Jobs, growth and warmer homes

Evaluating the Economic Stimulus of Investing in Energy Efficiency Measures in Fuel Poor Homes

Final Report for
Consumer Focus

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Foreword from Consumer Focus

Over recent years, successive governments have struggled to face up to the growth in fuel poverty.

The commitment to eradicate fuel poverty was taken in 2001 when Britain was largely self sufficient in gas and household bills were comparatively low. With just under 2 million[1] households in fuel poverty it felt like a challenge that could be met.

Today over six million households cannot afford to keep their homes warm due to a combination of stagnant incomes, higher energy prices and Britain's legacy of old, leaky homes. That commitment feels like it has been consigned to the too difficult and too expensive drawer.

Incomes for those in fuel poverty are unlikely to rise anytime soon. Energy prices seem just as unlikely to fall. It is clear that a step change in the energy efficiency of our housing stock is the only viable solution. But that costs money. More money than any government has been able to commit to date.

This report challenges the assumption that we cannot afford to tackle fuel poverty. It argues that there is a triple win available of warmer homes, greater energy efficiency and economic growth if we can use carbon taxes revenue to benefit consumers, and fuel poor households in particular.

Over the next 15 years £63 billion will be added to consumer energy bills through the carbon floor price and EU Emissions Trading System (ETS). That is an average of £4 billion a year not available for consumers to spend keeping warm, or for companies to invest in cleaner generation and smart grids. If we were to direct this £4 billion toward a major programme to improve the energy efficiency of our homes we could make homes warmer, more affordable to heat and take a major step toward our legally binding carbon reduction targets.

This is the approach being taken by the French Government. It recently announced it will be insulating one million existing homes per year partly funded from the proceeds of auctioning its allocation of EU-ETS allowances[2].

Cambridge Econometrics and Verco's research shows that an energy efficiency programme is also a more effective way to stimulate the economy – compared to likely alternatives like cutting VAT, reducing fuel duty or investing in capital infrastructure projects such as building roads. It shows that such a programme would also have substantial economic benefits. It would create 71,000 jobs by 2015 and boost gross domestic product (GDP) by 0.20 per cent.

Energy efficiency is on the government's agenda. Its Green Deal is a new finance mechanism that will make it easier for consumers to pay for energy efficiency improvements to their homes.

The new Energy Company Obligation (ECO) on fuel suppliers will complement Green Deal

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[1] http://www.decc.gov.uk/assets/decc/11/funding-support/fuel-poverty/3226-fuel-poverty-review-interim-report.pdf Hills Fuel Poverty Review Interim Report

[2] http://www.gouvernement.fr/gouvernement/systeme-d-echange-de-quotas-d-emission-de-gaz-a-effet-de-serre-periode-2013-2020-0

and help pay for improvements to the homes of low income consumers and those that are ‘hard to treat’.

However, these policies just brush against the scale of the problem. Government projections indicate ECO will remove between 125,000 – 250,000 households from fuel poverty by 2023[3]. At best, this represents only 5 per cent of the current number of fuel poor households.

The programme of energy efficiency investment proposed in this report would complement the Green Deal and ECO. Research published for the Energy Bill Revolution demonstrates the social and environmental benefits of the programme – nine out of 10 fuel poor households removed from fuel poverty; quadruple the impact of Green Deal and ECO alone on carbon emissions[4].

The research is very timely. According to the Office of Budget Responsibility’s most recent report[5] the UK’s economic activity, as measured by GDP, is 2.6 per cent below the level it would be if employment, consumer and business confidence were at normal levels.

The Government is considering a range of options to help boost the economy. It has already announced plans to stimulate investment in the country’s infrastructure, including an element for new housing. This report makes a strong case for investment in a vital but sometimes over-looked part of the economy’s infrastructure, namely the energy efficiency of our existing housing stock.

Compared to the alternative stimuli policies investigated, the improved performance of the energy efficiency programme is in part due to reduced gas and oil imports. This feeds directly into increased GDP as well as improving the country’s energy security. By reducing the amount of money consumer have to spend on energy there is more money in the wallet to spend on other products and services, which are in part supplied domestically.

The energy efficiency programme has other advantages. It is ‘shovel ready’ - fast to mobilise. It stimulates economic activity and jobs in all regions of the UK. It employs workers in construction and allied sectors where there is surplus capacity – so investment is less likely to ‘crowd out’ alternate economic activity. It will also reduce NHS expenditure on treating cold-related illnesses such as respiratory and coronary diseases.

