case where retrofitting activity is evenly distributed in HG2-5 households.

The key outcome is that, depending on the funding model, the impacts from efficiency gains may not be sufficient to completely avoid temporary negative GDP changes in all time periods. In particular, under Regulation and 5-year Loans (with larger instalments than 25-year Loans) approaches, substantial repayment requirements during the period 2022 to 2025 restrict the extent of additional household consumption that powers the expansion. In this timeframe, full efficiency gains have not yet been realised, with the implication that, combined with the impacts of increased labour costs, the economy suffers temporary net losses in GDP. This is more so under Regulation option, which has greater repayment requirements at any early stage. However, efficiency gains build sufficiently to generate net gains in GDP return from year 6 (2026) and from 2050 onwards the economy shifts to the long-run trajectory.

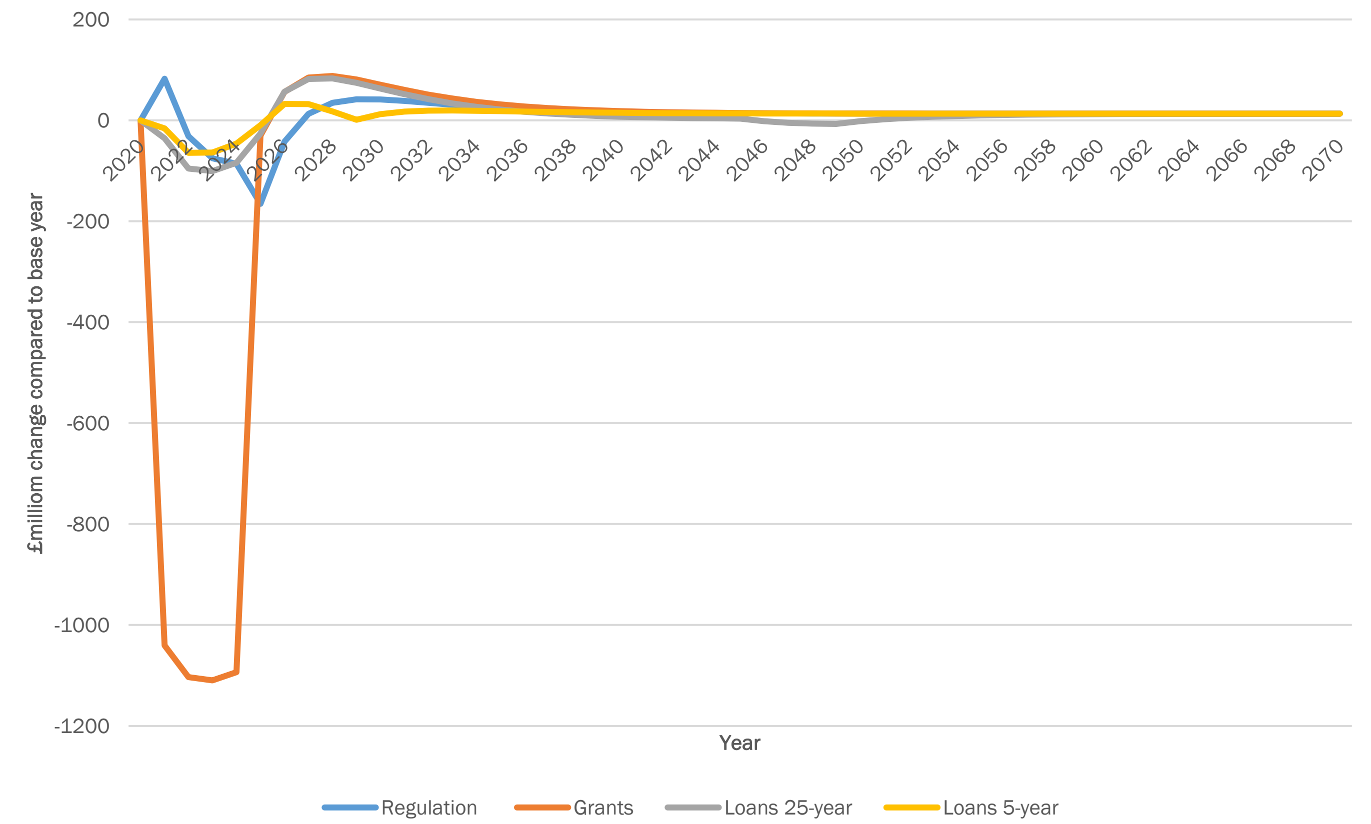
Figure 2: Evolution of GDP over time due to residential energy efficiency improvements in HG2-5 of UK households



Essentially, the provision of support through low interest loans or grants help offset, or at least reduce the magnitude of, wider economy contractions reflected in net negative GDP impacts during the enabling stage. However, under either 5-year or 25-year Loan models, reducing the magnitude of or offsetting net losses does involve a trade-off in terms of how the economy responds following the end of the retrofitting activity (enabling stage) and how soon the sustained, long-run outcomes, are reached. Although with 5-year loans the long-run results are achieved at the same time as the regulation option, the transition of the economy is slower compared to regulation, under which we observe a swifter economic recovery following the end of the enabling stage. On the other hand, 25-year loans completely offset any negative GDP impacts across all timeframes, but with the repayment period extending well beyond the end of the enabling stage, this leads to a temporary erosion of the gains achieved through the efficiency improvement, to the extent that they are almost offset. As a result, the long-run results are not reached until 2060, 10 years later compared to all the other options we consider here. Of all the different options, grants are the most effective in completely offsetting net negative GDP impacts, while reaching the long-run outcomes at the same time as regulation and 5-year loans options. However, this is done at the expense of greater transitory budget deficit during the enabling stage of up to £1.1billion in 2023 (year 3) – see Figure 3.

We can also see in Figure 3 that, to some extent, all funding options lead to government budget deficits in some timeframe. This is linked to the relationship between the price increases, reflected in the CPI, and the additional government revenue due to household consumption and the wider increase in economic activity. Especially during the enabling stage, the increased labour requirements to deliver the retrofittings generate substantial pressure to the prices across the economy and lead to additional government expenditure above the additional revenue returned. As the retrofitting activity ends, the price pressures ease and so does the need for greater government expenditure. Along with the increased household consumption due to the efficiency gains, this means that under all options government budget savings are observed from 2028 onwards. The exception to this is the 25-year loan option. At the end of the repayment period (2048) and shortly after it, the erosion of household consumption and the associated wider economic activity is sufficient to lead to temporary budget deficit of up to £6.9million in 2049.

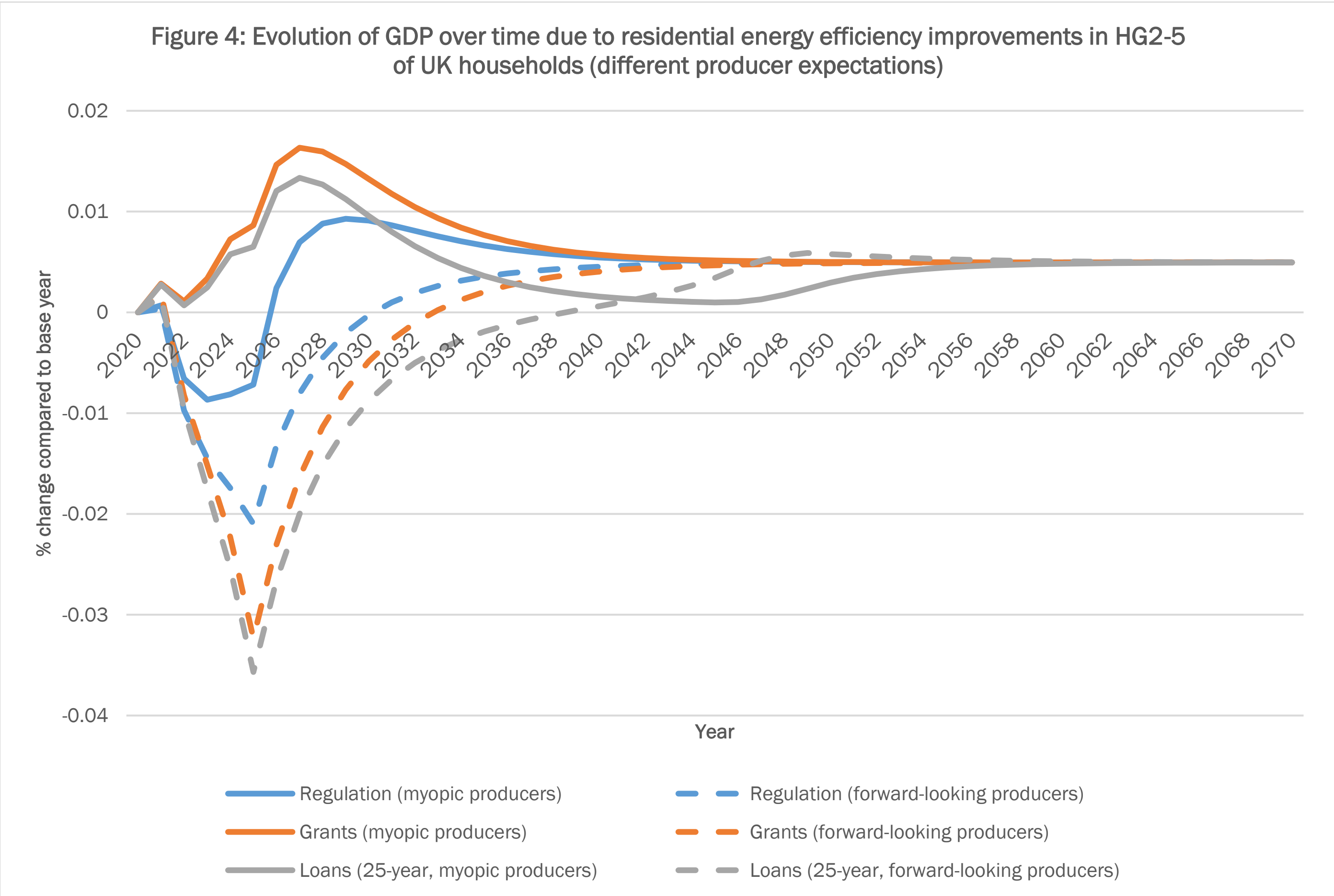
Figure 3: Evolution of government budget balance over time due to residential energy efficiency improvements in HG2-5 of UK households



Note here that our central assumption for the 4-year programmes is that all UK producers do expect subsequent rounds of retrofitting activity after the end of this programme (i.e. we assume they behave optimistically). This is an important assumption, as it acts to smooth the allocation and reallocation of resources. We make it on the basis that energy efficiency programmes in the UK – to date through ECO – have involved sequential shorter-term programmes. However, particularly in terms of more direct comparability with the nature of results under scenarios investigating the impacts of a longer-term (15-year programme below, it is useful to consider how the transitory GDP results in Figure 2 would change if we relax this assumption and consider how (pessimistic) producers react to a definite end point.