We believe our research findings have important implications for future Government policy. The economy will benefit from increased economic activity, job creation and reduced imports of gas and oil arising from the energy efficiency programme proposed. And, millions of British families will get ongoing benefits from warmer homes, reduced energy bills and better health.

Mike O’Connor
Chief Executive
Consumer Focus

[3] DECC (2012), Final stage impact assessment for the Green Deal and Energy Company Obligation

[4] Camco (now Verco) (2012), Energy Bill Revolution Campaign report, Transform UK

[5] Office for Budget Responsibility (2012), Economic and fiscal outlook, HM Treasury

Executive Summary

Summary

- The UK has just emerged from the middle of the longest double dip recession since reliable economic statistics have been collected. Much of the economy, including the construction industry, is operating below its normal capacity. At the same time the number of households in fuel poverty seems set to increase if fuel prices rise at the rate expected by Government.
- Significant sums are due to be paid to Government through new carbon taxes – the modelling in this study shows £63 billion will be raised from electricity consumers between 2012 and 2027. Prompted by these twin problems of underutilised economic capacity and vulnerable people's need, Consumer Focus commissioned Cambridge Econometrics and Verco to model the macroeconomic effects of investing revenue from carbon taxes into installing energy efficiency measures into fuel poor households.
- The findings suggest there are clear benefits from spending carbon tax revenues on improving energy efficiency in fuel poor households. Such a policy will provide macroeconomic benefits as well as the environmental and social benefits. If the carbon revenue is so invested it could create up to 71,000 jobs by 2015 and up to 130,000 jobs by 2027. It will also remove 87% of the 9.1 million households projected to be in fuel poverty in 2016 from that risk and reduce energy bills in all treated homes by over £200 a year.
- Crucially, the results suggest investing in such a programme generates greater macroeconomic benefits – more jobs and greater growth – than the same injection of spending through other Government spending programmes or cuts in VAT or fuel duty.
- The modelling outcomes therefore suggest that investment in the UK housing stock is one of the best investments possible in terms of boosting short-term employment and economic activity, and it also improves medium to long-term economic efficiency by reducing the economy's dependency on imported gas.

Approach

- This report presents an assessment of the economic and environmental impacts of investing in energy efficiency in fuel poor households. Previous analysis has shown that 9.1 million households were at risk of falling into fuel poverty by 2016[6]. The effect of the investment is judged relative to the business-as-usual position as set out in the Office of Budgetary Responsibility's (OBR's) economic forecasts and the Department of Energy and Climate Change/Climate Change Committee (DECC/CCC) energy and emissions forecasts. The study assessed the effect of stimulating the economy through spending on energy efficiency in comparison to four other polices that injected the same amount of money into the UK economy:

  1) general government investment (or capital) spending programme;
  2) general government current spending programme;
  3) reduction in VAT; and
  4) reduction in fuel duty.

[6] Please refer to the Energy Bill Revolution Report on http://www.energybillrevolution.org/resources/ for further details.

- Each of these was assessed using Cambridge Econometrics' model of the UK economy, MDM-E3.
- Three scenarios for spending on energy efficiency were modelled:
  - **Energy Efficiency All (EE-All):** This spends just under 95% of the revenues raised from carbon taxes and allows investment in all 9.1m households at threat of fuel poverty, therefore largely eradicating fuel poverty.
  - **Energy Efficiency Targeted (EE-T):** This spends just under 35% of the revenue collected from carbon pricing, and the revenues are targeted at the 6.8m fuel poor homes that can be treated for less than £10,000. This eradicates fuel poverty in 75% of the households projected to fall under fuel poverty by 2016.
  - **Energy Efficiency Targeted with early action (EE-EA):** in this scenario again the 6.8m fuel poor are targeted but the spending is brought forward, using 100% of the carbon pricing revenues in 2013-19 and a share of the revenue in 2020. By 2020 6.8m homes are removed from fuel poverty.
- For each energy efficiency scenario, we developed a comparable scenario whereby the same amount of government investment is injected into the economy, but spread across standard government investment projects (GK-All, GK-T, GK-EA).
- Against the Energy Efficiency Targeted (EE-T) scenario we also compared the impact of increasing government spending, reducing VAT and reducing fuel duty by equivalent amounts.
- Tables ES.1 and ES.2 show the key characteristics and summary results for the main scenarios, compared to the other government investment scenarios.