How would impact change if producers do not anticipate refunding of 4-year programmes?

Figure 4 highlights the importance of managing producers' expectations, particularly if the policy choice is to continue with a short-term but sequential residential energy efficiency. The key point is that, here, we assume producers do not expect any further retrofitting work following the end of the current programme (pessimistic producers), with the implication that they reallocate their resources away from this activity at an earlier stage. We emphasise that the pessimistic assumption applies to all UK production sectors, not just the ones directly involved in delivering the retrofittings, and that it has greater impacts on the behaviour of sectors not involved in the retrofitting activity itself (i.e. those stimulated by the wider expansion triggered). The key outcome is that, while the sustained long-run outcomes discussed above are not affected, the extent of transitory net GDP losses could increase to more than 0.036%.

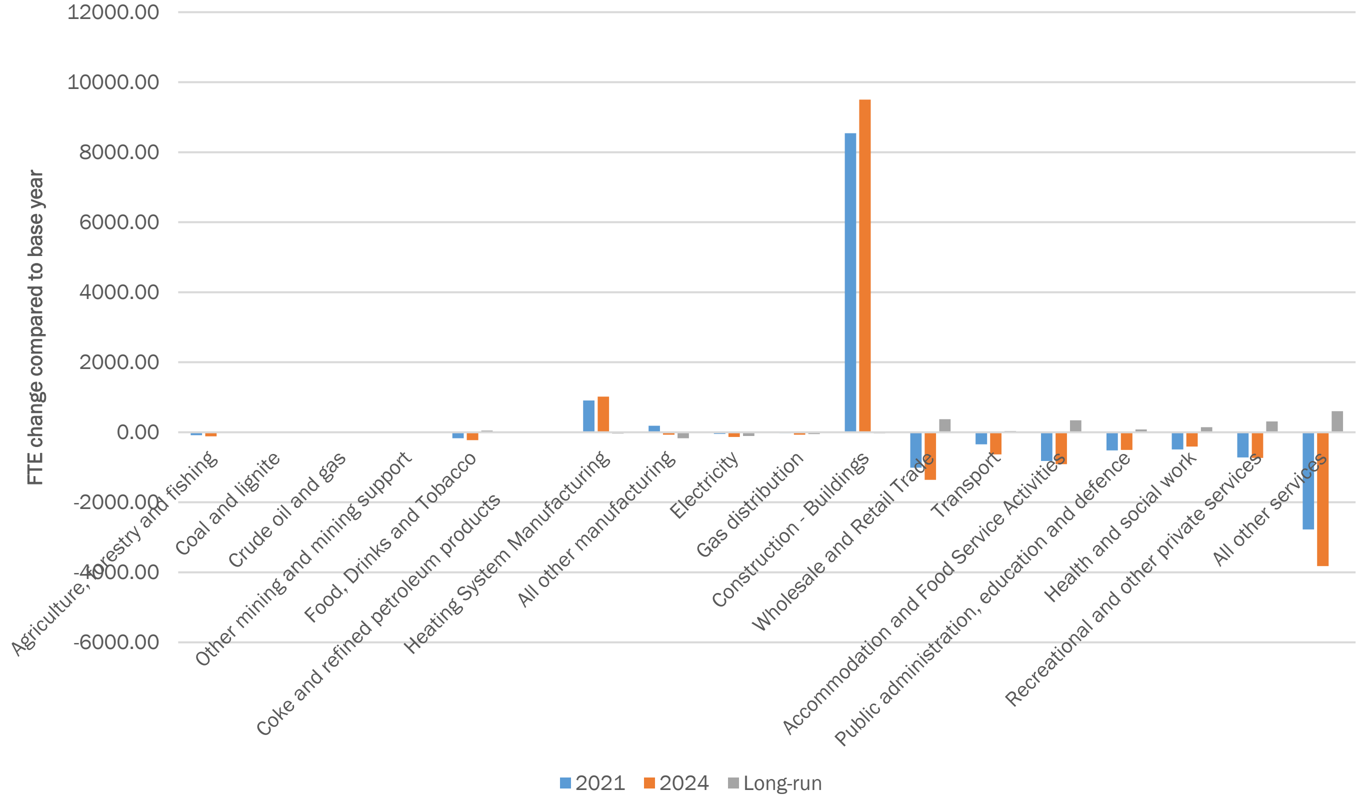


The impacts across the different funding models is also interesting. In contrast to the optimistic case in Figure 2, here Figure 4 shows that Regulation is no longer the option delivering the bigger temporary net negative GDP impact where producers behave in a pessimistic manner and expect no further short-term retrofitting programmes. The driver behind this result is the different direct impact on household incomes under each funding option. Regulation still places the greater restriction on HG2-5 incomes during the enabling stage. However, in the results underlying Figure 4 this has the implication that at least in the first year prices across the economy fall due to reduced household consumption. This drives an increase in exports that initially completely offsets and subsequently mitigates the GDP losses that manifest under the other two options. Grants on the other hand, place no restriction on HG2-5 incomes, who are of course also benefitting from the efficiency gains achieved in the same timeframe. As a result, greater consumption demand drives price increases from the outset, which dampens export demand and leads to temporary GDP losses instead of GDP gains in all timeframes. However, on balance, the 25-year Loans case now delivers the worst outcome in terms of transitory net GDP losses, here with a restriction on household incomes that is less severe than the Regulation case, but not being large enough to prevent export losses.

Employment impacts

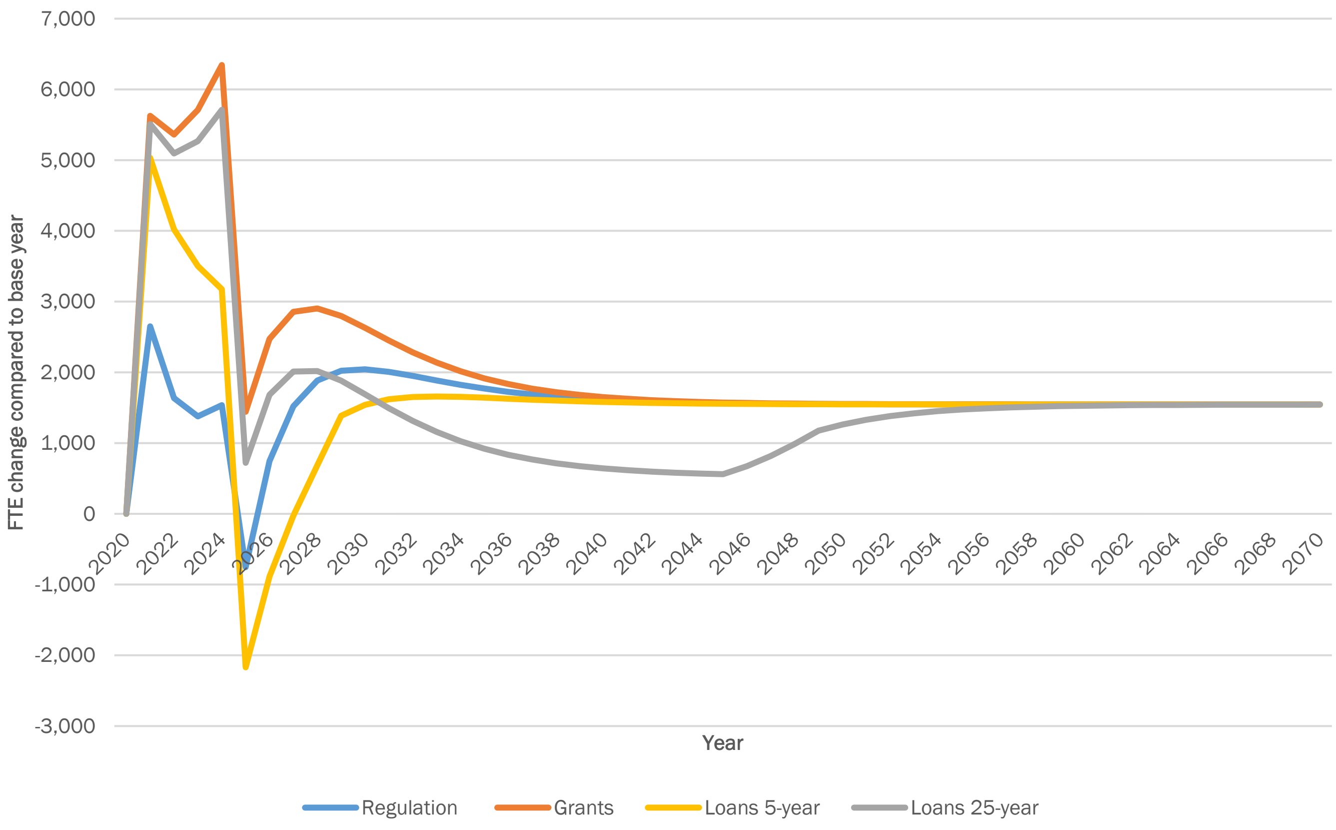
Returning to our central case (optimistic producers), a key variable of policy interest is what happens to the level and distribution of UK employment over time. Our long-run results show that the energy efficiency gains studied here do enable the net increase of employment, with the pool of unemployed labour (which is considered here in full-time equivalent rather than 'head count' terms) providing the flexibility for numbers of workers and/or worker hours to increase. The long-run sectoral breakdown of employment gains is shown in Figure 5, and largely reflects the distribution of output changes in Figure 1, but with the variation in the magnitude of sectoral impacts also reflecting the labour intensity of each sector (wage intensity is reflected more in considering the value-added outcomes in Figure 1). However, it is also important to consider the evolution of employment gains over time, which we report in Figure 6 for the scenario where energy efficiency actions are concentrated in the able to pay households (HG2-5).

Figure 5: Sectoral employment changes due to residential energy efficiency improvements in HG2-5 of UK households



An initial observation is that the retrofitting activity, generally, enables a net increase in FTE employment. As reflected in Figure 5, the increased employment opportunities are located in 'Construction', 'Heating System Manufacturing' and 'Cement manufacturing' sectors (embedded in 'All other manufacturing' in Figure 5), i.e. the ones mainly involved in retrofitting the households. Note, however, that the employment gains in these sectors may be dominated but are not solely driven by retrofitting activity though: our modelling captures direct, indirect and induced impacts, therefore the employment changes in any sector reflect the cumulative outcome of multiple of these types of employment impacts.

Figure 6: Evolution of employment over time due to residential energy efficiency improvements in HG2-5 of UK households



On the other hand, Figure 5 shows transitory net losses in employment drop in sectors like 'Wholesale and Retail trade' and 'Accommodation and Food Service Activities' sectors, even in timeframes where Figure 6 shows net total employment gains. The driver of the employment drop in these sectors is twofold. First, these are labour-intensive sectors so an increased labour cost forces them to increase the price of their output, negatively affecting the consumption demand and forcing them to lay off some of their employees. Second, in the Regulation and Loans cases the reduction in the disposable income of households due to the repayment requirements further reduces the household consumption demand, mainly affecting the sectors where households usually spend their income. This is why we see worse employment outcomes results for a number of years under these funding models, compared to Grants.

As can be seen in Figure 6, any net negative employment changes are only observed after the end of the retrofitting period, from year 5 (2025). The duration varies depending on the funding option under consideration, and usually does not exceed, 3 years. A key point to note is that, despite not leading to net employment losses, the use of loans with long repayments greatly erodes the potential net employment gains at the end of the repayment period, linked to the erosion of GDP gains at the same timeframe. Furthermore, while not included in the figures here, we note that if the producers' expectations are not managed effectively where the 4-year programme may in fact be followed by subsequent sequential programmes, this could intensify the net employment losses by up to over 2,000 additional FTE job losses. Moreover, the timeframe over which net negative employment impacts occur could increase up to the 10-year mark.

The fluctuations we observe in Figure 6 are also reflected in the societal returns of the £4billion programme. For example, in year 1 (2021) we see that a focus to able-to-pay HG2-5 households can return up to 1.41 FTE jobs per £million spent, or 9,425 FTE jobs per % unit of efficiency gains if retrofittings are funded through grants. Interestingly, for the same funding option, a HG1 focus returns 1.38 FTE jobs per £million spent in year 1 or 9,077 FTE jobs per % unit of efficiency gains. There is then a very small difference in early years between a HG2-5 and an HG1 focus. By the end of enabling stage the gap in societal returns is bigger, 1.59 FTE jobs per £million spent from retrofitting HG2-5 households and 1.46 FTE jobs per £million spent from retrofitting HG1 households, but still smaller than the long-run difference. Furthermore, under a regulation approach an HG1 focus generates better societal returns, 0.77 FTE jobs rather than 0.66 FTE jobs per £million spent, compared to an HG2-5 focus and overall there is very limited difference in the two focusses across the entire enabling stage. Similarly, a 5-year loan option keeps the societal returns almost identical regardless of whether HG1 or HG2-5 properties are retrofitted. It is important to highlight though that if HG2-5 households have to pay for HG1 efficiency improvements then the societal returns during the enabling stage are noticeably impacted.

Another interesting observation can be made if we compare Figures 2 and 6. This is that GDP impacts will not necessarily be accompanied by net employment impacts of the same magnitude over the same timeframes. The implication is that throughout the enabling stage of the residential energy efficiency policy, and for part of the realising stage, the productivity of the UK labour force falls. The exact evolution path and long-run result depend on the option used and which households directly benefit from retrofitting action. Underlying our results, we find that focussing retrofitting activity in HG2-5 households leads to a (small) labour productivity decrease, while retrofitting HG1 households drives a small labour productivity increase. The difference is due to the differences in sectors where households choose to spend their disposable income, which varies between households of different quintiles.

Summary of outcomes for 4-year programmes simulated

Our analysis of the 4-year programmes shows that improving the energy efficiency of households can drive positive outcomes in a range of economy-wide variables of policy interest, regardless of the focus between able to pay (HG2-5) and fuel poor (HG1) households. Under our central assumptions we find that:

- In the extreme case where energy efficiency improvements are focussed in HG2-5 households, these lead to average income boosts between £10.36 per household per year (HG2) and £19.3 per household per year (HG5). When funding is concentrated in supporting HG1 households are retrofitted they experience income gains of £25.58 per household per year.
- Income gains lead to expansion of the economy but the key driver is the level of real spending power freed up. In the extreme, a sustained GDP increase of up to £86.7million per annum is possible, along with 1,545 new full-time equivalent (FTE) jobs, when HG2-5 households are retrofitted. However, even if funding is entirely focussed in retrofitting HG1 households, this would generate net per annum gains of £63.4million GDP gains and 957 FTE jobs.
- Societal returns of 4-year £4billion programmes range between 0.24 FTE jobs per £million spent or 1,574 FTE jobs per % unit of efficiency gains when only HG1 households are retrofitted and 0.39 FTE jobs per £million spent or 2,541 FTE jobs per % unit of efficiency gains when HG2-5 households are retrofitted. The long-run societal returns only depend of the focus of the retrofitting activity, however, the funding option significantly affect societal returns during the enabling stage of the programme.
- Value-added gains are driven mainly by sectors like 'Wholesale and Retail trade', 'Accommodation and Food Service Activities' and more widely services, i.e. sectors where households spend most of their income. There are losses in exporting manufacturing sectors due to price increases.
- The long-run outcomes can be significantly higher in the absence of any price pressures due to increased labour cost.
- Using Regulation and 5-year Loans to promote efficiency improvements may lead to transitory GDP and employment losses during and following the enabling stage.
- Not managing the expectations of UK sectors to convince them that there will be another programme following the end of the 4-year one, can drive GDP and employment losses under every funding option and intensify the ones observed in central case.
- Efficiency improvements enable small long-run budget savings. However, there are also transitory budget deficits under all funding options. The timing, magnitude and duration depends on the option.

4. Economy-wide impacts of shifting to more substantial longer-term programmes to meet the 2035 EPC C policy target

Overview of key long-run outcomes

We see in the case of short-term programmes that uncertainty over future retrofitting activity can be a driver of longer and more negative temporary impacts to the UK economy, in areas like GDP and employment, if the producers' expectations are not managed properly to eliminate them. An alternative approach to eliminate any uncertainties is to announce a programme long enough and with sufficient volume of activity to be able to deliver the UK's 2035 energy efficiency goals.

The estimated cost of such a programme is around £68.5billion over 15 years and in this case data are available to allow a distribution across all household income groups. Generally, the significantly larger retrofitting activity of this programme means that a lot more households, both within each income group and in total, can improve their energy efficiency compared to the 4-year programmes we consider. The whole UK household stock become 10.41% more energy efficient, while the efficiency gains of each of the quintiles depends on the exact share of activity allocated to them. HG3 receives the smallest share and therefore becomes 9.36% more energy efficient, whereas HG5 receives the highest share and becomes 11.45% more energy efficient. With greater efficiency gains enabled for all income quintiles, and under our central assumption of more constrained expansion with wage bargaining under a fixed labour supply, we also observe greater long-term real income gains. Note also that, as in the 4-year/£4billlion case, that the long-run outcomes of the programme are not variable based on the funding option chosen. A key outcome for this scenario is that the **maximum average real income gains in the lowest and highest income household levels are £100.52 per HG1 household per year and £271.58 per HG5 household per year.**

Greater household income gains lead to higher consumption demand increase and through that greater economy-wide gains, compared to the 4-year programmes. Once a 15-year programme has been completed the potential enabled efficiency gains can get the UK GDP to grow by a **sustained 0.07% (£1285million) compared to before the efficiency improvement** along with **over 22,545 (0.077%) new FTE jobs.** From a societal returns point of view, a long-term programme of that scale can deliver **0.33 FTE jobs per £million spent**[8] or 2,167 FTE jobs per % unit of efficiency increase.

The changes in GDP and employment indicate that the efficiency improvement leads to a drop in the labour productivity of the UK economy. In terms of the real earnings from employment, the 15-year programme could enable a 0.213% increase. Crucially, the additional household consumption and wider economic activity is enough to offset any increases in government expenditure due to higher prices across the economy. As a result, a 15-year programme could drive sustained government savings of £195million.

Our observations regarding the impact of increased labour cost on the potential long-run outcomes also apply to the 15-year programme. In the absence of any additional labour cost the sustained GDP gains possible rise to £4,416million (0.25% p/a) along with 78,582 new FTE jobs. Without any additional labour costs then the UK economy would achieve a return of 1.15 FTE jobs per £million spend or 7,552 per % unit of efficiency improvement. Alongside greater GDP and employment gains, there could also be greater government budget savings of £1,708million.

The adjustment of the economy over time to the 15-year programme

One of the findings regarding the 4-year programmes is that the funding option does not affect the long-run outcomes of the programme but it does play a key role on how the economy evolves until we reach the long-run results. Crucially, as we can see in Figure 4, whether UK producers expect the retrofitting activity to continue beyond the end of the current 4-year programme determines whether there will be negative impacts in some timeframes and their potential magnitude. In fact, we find that if UK producers do not expect any further retrofitting activity beyond the 4-year programme (as under our alternative 'pessimistic producers' assumption), then not only there may be transitory negative impacts in some timeframes, but, for example, Grants is no longer the preferable option from a GDP perspective. We also find that longer term (25-year) Loans help avoid negative impacts, when producers expect additional retrofitting activity (as under the 'optimistic producers' assumption in the 4-year case), by limiting restrictions on real household incomes and spanning them over multiple years. However, with pessimistic producers the greater shorter-term income restrictions of Regulation are preferable, at least from a GDP perspective.

The key point to focus on going forward is that a 4-year programme is relatively short-term in nature. Crucially, it introduces disruptions to the UK economy that, unless there is a plan to continue retrofitting properties beyond the end of this initial programme, those sectors not directly involved with retrofittings may opt to reduce their output (and their production capacity) until such time that efficiency gains make it profitable for them to expand their production again. To ensure that retrofitting activity takes place for long enough to overcome the disruptions to the economy observed in the 'pessimistic producers' case), one option would be to implement multiple programmes in sequence or, as we model here, introduce a long-term 15-year programme. In either case, a key outcome would be largely delaying the reallocation of resources until the core policy objective of delivering the 2035 EPC C energy efficiency goal is achieved. In modelling terms, this means the 'pessimistic producers' assumption can become the core one, corresponding to what the 'optimistic producers' case attempts to consider in the 4-year case where the longer-term progress of retrofitting activity is unknown.

Shifting attention to the 15-year programme case, Figure 7 demonstrates how the economy adjusts in the context of each of the funding options, when the retrofitting activity is spread evenly across the duration of the programme (steady action). It is important to highlight that since the 15-year programme we consider here is designed to deliver the 2035 EPC C energy efficiency goal, we assume that the expectation of the UK sectors would be that there will not be another retrofitting programme following the end of this one. As a result, we assume that they will behave in a pessimistic way, making the results here more comparable to the pessimistic ones in Figure 4.