Table ES.1: Summary of Short-Term Modelling Results

SUMMARY OF SHORT-TERM MODELLING RESULTS

For 2015	EE-All	GK-All	EE-T	GK-T
Annual carbon price revenue (£m 2008 prices)	2786.60	2786.60	2786.60	2786.60
Annual fiscal stimulus (£m 2008 prices)	2618.00	2618.00	963.00	963.00
Total Homes Treated ('000s)	1094.90	n/a	821.20	n/a
Annual jobs created ('000s FTE)	71.00	64.50	26.60	23.60
GDP impact %	0.20	0.21	0.08	0.08
Annual energy bill savings per household treated (£ 2008 prices)	237.40	n/a	231.30	n/a

Table ES.2: Summary of Long-Term Modelling Results

SUMMARY OF LONG-TERM MODELLING RESULTS

For 2027	EE-All	GK-All	EE-T	GK-T
Annual carbon price revenue (£m 2008 prices)	6,794.80	6,794.80	6,794.80	6,794.80
Annual fiscal stimulus (£m 2008 prices)	6,382.80	6,382.80	2,349.10	2,349.10
Total Homes Treated ('000s)	9,100.00	n/a	6,825.00	n/a
Annual jobs created ('000s FTE)	129.40	105.20	52.00	38.50
GDP impact %	0.38	0.36	0.16	0.13
Annual energy bill savings per household treated (£ 2008 prices)	212.00	n/a	216.10	n/a

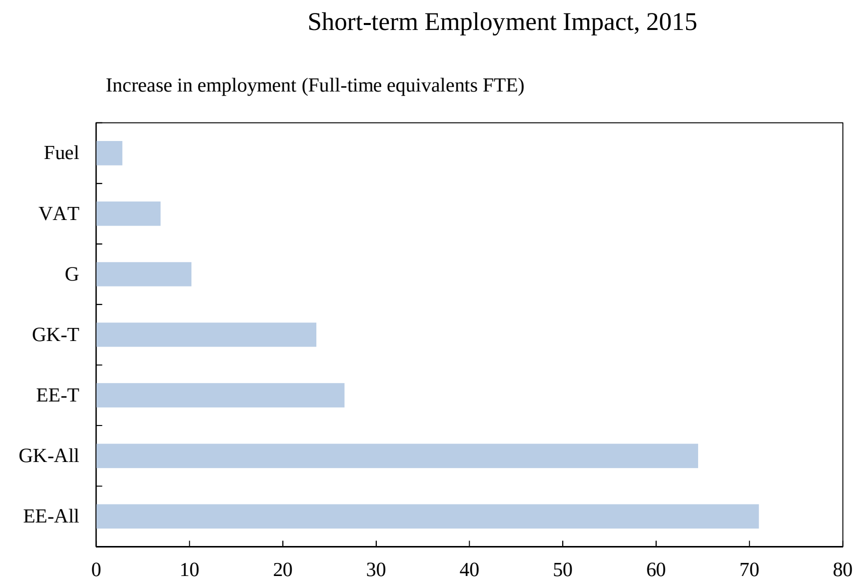
Short-term findings

- Investing in energy efficiency measures in fuel poor households has a similar or more positive macro-economic impact than an equivalent stimulus package either through increases in government current spending (e.g. NHS, education) or government capital spending (e.g. roads, building hospitals), or reductions in VAT or fuel duty. Each of the three spending options causes an increase in economic output, but investment in energy efficiency has the added and persisting benefit of also reducing natural gas imports. If households spend less on energy imports, they are able to spend more on other products and services, which are in part supplied domestically. Energy security is also improved.
- The positive impact of the energy efficiency investment on GDP (between 0.08% and 0.2% in 2015, compared to the baseline) is also reflected in jobs. In 2015, the EE-T and EE-All scenarios create 26,600 and 71,000 jobs, respectively. The difference is because spending in the latter is almost three times greater. These jobs are created firstly in the construction industry and its supply chain but the jobs diffuse throughout the economy.
- The impact on jobs in the short term is broadly similar to the GK-all scenario. Figure ES.1 shows the impact of the fiscal stimulus in 2015 on jobs across the various scenarios. In the bottom two scenarios the fiscal stimulus is £7,138m, while in the other scenarios the fiscal stimulus in 2015 is £963m.
- The modelled increase in employment is broadly consistent to findings from other countries. In 2009 the German KfW eco-refurbishment programme stimulated nearly €8bn of private and public sector investment in energy efficiency building, leading to 128,000 additional jobs. This compares to our finding that around £2.6bn of investment in 2015 would stimulate 71,000 jobs. This is a similar number of jobs per unit of investment.

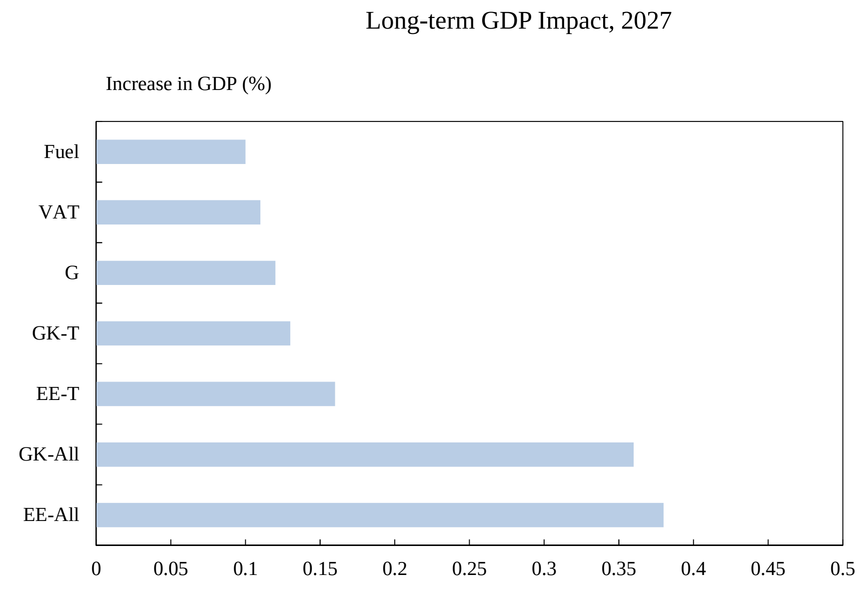
Long-term findings

- In the longer term, improved energy efficiency and a reduced dependency on gas imports serves to increase GDP by 0.38% and jobs by 129,400 in 2027, in the EE-All scenario. By way of comparison, an equivalent general government investment programme would provide an increase of 105,200 jobs, which suggests that the additional stimulus of shifting from imported energy to domestic goods and services is contributing a further 24,200 jobs. These extra jobs arise from a permanent improvement in the country's gas self-sufficiency.

Figure ES.0.1: Short-term Employment Impact, 2015



Source(*s*): MDM-E3, Cambridge Econometrics.



Source(*s*): MDM-E3, Cambridge Econometrics.

- Figure ES.2 shows the long-term impact on GDP of the various scenarios. In the longer term the energy efficiency impact, which serves to increase overall economic efficiency and reduce import dependency on natural gas, leads to larger increases in GDP than scenarios with an equivalent fiscal stimulus.

Modelling assumptions: Available revenues

- The revenue raised in the UK through auctioned EU Emissions Trading System (ETS) allowances and the carbon floor price is substantial. By 2027[7] it is estimated to account for an accumulated £63.1bn (2008 prices).
- If nearly all (93.9%) of the £63.1bn revenue from the carbon floor price is invested in fuel poverty measures, fuel poverty could be largely eradicated. Even the most hard-to-treat households which require funding levels of more than £10k (around 25%) could be removed from fuel poverty. (Around 13% of households with very low incomes will still be in fuel poverty and will need additional income to support them.)
- Alternatively, if the revenue is only spent on homes requiring less than £10,000 of investment, 6.8m households (or 75%) could be removed from fuel poverty by 2020, as shown in the EE-EA scenario.

Wider benefits

- Investment in energy efficiency measures in fuel poor households could reduce total household energy consumption by 5.4% in 2027; this would represent annual fuel bill savings in 2027 for previously fuel poor households of on average £212 (2008 prices) per household.
- This programme has an impact on the UK's carbon targets, reducing emissions of carbon dioxide by 4 $MtCO_2$ pa by 2027. However, even with this reduction, the UK is likely to miss its fourth carbon budget on current policy and so more measures would be required.
- In summary, these results suggest that investment in energy efficiency in fuel poor homes provides social, economic and environmental benefits beyond those that would be expected from the alternative measures considered in this study:
  - **Economic benefits**: Investing the money in fuel poor households has a better outcome on growth and employment than the alternative options modelled
  - **Social benefits**: Between 75% and 100% of the households that would have otherwise been in fuel poverty are removed from fuel poverty, improving the quality of millions of lives of some of the most vulnerable members of society and reducing health care costs
  - **Environmental benefits**: UK household direct CO_2 emissions fall by more than 5% compared to baseline by 2027 contributing to the UK's legal commitment to reduce greenhouse gas (GHG) emissions by 2050
- Few policy options can claim to offer such clear benefits in each of these three pillars of sustainable development.