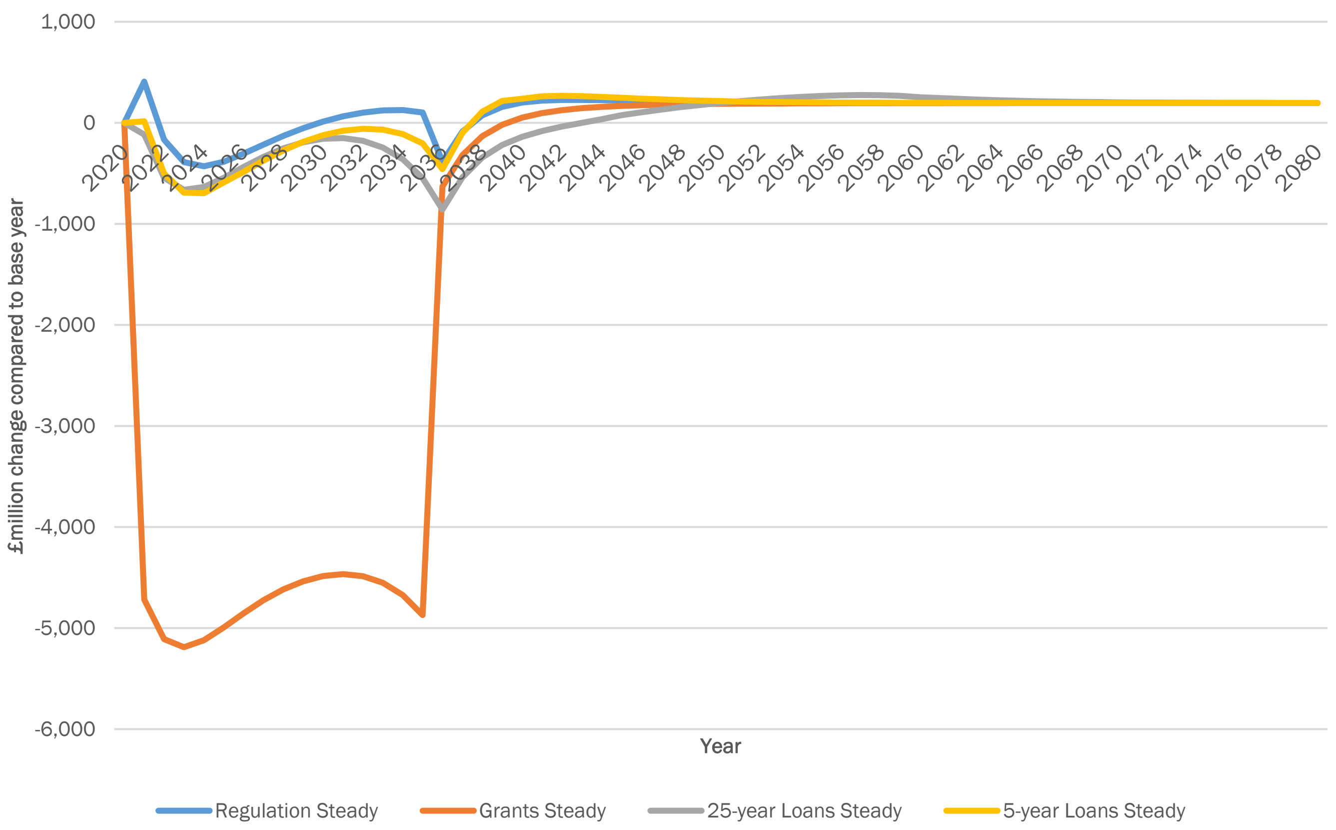
Figure 7: Evolution of GDP over time due to 15-year programme of residential energy efficiency improvements of UK households

Comparing Figure 7 to Figure 4 (noting that the latter is limited in terms of its household coverage), we see that a direct impact of announcing a 15-year programme is that the duration of any negative impacts is significantly reduced. For instance, in Figure 4 we see that the 25-year Loan option could lead to a 17-

year period of negative GDP impacts, which is shortened to 12 years – over two spells at the beginning and the end of the enabling stage – when a 15-year programme is used. This is a common outcome across all funding options. However, there is an important trade-off in that the larger-scale longer-term programme also leads to a greater disruption to the economy, meaning that the negative GDP impacts might be shorter in duration but, depending on the funding option, can also be greater in magnitude. Again, for the 25-year Loan option, the maximum negative GDP impact of 4-year programme is 0.036% while for the same funding option the 15-year programme could have maximum negative GDP impact of 0.09%. On the other hand, when efficiency improvements are funded through grants the duration of any negative GDP impacts is restricted, from 11 to 3 years, and the magnitude of the maximum negative GDP impacts, from 0.032% to 0.017%.

A point of similarity between the 4-year and 15-year programmes is that the funding option determines when and if any negative impacts will manifest. A key message from Figure 7 is that in the case of the 15-year programme all options drive temporary negative GDP impacts in some timeframe. However, there are considerable differences between them. For example, a Regulation approach means that there will be GDP losses at the beginning of the enabling stage of the programme (5 years 2022-2026), but once they are compensated for by the efficiency gains there will be no more negative impacts. If a Grants approach is favoured then the cumulative period of negative GDP impacts is smaller (3 years) and is broken in two periods at the beginning and the end of the programme (2022-2023 and 2036), while the maximum temporary GDP losses are smaller. A 5-year Loan approach means larger impacts at the beginning of the programme which are gradually reduced, and completely eliminated from 2036 onwards, while allowing a period of GDP gains between 2029-2034. Finally, a 25-year Loan significantly reduces the losses at the beginning of the programme, moving the bulk of negative GDP changes in a longer 9-year period at the end of the programme and beyond it.

Figure 8: Evolution of government budget balance over time due to 15-year programme of residential energy efficiency improvements UK households



Apart from the difference on the timing and magnitude of any temporary negative impacts, the choice of funding option also determines what the impacts will be on the income of the different households. For example, if there is concern on the income of the most vulnerable, lowest income households (HG1), we find that a Regulation approach, under steady action, could restrict the HG1 income by a maximum £145.58 per household per year in 2021 and lead to negative income impacts throughout the entire duration of the programme. On the other hand, 25-year Loans limit the impact to a maximum of £21.45 per household per year in 2036 and reduce the period of negative income effects to 12 years, all of them after the end of the programme. Grants eliminate negative impacts on HG1 income, and indeed all household groups, but this comes at the expense of government budget deficit of up to £5,189million in 2023. This introduces another key consideration. How does each of the funding options fit, and potentially complement, a wider transition to net zero? Each of the funding options provide some flexibility in terms of when any negative impacts could manifest, ensuring that the timing is such that enables the implementation of a transition to net zero agenda. Figure 8 shows the evolution of the government budget balance over time.

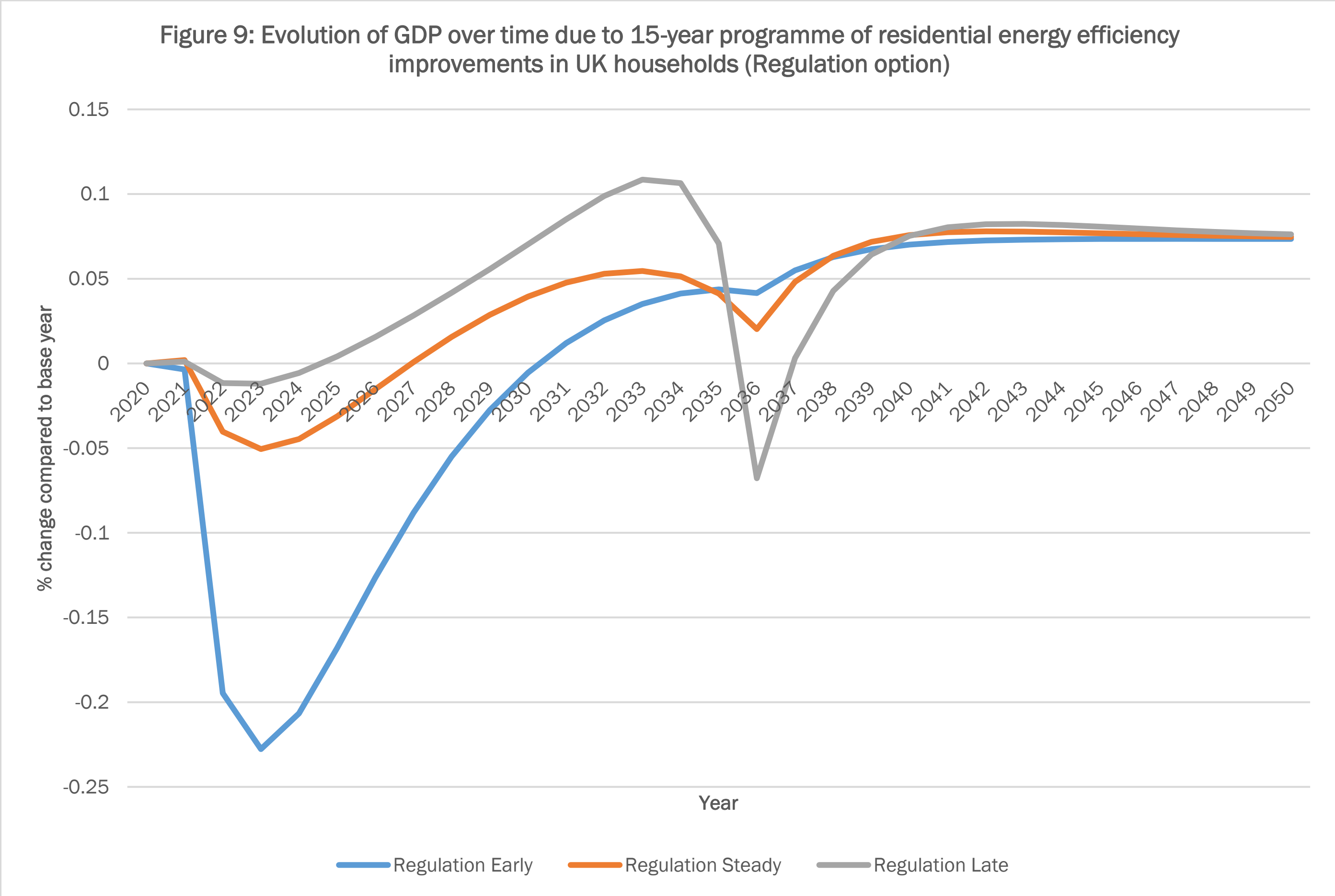
As was observed in the cases of the 4-year programmes above, under all the different funding approaches we observe government budget deficits in some timeframes. The largest deficit for each approach manifests by year 3 (2023). From that point onwards, the efficiency gains achieved start mitigating the deficit outcome until eventually, by year 23 (2043) at the very latest, there are sustained budget savings under all funding approaches. This is the case even for 25-year Loans, despite the fact that households are still repaying their loans, with the implication that their disposable income is constrained, leading to smaller consumption demand.

How can timing the activity can affect the potential outcomes?