[7] 2027 is the last year in the fourth carbon budget period and is therefore the last year of investment for most of the scenarios.

1 Introduction

1.1 Background

The residential sector accounts for around 23% of total UK CO_2 emissions

The UK's housing stock makes a substantial contribution to the UK's national energy demand and consequent CO_2 emissions. The residential sector accounts for around 23% of total UK CO_2 emissions, much of which arises from the use of natural gas for heating. The Committee on Climate Change (CCC) has set a target for a 35% reduction in buildings emissions by 2020[8], primarily through improvements in energy efficiency and increased deployment of renewable heat. This is very important if the UK is to meet its legally binding carbon reduction commitments for 2020 and 2050.

Households' budgets are under pressure from rising energy prices, leading to more households in fuel poverty

Households, in particular low-income households, are facing increasing energy prices and stagnating (real) incomes. Several factors are combining to put upward pressure on wholesale energy prices, including increasing global demand, but also geopolitical uncertainties. Retail energy prices for households are increasing faster as a result of carbon mitigation policies like the EU Emissions Trading System (ETS). At the same time household disposable income is, at best, growing slowly as the UK economy emerges from recession. The combination of these factors is resulting in a significant increase in the number of households in fuel poverty. Current estimates put the figure at 6-7 million households – the same level as in 1996[9].

Improving energy efficiency of fuel poor households could reduce fuel poverty, stimulate the economy and reduce CO_2 emissions…

Improving the energy efficiency of the UK's housing stock could mitigate the impact of energy price rises, including the higher costs of bills arising from policies to develop low-carbon energy. Previous studies have shown it is a cost-effective option for reducing carbon emissions, and energy efficiency programmes could have a positive macroeconomic impact, contributing to growth and employment[10] .

The direct effects of additional investment create a demand stimulus that could benefit many of the sectors that were affected most severely by the recession (and therefore have spare capacity). In addition, energy efficiency improvements could reduce reliance on imported fossil fuels, thus increasing GDP and benefiting energy security.

… but there is concern as to whether current policy will deliver this…

However, there are concerns about whether the UK's changing energy efficiency policy framework can realise these benefits. A number of studies suggest that the government's Green Deal initiative and the Energy Company Obligation (ECO), which replaces the Carbon Emissions Reduction Target (CERT) energy efficiency and Warm Front fuel poverty programme, will be insufficient to meet statutory carbon and fuel poverty targets[11].

… additional support could be provided through EU ETS revenues

If the government is to achieve its policy goals, it is likely that the Green Deal and ECO will need to be enhanced by additional investment. This report assesses the impact of spending revenues generated through the EU ETS in Phases III and IV, and the introduction of a carbon floor price post-2013, to provide additional funds for investing in energy efficiency, prioritising the homes of the fuel poor and vulnerable.

[8] Compared to 1990 levels.

[9] Annual report on fuel poverty statistics 2012 (DECC)

[10] National Action Plan for Energy Efficiency (2009). Energy Efficiency as a Low-Cost Resource for Achieving Carbon Emissions Reductions. Prepared by William Prindle, ICF International, Inc.

[11] The Green Deal and Energy Copmany Obligation. Citizens Advice response to DECC. 2012. The Citizens Advice Bureau.

This report focuses on the economic impact of an investment programme in fuel poor households

In view of the highly constrained public spending climate, this report focuses on the wider benefits that investment in household energy efficiency could achieve. Looking beyond the important environmental and social goals, the report evaluates the size of the economic stimulus that results from investing these revenues in energy efficiency programmes and compares this with alternative options for infrastructural investment and other ways in which the government might stimulate the economy.

1.2 Report structure

This report presents the analysis of investing EU ETS and carbon floor price revenues into household energy efficiency measures targeted at the fuel poor

The purpose of this report is to assess the macroeconomic impact of investing in energy efficiency in fuel poor homes. It builds on earlier analysis undertaken by Verco (then Camco) for Consumer Focus, Transform UK and The Co-operative, as part of the Energy Bill Revolution campaign[12].