An important consideration when designing a long-term programme is how to distribute the activity across its duration. Figure 9 demonstrates the evolution of GDP for the Regulation option under the early, steady and late action approaches. We see in Figure 9 that a steady approach is the one leading to the smallest negative GDP impacts (5 years 2022-2026). This is due to the even spread of the activity across different years which means that there are smaller disruptions to the UK economy due to existing constraints. On the other hand, either the early or the late action approaches will lead to greater negative GDP impacts. The maximum negative GDP impacts of early and late action approaches materialise around the time when the bulk of the activity takes place so after the first 3 years for early action and immediately after the end of the programme for late action.

However, there are key differences in both the magnitude and duration of those temporary negative impacts. The driver of this difference is that in the case of early action there are no prior efficiency gains to mitigate the GDP losses in year 1 (2021) and by the time the maximum GDP losses are observed only 50% of the efficiency gains have been achieved. Actually, under early action, we observe negative GDP impacts until almost 90% of the retrofitting activity has been completed (in 2031). On the contrary, under a late action approach there are limited GDP losses at the beginning of the programme (2022-2024), smaller than the steady action approach, due to the smaller level of activity and the maximum GDP losses are observed in 2036, which is the year after the end of the programme. The 2036 GDP losses are the combination of two factors. First, UK producers, being pessimistic, anticipate both the increases in labour costs and prices (and the associated competitiveness and demand losses) and adjust their production accordingly. Second, the retrofitting activity has ended, as are the value-added gains it generated. However, by that time, the full efficiency gains have been achieved, meaning that the boost in economic activity they trigger helps to significantly mitigate the magnitude of the GDP losses of late action and also restrict them to a single year. In fact, late action is the approach that causes the shorter negative GDP impacts.

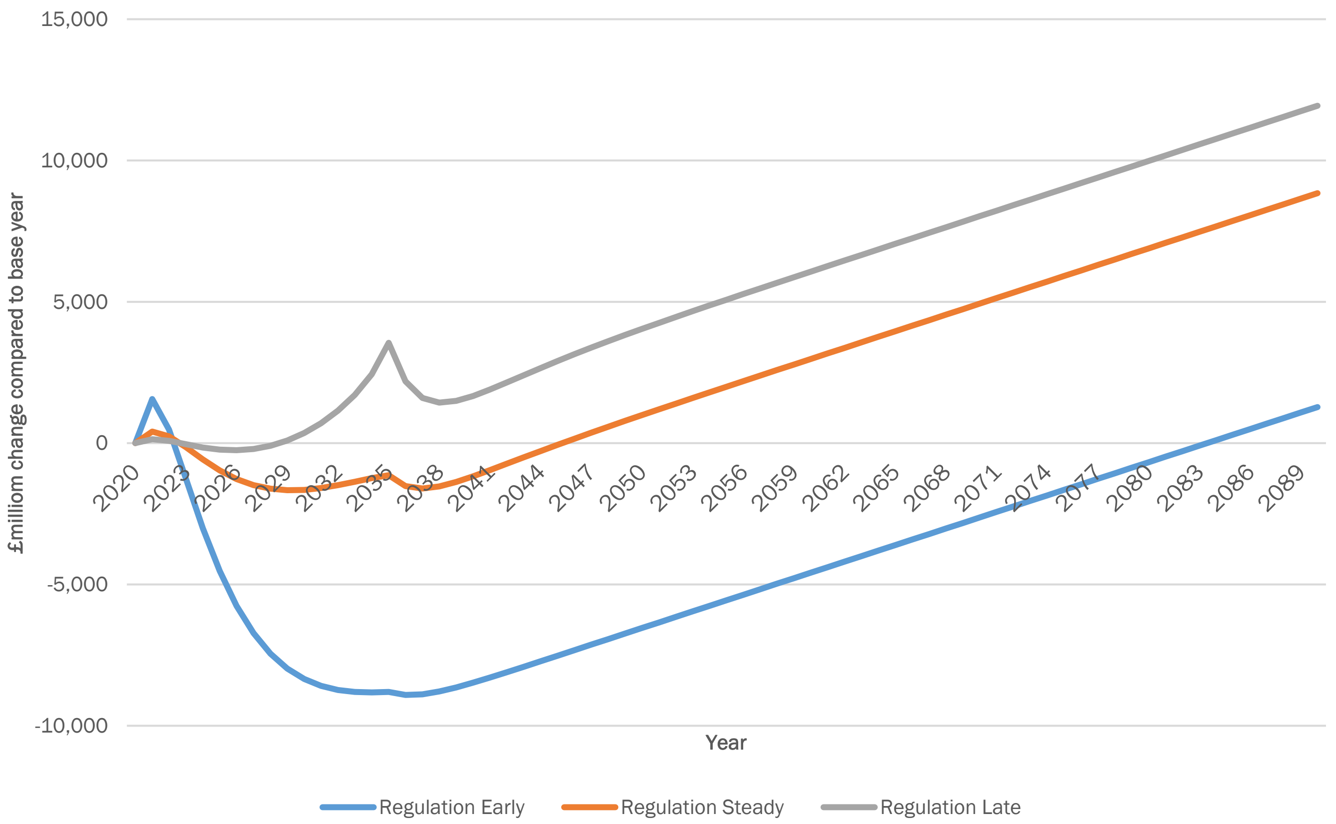
The findings in Figure 9 can also be extended to other variables like employment and to the remaining funding mechanisms. Across all funding mechanisms, steady action allows to mitigate the magnitude of any negative impacts. Front-loading the majority of the activity in a short number of years leads to ‘crowding-out’ pressures, which have a more significant impact when this period is early in the programme as there are no efficiency gains to offset them. On the other hand, a late action approach can reduce, or even completely offset any early year negative impacts (under Grants and 25-year Loans), but can lead to greater losses around and following the end of the programme, albeit for a smaller amount of time compared to the other options.



A notable exception is when we consider the cumulative government budget changes. The evolution of the government budget balance on a year by year basis closely follows the evolution of GDP. We can see from Figures 7 and 8 that when the economy is expanding we also observe budget savings, or at least reduction in any existing budget deficits. The opposite is true when the economy is contracting or when GDP gains are eroded. However, when exploring the cumulative government budget balance, there are some interesting observations regarding the role that the timing of the activity plays. Figure 10 shows the evolution of cumulative government budget balance changes for the Regulation approach. The first observation that can be made in this regard is that, when considering the cumulative government budget, acting late helps not only to mitigate any cumulative budget deficits, but also means that, once savings are achieved in year 9 (2029), there are no further cumulative budget deficit impact is observed. This is despite the temporary GDP losses by year 16 (2036) that erode but do not offset the cumulative budget savings.

The explanation is two-fold. First, in years 1-12 there is limited retrofitting activity, and therefore limited pressure on household incomes. Household consumption demand is slightly constrained in these years but the retrofitting activity helps mitigate some of the pressure on government budget in those years. Eventually, when the majority of the retrofitting activity takes place, there are considerable efficiency gains achieved and therefore the government can benefit from both the increased retrofitting activity and the increased consumption demand that energy efficiency driven income gains trigger. As a result, a substantial extent of cumulative budget savings are achieved by the end of the programme, enough to cover the budget deficit observed immediately after the end of the programme (along with negative GDP changes). This is unique to the late action approach. With steady action there is a somewhat steady cumulative budget deficit for a longer period of time. Crucially, however, under early action the substantial costs in the first 3 years of the programme place significant constraints to household incomes and consumption, leading to government revenue losses. The retrofitting activity only mitigates a small part of the revenue losses, meaning that under early action the government budget reaches a substantial cumulative deficit, kept fairly constant for the entire duration of the 15-year programme, and it takes a very long amount of time (over 60 years) before cumulative budget savings can be achieved.

Figure 10: Cumulative government budget balance change over time due to 15-year programme of residential energy efficiency improvements in UK households (Regulation option)



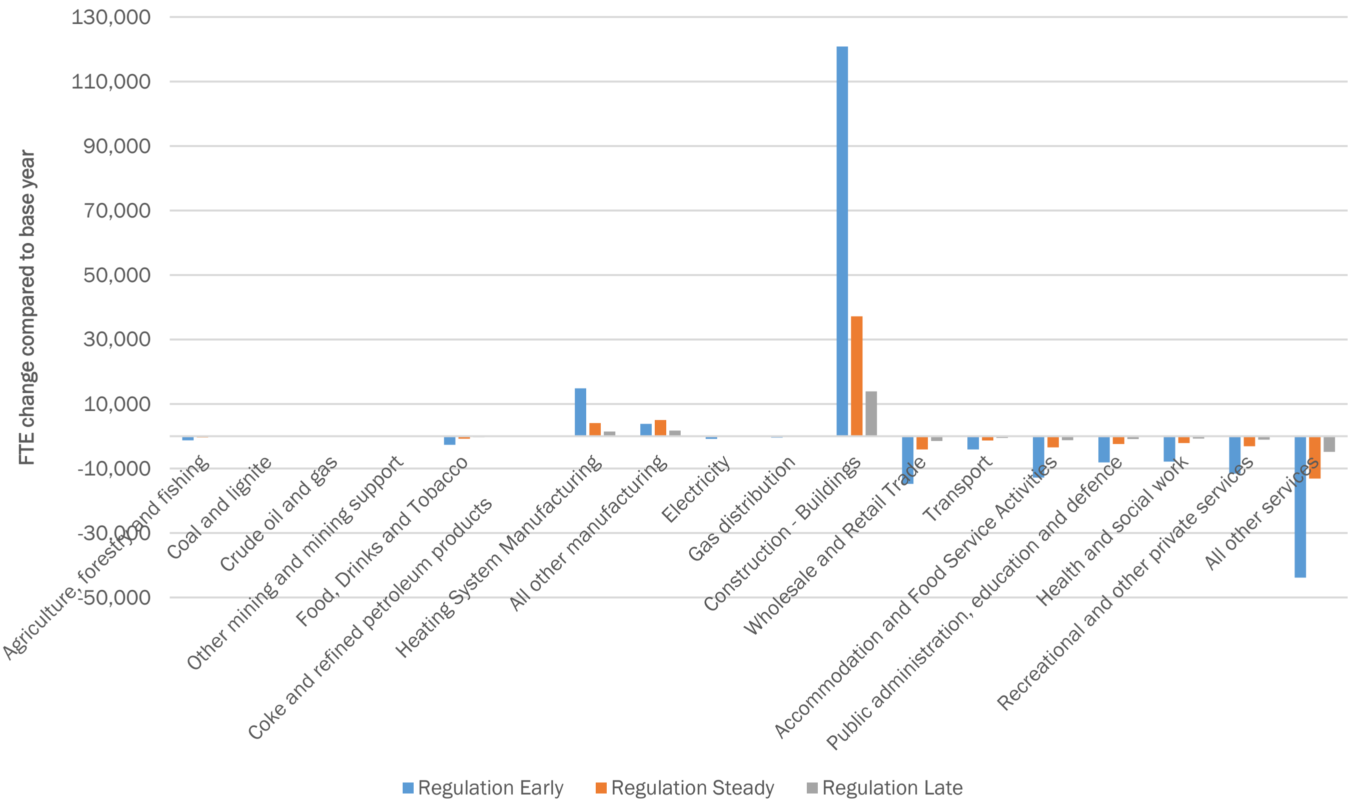
An important point to highlight is that the impacts discussed here assume an economy that starts out with a pool of unemployed labour, and the general state of the UK economy reflects that captured in the in our base year data for 2016 (as reported in the ONS analytical IO tables for that year). In the present circumstances, following the general economic slump of the Covid-19 pandemic, capacity constraints could be significantly reduced. Indeed, where we test the sensitivity of our results to wage setting assumptions (with our core scenarios the interaction of labour cost pressures), the negative GDP impacts of acting early under the Regulation option are reduced to 5 instead of 10 years (in Figure 9), and the maximum GDP losses fall from 0.23% to 0.16%.

Trade-offs in choosing how to time the retrofitting activity

The findings presented in Figure 9 indicate that the choice of how to time the retrofitting activity can influence the timing, duration and magnitude of any potential negative impacts (in Figure 9 in GDP). However, there are additional trade-offs that need to be considered when choosing how to spread the activity over the years. One consideration has to do with the available skilled labour to deliver the efficiency improvements. Figure 11 shows the changes in employment in each sector in the first year of the 15-year programme for the Regulation option. Although our model does not capture the specific skills required, in the first year of the programme the ‘Construction’ sector will require over 120,000 additional skilled workers to retrofit residential properties under early action (see Figure 11).

Moreover, over 14,000 workers will be necessary in the ‘Heating System Manufacturing’ sector, meaning that in total over 135,000 skilled workers will be required in the two main sectors delivering the retrofitting activity, if early action was to be adopted. Sourcing the necessary labour force is a significant challenge that needs to be addressed if the programme is to be delivered. A steady approach limits the requirements to 37,000 additional ‘Construction’ sector workers in the same year, 41,000 across both ‘Construction’ and ‘Heating System Manufacturing’, and overall allows to keep the total number of skilled workers in both sectors under 50,000 across the entire duration of the programme. On the other hand, acting late means that only 15,000 more skilled workers, in both ‘Construction’ and ‘Heating System Manufacturing’ are necessary straight from the outset. In essence, acting later allows for more time to source and/or train the necessary labour force to deliver the retrofittings. However, by the time the bulk of the retrofitting activity takes place under late action, there are also efficiency gains in place that drive additional economic activity across the wider UK economy. As a result, in the last year of the programme, under late action, the ‘Construction’ sector, for example, needs to produce £14.4billion additional output in year 15 instead of £12.4billion additional output[9] in year 1 under early action. There are similar additional output requirements in year 15 for ‘Heating System Manufacturing’, meaning that over 137,000 skilled workers will be necessary for ‘Construction’ and ‘Heating System Manufacturing’.

Figure 11: Year 1 sectoral employment changes due to 15-year programme ofresidential energy efficiency improvements in UK households



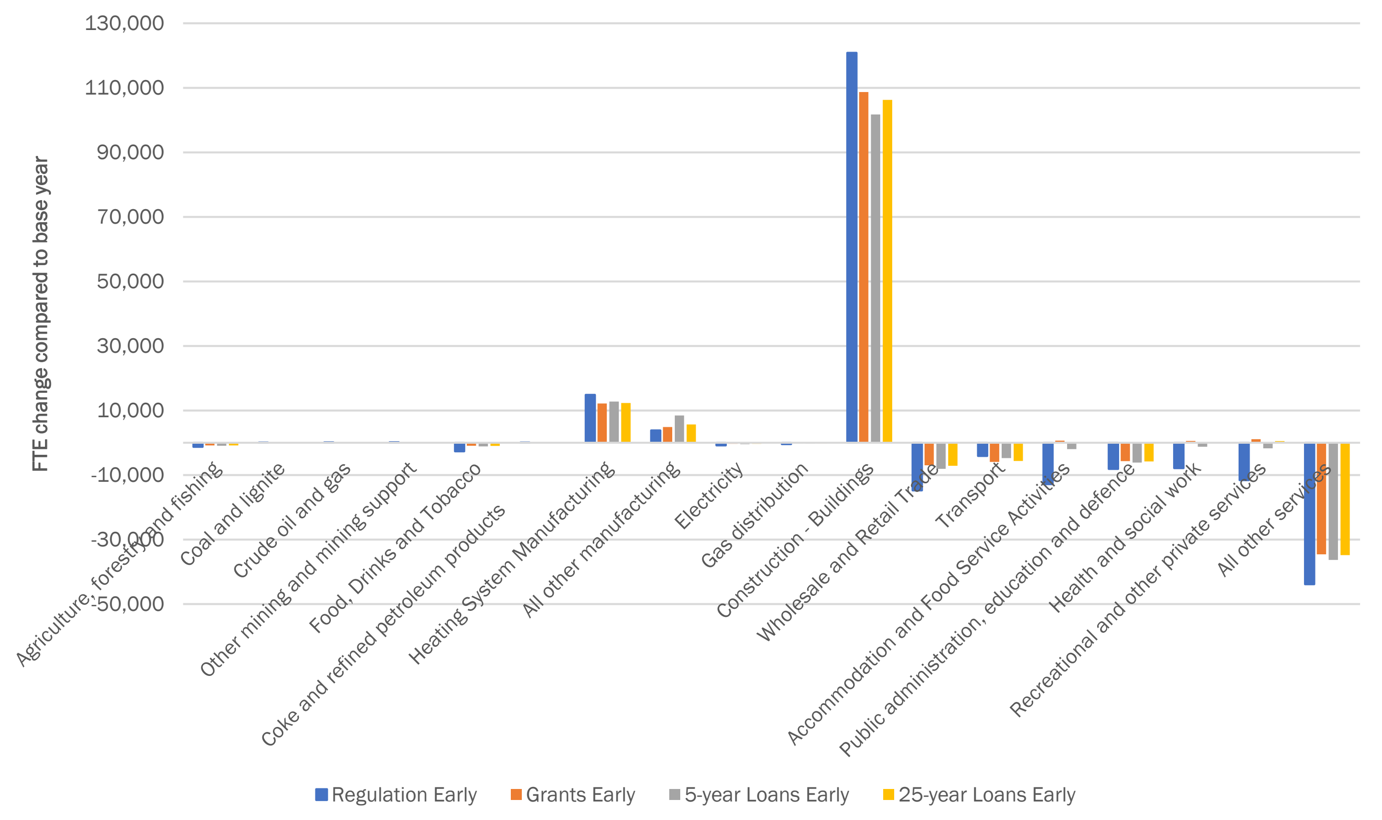
Timing the retrofitting activity is one way to address potential concerns regarding the availability of skilled labour. In fact, it is the most effective way as the labour requirements are mainly driven by the magnitude of the retrofitting activity in any given year. Alternatively, choosing a different funding option can have some effect on the labour requirements, primarily through the differences in labour cost across the different funding options. Figure 12 shows the sectoral breakdown of employment changes in year 1 of early action, for the different funding options. We see that moving away from the Regulation option can reduce total ‘Construction’ and ‘Heating System Manufacturing’ labour requirements by a minimum of 15,000 FTE workers (using Grants). This almost an 11% reduction in skilled labour requirements and could potentially expand to over 15% if 5-year Loans are used. Obviously, the difference is not as significant as when different timing is used but could be sufficient to remove some barriers from adopting an early action approach.

Labour requirements are an area that could lead to opting for different timing of the retrofitting activity, if it cannot be addressed through choosing a different funding option. However, delaying action introduces new uncertainties associated with the duration of the programme itself. From a purely technical point of view, improved energy efficiency is expected to reduce the stress on the electricity system, and therefore its security, at a time when more and more energy services are expected to be delivered by the electricity system. Delayed action on energy efficiency then could introduce costs, not captured here, linked to the need to reinforce the electricity network beyond what would be necessary if energy efficiency gains were achieved sooner rather than later.

From a wider political point of view, later action could also lead to a slower pace towards achieving UK's climate change targets, introducing uncertainties on whether and/or how easy it will ultimately be to achieve them. A crucial issue is that delaying action introduces uncertainty over the support that a 15-year programme will have, both in financial and social terms. Indeed, the duration of such a programme means that it runs for multiple parliamentary terms; at least 3. In this respect, the benefit of early action is that with support and funding during the term in which it is announced, it is possible to complete up to 64% of the total activity, while the minimum possible (if announced at the end of a term) is 25%. This provides a high degree of certainty that a substantial part of the necessary activity will take place, even in the event that support is removed in subsequent terms.

This is the challenge presented when steady or late action are used. If there is support for only one term, the first one, under steady action the activity that will take place is between 6.6% and 33.3%. Late action ensures an even smaller amount of retrofitting activity in a single term, ranging between 2.3% and 13.5% of the total retrofitting activity. This is indeed the main limitation of late action. Because the vast majority of the retrofitting activity takes place in the last 3 years of the programme, withdrawing the support and funding before that point would mean that only 50% of the total activity would be completed, when the equivalent figure is 80% for steady action and 92.5% for early action. Late action then comes with a challenge that support and funding for the programme must remain in place, throughout its duration but crucially in the last 3 years, despite changes in government and wider social acceptance of energy efficiency improvement policies.

Figure 12: Year 1 sectoral employment changes due to 15-year residential energy efficiency improvements in UK households for different funding options (early action)



Summary of outcomes for 15-year programmes simulated

Our analysis of the 15-year programmes shows, as with 4-year programmes, improving the energy efficiency of households can drive positive outcomes in a range of economy-wide variables of policy interest. The larger scale of the 15-year programmes means that their impacts will also be greater compared to the 4-year ones. Under our central assumptions we find that:

- The implementation of a 15-year programme can lead to average income boosts between £100.52 per household per year (HG1) and £271.58 per household per year (HG5). The differences are driven by the amount of activity directed to each household group and also the differences in absolute residential energy consumption across different household groups.
- The household income gains, and most importantly the real spending freed up, trigger an expansion of the economy. We find a sustained GDP increase of £1,285million per annum (0.07% p/a) is possible, along with 22,545 (0.077% p/a) new full-time equivalent (FTE) jobs, regardless of the funding option used.
- A 15-year programme can achieve societal returns of 0.33 FTE jobs per £million spent or 2,167 FTE jobs per % unit of efficiency gains. These returns are between the ones we found for the 4-year programmes as we have a mixed focus on household groups rather than the extremes we considered for the 4-year programmes.
- As in the 4-year programmes, the absence of any price pressures due to increased labour cost can lead to significantly higher long-run outcomes.
- Every funding option will lead to some transitory GDP losses but the magnitude of these losses and their duration depends on the specific funding mechanism used.
- Despite some funding option depended transitory government budget deficit, the efficiency gains enabled through a 15-year programme can lead to sustained budget savings of £195million per annum.
- The timing of the retrofitting activity plays a significant role on the labour requirements in the sectors that deliver the retrofittings and the economy-wide impacts in general. Early action means that over 135,000 skilled workers will be necessary in year 1, while under late action the requirements are raised to over 137,000 skilled workers in year 15. Steady action smooths out the labour requirements and the wider economic impacts. The funding option can also influence the labour needs during the enabling stage, however, the impact of timing is far greater.
- There are important trade-offs associated with the timing of the retrofitting activity, linked not only to labour requirements but most importantly to what can be achieved by certain timeframes in the event that social and political support for a 15-year programme is no longer present.