The next chapter outlines the approach that was used to estimate the energy efficiency measures that could be undertaken using the available EU ETS and carbon price floor revenues. It also discusses the macroeconomic logic and the expected impacts of the investment, represented by the main flows captured in Cambridge Econometrics' MDM-E3 model that was used to carry out the analysis.

Chapter 3 describes the baseline used for the modelling, the scenario with additional investment in energy efficiency and the alternative options for the revenues. At the end of this chapter we outline the sensitivities tested.

The results from these scenarios are presented in Chapter 4. In particular we focus on the economic impact of the energy efficiency investment scenarios. We also discuss the impact on employment, drawing comparisons with other estimates and explaining the differences between the estimates.

In Chapter 5 we present our conclusions from the analysis.

[12] http://www.energybillrevolution.org/wp-content/uploads/2012/02/Energy-Bill-Revolution_full-report.pdf

2 Analytical Approach

2.1 Overview

The analysis was undertaken in two stages. First to analyse the potential investment fund and energy savings, followed by an economic assessment using the MDM-E3 model

This chapter explains the analytical approach that was used to assess the impact of investing in energy efficiency measures in fuel poor households. There are two main stages:

- a bottom-up assessment of the potential energy savings from investing EU ETS and carbon floor price revenues in efficiency measures for fuel poor households.
- a macroeconomic assessment of the impact of these energy savings in the MDM-E3 model (see Section 2.4 and Appendix A) compared to alternative fiscal options.

For the purpose of comparison, the impacts of the scenario in which investment is made in energy efficiency are compared to two scenarios of government spending and investment programmes and two scenarios of tax reduction in the form of VAT and fuel duty. The full set of scenarios is described in Chapter 3.

2.2 Estimating the energy savings from efficiency measures

The method that was used to estimate the potential energy savings from the available funding consists of two main steps:

- First, an estimate of the number of fuel poor households in the UK by 2016 is made, taking into account the projected increase in fuel prices, the likely rise in real household incomes and the estimated reduction in energy consumption from current policy instruments.
- Second, the energy efficiency improvements required to bring households out of fuel poverty are modelled.

Projecting the number of fuel poor households in the UK

It is projected that 9.1m households will be in fuel poverty by 2016. Households are defined as being in fuel poverty if they need to spend 10% or more of their income on fuel in order to heat their homes to an adequate level and to allow for adequate consumption of other energy services.

To estimate the number of fuel poor households in England by 2016, data from the 2009 English Housing Survey (EHS) was used as the basis for the analysis. Household incomes for each of the data points in the EHS were then projected based on Office for Budget Responsibility (OBR) forecasts[13]. The household fuel bills in the EHS dataset were converted to energy demand figures based on the 2008 or 2009 energy tariffs[14], as applicable depending on the survey year for that data point. The associated energy tariffs are applied taking account of the household payment method and region.

When projecting household fuel bills, allowance was made in the calculations for improvements to the energy efficiency of the housing stock over time compared with 2008/09 levels. This is based on data published by the CCC[15], which provides past trends and future projections of energy consumption taking into account current and proposed policies, including

[13] Office for Budget Responsibility (2011) November 2011 Economic and Fiscal Outlook.

[14] As provided by DECC (Source: email dated 30th Nov 2011).

[15] Committee on Climate Change (2011) Household energy bills – impacts of carbon budgets.

the Green Deal and ECO[16]. Energy bills in future years are then calculated using DECC's central scenario for energy price forecasts[17].

In the devolved nations, fuel poverty levels have been estimated using the 2008 fuel poverty numbers published by DECC for Wales and Northern Ireland and 2009 numbers for Scotland as the starting point. These are then projected to take into account the profile of income distribution within each country, the relative increase in fuel prices and the reduction in energy consumption over the corresponding period.

New housing expected to be built in the UK during this time frame was not incorporated into the analysis.

Estimating the required energy savings to get households out of fuel poverty

For the purpose of this study, a 'Target SAP rating' was determined for each dwelling in the EHS data. The 'Target SAP' is defined as the minimum SAP score a dwelling needs to achieve to avoid the current household being in fuel poverty, up to a maximum SAP score of 81 corresponding to an EPC rating of 'B'. This is calculated by estimating the maximum that a household can spend on energy bills without falling into fuel poverty, based on 2027 fuel prices and household incomes.

The energy savings required to get households out of fuel poverty are then calculated as the difference between their starting energy demand and the energy demand required to hit the Target SAP rating. The required energy savings are then averaged across all data points in the EHS.

2.3 Assessing the economic impact of energy efficiency investment

The economic assessment uses the bottom-up estimates of energy savings and the associated investment as inputs

The energy savings, and associated investment, are used as inputs to the MDM-E3 model. The investment has the following impacts:

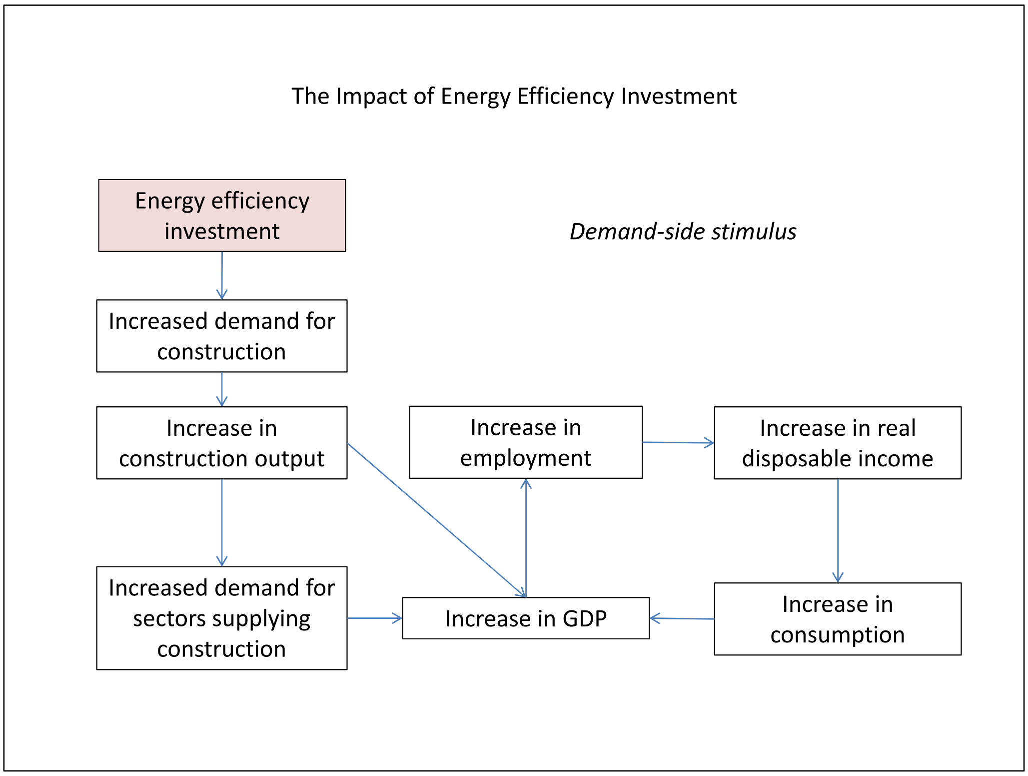
- there is a direct and immediate stimulus effect to the construction sector and its associated supply chains
- households receiving the investment will see long-term reductions in their energy bills; they will have higher disposable income to spend on other products which may be produced domestically or imported
- there is reduced demand for natural gas and (to a lesser extent) electricity from households
- there is a reduction in economy-wide carbon emissions

Figure 2.1 and Figure 2.2 present a schematic of the key elements of the intervention logic for the investment programme. The logic chain, which is fully represented in the MDM-E3 model, begins with the investment in energy efficiency.

[16] These are based on the DECC energy demand projections used to develop the MDM-E3 baseline. See Chapter 3 for details.

[17] DECC (2011) Valuation of Energy Use and Greenhouse Gas Emissions for Appraisal and Evaluation.

Figure 2.1: The Impact of Energy Efficiency Investment: Demand-Side Stimulus



The investment stimulus has a direct impact on energy demand and on the construction sector, which in turn has supply chain impacts…

The immediate effects of the investment stimulus are divided into:

- demand-side stimulus on the construction sector from the measures' installation requirements (Figure 2.1)
- supply-side impacts of installing energy efficiency measures (Figure 2.2)

Beginning with Figure 2.1, the initial impact on the real economy from the investment is higher demand for, and thus output from[18], the construction sector, which is responsible for installing the energy efficiency measures. This, by itself, leads to higher UK production, but also has supply-chain effects through construction's increased demand for inputs such as metals and minerals. These indirect effects also boost total UK production.