5. Conclusions

Our analysis highlights that the long-run results of any potential energy efficiency improvement actions are driven by the efficiency gains, the household income boosts that the efficiency gains enable and the associated increase in consumption demand. Any differences in the long-run outcomes depend on the volume of the retrofitting activity taking place and which households are retrofitting their properties. The impact of the mechanisms used to promote efficiency improvement is transitory and is only observable during the enabling stage of the energy efficiency policies.

Some of the energy efficiency promotion mechanisms that we examine will trigger temporary negative changes in areas of policy interest like GDP and employment, while others avoid that at the expense of other impacts such as transitory government budget deficits in different timeframes. The timing and magnitude of any negative impacts, as well as the timing of when the long-run gains are achieved, are determined by the specific mechanism under consideration. Another factor determining the timing and magnitude of any negative impacts is the expectation across UK producers on whether there will be additional retrofitting activity at the end of an efficiency improvement programme. Expecting a programme to be a one-off retrofitting opportunity tends to lead to negative impacts across all funding options, and exacerbate and prolong those originally observed. On the other hand, maintaining a fixed labour cost enables a larger consumption demand boost and greater levels of employment, mitigating and/or offsetting any negative impacts.

The findings of our analyses, show that when energy efficiency is considered in the wider net zero context there are important trade-offs that need to be considered before choosing the appropriate approach, be it the choice of a promotion mechanism or how to spread the activity across the duration of a longer-term programme. With negative impacts manifesting in most cases, it is important for policymakers to choose the appropriate promotion mechanism that will allow negative impacts to appear in a period in which they could be mitigated/offset by other net-zero measure or at the very least in a period where there are limited additional negative impacts by other measures.

Crucially though, when considering long-term programmes, policy makers need to carefully think whether to act early, late or with a steady pace. The skilled labour requirements could effectively rule out acting in certain timeframes. But with long-term programmes also exceeding multiple parliamentary terms, policy makers need to carefully consider which is the most viable approach in terms of ongoing support both in parliament and across society. Lack of support at any point can reduce the interest for retrofittings and lead to the loss of necessary financial resources, both of which can lead to a long-term programme delivering less efficiency improvements, and therefore economy-wide benefits, than those anticipated during the policy’s design.

References

HM Government (2019). Leading on Clean Growth. The Government Response to the Committee on Climate Change's 2019 Progress Report to Parliament – Reducing UK emissions. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/839555/CCS0819884374-001_Government_Response_to_the_CCC_Progress_Report_2019_Web_Accessible.pdf

Figus, G., Turner, K., McGregor, P., & Katris, A. (2017). Making the case for supporting broad energy efficiency programmes: Impacts on household incomes and other economic benefits. Energy Policy, 111(September), 157–165. https://doi.org/10.1016/j.enpol.2017.09.028

Lecca, P., McGregor, P. G., Swales, J. K., & Turner, K. (2014). The added value from a general equilibrium analysis of increased efficiency in household energy use. Ecological Economics, 100, 51–62. https://doi.org/10.1016/j.ecolecon.2014.01.008

Turner, K., Katris, A. & Race, J. (2020). The need for a Net Zero Principles Framework to support public policy at local, regional and national levels. Local Economy, 37(7), 627-634. https://doi.org/10.1177/0269094220984742

About this project

The research reported here is supported by an EPSRC Impact Accelerator project linked to the EPSRC-funded project "Energy saving innovations and economy-wide rebound effects" [EPSRC Grant Ref: EP/M00760X/1]. It builds on the following previously published papers:

Acknowledgements

The authors would like to thank Michael Twist, Calum Knox, Cameron Murdoch and Chris Nicholls of Clean Growth team at the UK Department for Business, Energy and Industrial Strategy (BEIS) for their cooperation throughout this project. Their comments, feedback and access to the necessary data has been instrumental to the completion of this research.

About the authors

Karen Turner is Director of the Centre for Energy Policy (CEP), University of Strathclyde and an expert on modelling and analysis on the economy-wide impacts of decarbonisation and low carbon solutions and energy policies. She currently serves on the Scottish Just Transition Commission.

Jamie Stewart is the Depute Director of the Centre for Energy Policy, University of Strathclyde. His role focusses on knowledge exchange and policy engagement.

Antonios Katris is a Research Associate at the Centre for Energy Policy, University of Strathclyde. He specialises in economy-wide modelling to understand the potential impact of energy policies and the transition to a low carbon economy.

Annex A: Brief description of the UKENVI CGE model and the data used

Model and scenario data

In this work we use the UKENVI multi-sector computable general equilibrium, CGE, model of the UK economy. Lecca *et al.(*2014) and Figus *et al.* (2017), fully detail the model, while the latter also introduces the household disaggregation we use in this report to consider distribution effects. UKENVI is currently calibrated on a 2016 social accounting matrix (SAM) incorporating an industry-by-industry input-output (IO) table published in 2020 by ONS (and is currently the latest version available. The switch from 2010 to 2016 data means that there are some key differences in the structure of the UK economy compared to previous focussing on residential energy efficiency. For instance, we observe a significant shift in the composition of UK households' consumption. In 2016 households rely proportionately more on imports of goods and services compared to 2010, meaning that some of the gains due to increased household consumption are now taking place abroad rather than manifesting in domestic supply chains. In this annex we explain some key characteristics of the model that are particularly important for the analysis conducted here.

The data on the funding available for the 4-year programmes are purely indicative and do not correspond to any actual policies in place. On the other hand, the total volume of retrofitting activity we consider for the 15-year programmes is an estimate provided by colleagues at BEIS, reflecting the total cost of a programme this size aiming to achieve the 2035 EPC C goal. For both the 4- and the 15-year programmes we assume the same distribution of activity between 'Construction' and 'Heating System Manufacturing', informed by our previous work on residential energy efficiency.[10] For this analysis we also assume a fixed retrofitting cost per household of £4,100, also estimated by our colleagues at BEIS. This way we can determine the number of beneficiary households, in total and in each quintile. Using the number of beneficiary households we then identify what share of each household quintile is receiving efficiency improvements.

Table A.1: Summary of data used to inform scenarios

		4-year programmes (HG1 focus)	4-year programmes (HG2-5 focus)	15-year programmes
Amount Spend on Constructions (% of total)		3,488.73 (87.22%)	3,488.73 (87.22%)	59,699.10 (87.22%)
Amount Spend on Heating System manufacturers (% of total)		511.27 (12.78%)	511.27 (12.78%)	8,748.90 (12.78%)
Total cost paid by consumers (£million)		**4,000.00**	**4,000.00**	**68,448.00**
Total efficiency gains (in %)	HG1	3.04%	-	10.41%
	HG2	-	0.76%	9.88%
	HG3	-	0.76%	9.36%
	HG4	-	0.76%	10.93%
	HG5	-	0.76%	11.45%

For the efficiency improvement of each more efficient household we assume average efficiency gains per beneficiary household of 17.2%. This estimate is consistent with the estimate we used in our previous work and has been calculated using data from the National Energy Efficiency Data (NEED) framework.

We use this figure and the share of households in each quintile that receive an improvement to determine the efficiency improvement of the whole quintile. For example, if in 2021 243,902 households in HG1 receive efficiency improvements this is 4.42%% of HG1. With each beneficiary household being 17.2% more efficient, this means that the whole quintile is on average 0.76% (17.2% x 4.42%) more efficient. Adding together the efficiency gains of each year gives us the total efficiency gains of the entire programme (see Table A.1).

Which sectors are included?

The general equilibrium framework incorporates all sectors of the UK economy. This way we can capture and analyse the interactions between the different sectors and markets and identify how changes in one sector can spill across the entire UK economy through changes in prices and incomes generated in different markets and the availability of constrained supplies of labour and capital. We aggregate the 64 sectors reported in ONS IO accounts to 34 sectors (see Table A.2 for a full list). This includes five energy supply sectors: coal extraction, crude oil extraction, refined petroleum, electricity and gas distribution sectors. Please note that because the coal extraction and crude oil extraction sectors, as well as the electricity and gas distribution sectors, are aggregated in the ONS IO tables, we disaggregate them using information from the UK supply-use tables also published by the ONS. The aggregation (or not) of the other 29 sectors permits key activities impacting or impacted by the response to enabling and realising energy efficiency are distinguished. However, as is commonly the case, some important activities are still aggregated in the IO classification. For example, the 'Manufacture of fabricated metal products, excluding weapons & ammunition' sector (sector 25OTHER in SIC 2007) includes the production of heating systems such as gas boilers. We use the sector as a representative of heating system manufacturers, although we do note that not all the industries in the sector will be actively involved in manufacturing heating systems.

How is production activity modelled?

Each industry has a production function that incorporates labour, capital, energy and non-energy intermediate inputs. Capital, labour and intermediates are standard input classification in every CGE model, including the one used by HM Treasury. The key difference is that in our model we distinguish between energy and non-energy intermediates. Capital and labour are combined in one nest of a CES consumption function to produce value-added before combining with intermediates, dependent on relative prices. For our central assumptions, we assume that wages are determined by a wage bargaining curve where the level of the nominal wage is inversely related to the unemployment rate. However, we do consider alternative scenarios where the nominal wage is fixed. We also assume a fixed (national) labour supply, meaning there cannot be any migration to cover the excess labour demand. The base year data incorporate a small (5%) pool of unemployed labour that responds to additional employment opportunities and through which the labour demand is covered. We assume perfect mobility of employees to other sectors where increased demand for their output also leads to increased labour demand.

Capital is also constrained in that it does not instantly reach the desired level. We use two different approaches for the necessary investment. For the 4-year programmes we use as a central approach a year-by-year investment to adjust the production capital in UK sectors, what we refer to as 'optimistic producers'. The central approach for the 15-year programmes, which is also an alternative for the 4-year ones, is that the path of the necessary investment to the desired capital stock is calculated, as detailed by Figus *et al.* (2017), so that it maximises the value of the firms, while taking into account the depreciation of existing capital. We refer to that approach as 'pessimistic producers'.

Table A.2: Sectoral aggregation in CGE model and link to SIC2007 codes

Sector Number	Sector Name	SIC code
S1	Agriculture, Forestry and Fishing	01-03
S2	Coal and Lignite	05
S3	Crude Oil and Gas	06-07
S4	Other Mining and Mining Support	08-09
S5	Food, Drinks and Tobacco	10-12
S6	Textile, Leather and Wood	13-16
S7	Paper and Printing	17-18
S8	Coke and Refined Petroleum Products	19
S9	Chemicals	20
S10	Pharmaceuticals	21
S11	Rubber and Plastic	22
S12	Cement, Lime and Glass	23
S13	Iron, Steel and Metal	24&25.4
S14	Manufacture of Fabricated Metal Products, excluding weapons & ammunition	25.1-3&25.5-9
S15	Electrical Manufacturing	26-28
S16	Manufacture of Motor Vehicles, Trailers and Semi-Trailers	29
S17	Transport Equipment and Other Manufacturing (incl. Repair)	30-33
S18	Electricity	35.1
S19	Gas Distribution	35.2-3
S20	Natural Water Treatment and Supply Services	36
S21	Waste Management and Remediation	37-39
S22	Construction - Buildings	41-43
S23	Wholesale and Retail Trade	45-47
S24	Land Transport	49
S25	Other Transport	50-51
S26	Transport Support	52-53
S27	Accommodation and Food Service Activities	55-56
S28	Communication	58-63
S29	Financial and Insurance Services	64-66
S30	Architectural Services	71
S31	Services	68-70 & 72-82
S32	Public Administration, Education and Defence	84-85
S33	Health and Social work	86-88
S34	Recreational and Other Private Services	86-94

How is consumption modelled?

Our model includes a number of consumers including the government and households. The government consumption is treated as exogenous meaning that despite any changes in relative prices the government is assumed to maintain the same level of consumption. This affects the budget balance, but in all our simulations the government can accumulate savings or deficit. We do not enforce a balanced government budget to avoid any distortion in the results that would be driven by the government recycling any savings or passing any deficit to the rest of the economy.

The households are disaggregated into 5 quintiles based on their gross income. The process is detailed in Figus *et al.* (2017) but reflects the UK households in 2016. This allows us to study how households with varying income levels differ in their consumption of goods and services, including energy goods and services. Household income comes from different sources, including labour income, income from capital and transfers from the government. The marginal propensity to consume is assumed to be constant throughout the duration of our analyses. The initial consumption choices of each quintile are informed by the SAM data used as the basis for this model. However, the households respond to changes in the relative price of goods and services, so that they can maximise their utility; subject to budget constraints that fluctuate with every simulated period. This includes the consumption of residential energy, i.e. the energy required for households to run their properties and an efficiency parameter on energy use is shocked in our scenarios. As such our analyses capture any indirect rebound effects driven by a drop in the relative price of residential energy or by a general increase in the disposable income of households which increases the consumption demand of all goods and services.

Are there imports/exports in UKENVI?

UKENVI includes two external regions; Rest of EU (REU) and Rest of the World (ROW). Goods and services from these external regions can be imported for intermediate or final use and similarly UK industries have the option to export their output to these regions. UK goods and services are considered imperfect substitutes to those produced abroad and both import and export demands respond to changes in relative prices. In each simulated period firms can choose to either use domestically produced intermediate inputs or import them from abroad. However, since they are considered as imperfect substitutes, a greater difference in relative prices is required for the UK firms to opt to use imports rather than use domestic goods and services. A similar process applies to consumers, who have the option to meet their needs by using domestic or imported goods and services. The elasticity we assume between domestic and imported goods is in line with the existing literature and is generally accepted as being a reasonable assumption. However, a sensitivity analysis can be conducted by introducing different elasticities to reflect consumers of firms more or less prone to import the goods they need and how export demand does respond to changes in the competitiveness of UK industries.

Annex B: List of simulated scenarios

4-year programmes

Scenario number	Policy description	How policy is funded	Policy length	Annual spend	Spend per household	Quintile distribution of EE recipient	Assumptions
1	Regulation – FP (fuel poor)	Property owner FP	4 years	£1bn	**£4,100**	**Fuel poor** translated to quintiles	**Central assumption:** Optimistic producers and consumers
2	Regulation - ATP	Property owner ATP	4 years	£1bn	**£4,100**	**Non fuel poor** translated to quintiles	**Central assumption:** Optimistic producers and consumers
3	Regulation – FP but paid by ATP i.e. Landlords paying for tenants	**Property owner ATP**	4 years	£1bn	**£4,100**	**Fuel poor** translated to quintiles	**Central assumption:** Optimistic producers and consumers
4	Regulation- FP	Property owner FP	4 years	£1bn	**£4,100**	**Fuel poor** translated to quintiles	**Alternative assumption:** Pessimistic producers, optimistic consumers
5	Grant scheme – FP	Government funded through taxation	4 years	£1bn	**£4,100**	**Fuel poor** translated to quintiles	**Central assumption:** Optimistic producers and consumers
6	Grant scheme – ATP	Government funded through taxation	4 years	£1bn	**£4,100**	**Non fuel poor** translated to quintiles	**Central assumption:** Optimistic producers and consumers
7	Grant scheme – FP	Government funded through taxation	4 years	£1bn	**£4,100**	**Fuel poor** translated to quintiles	**Alternative assumption:** Pessimistic producers, optimistic consumers
8	Loan scheme - ATP	Property owner ATP	4 years	£1bn of loans, repaid over **25 years**	**£4,100**	**Non fuel poor** translated to quintiles	**Central assumption:** Optimistic producers and consumers
9	Loan scheme – FP	Property owner FP	4 years	£1bn of loans, repaid over **25 years**	**£4,100**	**Fuel poor** translated to quintiles	**Central assumption:** Optimistic producers and consumers
10	Loan scheme – FP	Property owner FP	4 years	£1bn of loans, repaid over **25 years**	**£4,100**	**Fuel poor** translated to quintiles	**Alternative assumption:** Pessimistic producers, optimistic consumers
11	Loan scheme – ATP	Property owner ATP	4 years	£1bn of loans, repaid over **5 years**	**£4,100**	**Non fuel poor** translated to quintiles	**Central assumption:** Optimistic producers and consumers
12	Loan scheme – FP	Property owner FP	4 years	£1bn of loans, repaid over **5 years**	**£4,100**	**Fuel poor** translated to quintiles	**Central assumption:** Optimistic producers and consumers
13	Loan scheme – FP but paid by ATP i.e. Landlords paying for tenants	Property owner ATP	4 years	£1bn of loans, repaid over **5 years**	**£4,100**	**Fuel poor** translated to quintiles	**Central assumption:** Optimistic producers and consumers

15-year programmes

Scenario name	Policy description	How policy is funded	Policy length	Annual spend	Spend per household	Quintile distribution of EE recipient
Steady regulation	Regulation	Beneficiary household	15 years	Variable	£4,100	All households based on breakdown
Late regulation	Regulation	Beneficiary household	15 years	Variable	£4,100	All households based on breakdown
Early regulation	Regulation	Beneficiary household	15 years	Variable	£4,100	All households based on breakdown
Steady grants	Grant scheme (no balanced budget)	Government funded through taxation	15 years	Variable	£4,100	All households based on breakdown
Late grants	Grant scheme (no balanced budget)	Government funded through taxation	15 years	Variable	£4,100	All households based on breakdown
Early grant	Grant scheme (no balanced budget)	Government funded through taxation	15 years	Variable	£4,100	All households based on breakdown
Steady 25-loans	Loan scheme	Beneficiary household	15 years	Variable, loans repaid by consumers over **25 years**	£4,100	All households based on breakdown
Late 25-loans	Loan scheme	Beneficiary household	15 years	Variable, loans repaid by consumers over **25 years**	£4,100	All households based on breakdown
Early 25-loans	Loan scheme	Beneficiary household	15 years	Variable, loans repaid by consumers over **25 years**	£4,100	All households based on breakdown
Steady 5-loans	Loan scheme	Beneficiary household	15 years	Variable, loans repaid by consumers over **5 years**	£4,100	All households based on breakdown
Late 5-loans	Loan scheme	Beneficiary household	15 years	Variable, loans repaid by consumers over **5 years**	£4,100	All households based on breakdown
Early 5-loans	Loan scheme	Beneficiary household	15 years	Variable, loans repaid by consumers over **5 years**	£4,100	All households based on breakdown

Endnotes

[1] An academic paper on the underlying research was published in the journal Energy Policy: https://doi.org/10.1016/j.enpol.2021.112375

[2] See our publication in the peer reviewed journal Local Economy: https://doi.org/10.1177/0269094220984742

[3] The distribution of the total activity volume over the 15-year period, as well as across the different household quintiles, is the outcome of internal analyses provided to us by our collaborating colleagues at BEIS.

[4] Multiple objectives may be associated with any energy efficiency improvement programmes. The primary aims are likely to be associated with alleviating social problems like fuel poverty and reducing emissions, hence the policy design aims to maximise the outcomes that help address the problem under consideration. However, secondary objectives may include maximising, where possible, wider economic benefits, not least where wider justification of public resources in administering and/or providing financial support, particularly where more able-to-pay households directly benefit from energy efficiency actions.

[5] Although the gains appear to be small, it is important to keep in mind that the volume of the retrofitting activity constitutes a relatively small 'shock' to the wider UK economy.

[6] The difference in impacts between 'Electricity' and 'Gas distribution' is partly driven by how the sales of gas and electricity are recorded in Input-Output (IO) tables, which are the basis for the 2016 social accounting matrix we use for our model. The IO accounts record all outputs of an industry as part of its primary activity, so the gas sales of an electricity firm are recorded as electricity sales. As a result, out of the joint electricity and gas sales, 77% are recorded as electricity sales and 23% as gas sales. Hence, the 'Electricity' sector is represented as being significantly larger than the 'Gas distribution' sector and an efficiency increase in residential energy use will mainly reduce the use of the outputs of the 'Electricity' sector.

[7] Part of the challenge is associated with gas sales recorded in IO tables as electricity sales. To understand the impacts electrification options may have to the sales of the 'Electricity' sector, for example, we need to identify which part of the current sales is used for heating purposes and how the energy use would change by the introduction of a new heating solution.

[8] The societal returns put the 15-year programme between the two extremes we explore in the 4-year programmes case. However, it is key to avoid generalising that switching to any of these distributions would deliver the same societal returns. There are multiple price pressures that determine the outcomes of a specific programme so a case-by-case analysis is necessary in order to obtain credible results.

[9] There are some export losses due to rising labour costs and output prices, meaning that the net output requirements are smaller than the additional retrofitting demand.

[10] The report detailing our previous work on residential energy efficiency can be found in this link: https://doi.org/10.17868/71454. An academic paper based on this work is currently under review for the peer reviewed journal Energy Policy.