… production increases drive increases in employment and incomes

Higher UK economic production drives an increase in labour demand and employment (particularly in sectors that have yet to recover from recession) and this leads to higher wage income, which is either saved or spent. Higher spending feeds back into further UK production (to meet the higher demand), giving a multiplier effect and completing the production-income-expenditure cycle.

[18] The scenario assumes that the construction sector has the necessary capacity and skills to carry out the installation. This is not unreasonable for the sector as a whole, which is yet to recover from recession, but there is the potential for bottlenecks in particular skillsets.

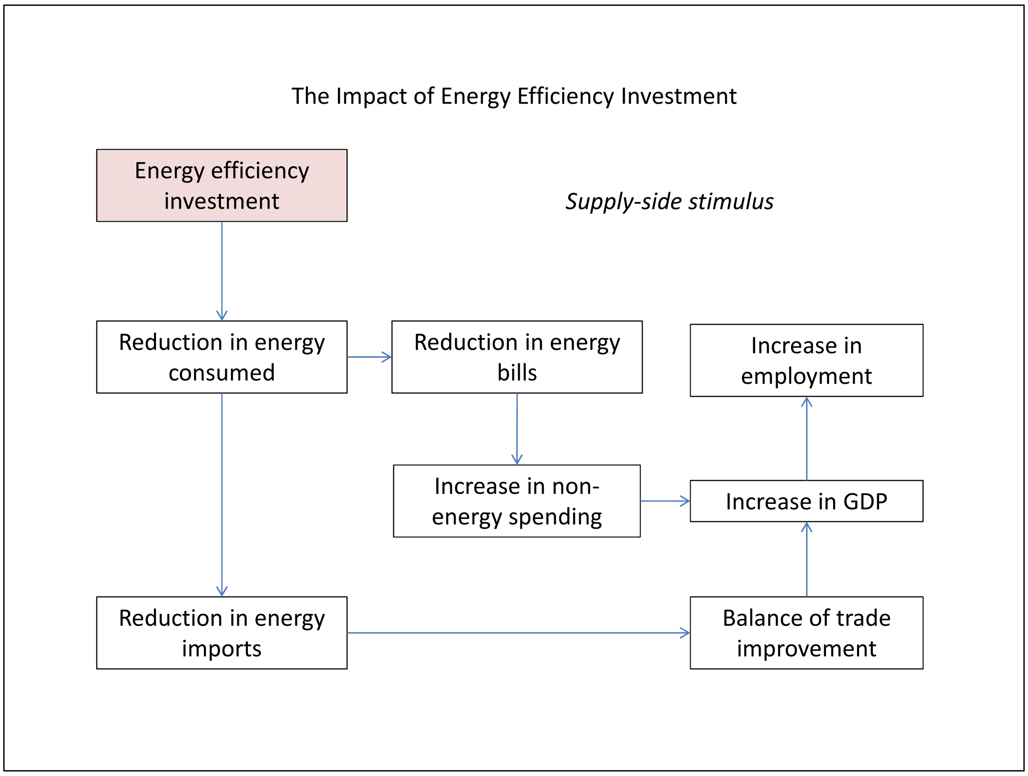
The reduction in energy bills could lead to comfort taking or higher spending on other goods or services; rebound effects could reduce the impact of the initial investment

Figure 2.2 is concerned with the energy efficiency impacts of the stimulus and begins with an initial decrease in energy demand. However, there is also the potential for rebound effects which are modelled but not shown in Figure 2.2 for simplicity (see Section 3.5 and 4.9 for a fuller discussion on the direct rebound effect and its impact on the results).

Rebound effects occur when the income that is no longer used for paying for heating is diverted to other forms of energy consumption (or to goods that require large amounts of energy in their production); if this happens the intervention gives rise to effects that both increase and decrease energy demand. Barring so-called 'backfire' effects, it would be expected that the overall effect is still to lower energy demand.

Overall, the reduction in household energy demand, and therefore energy bills, will lead to an increase in spending, and in doing so, stimulate economic growth and jobs.

Figure 2.2: The Impact of Energy Efficiency Investment: Supply-side Stimulus



2.4 An overview of the MDM-E3 model

A scenario-based analysis is conducted using the MDM-E3 model of the UK

The macroeconomic analysis is based on Cambridge Econometrics' (CE's) model of the UK energy-environment-economy (E3) system, MDM-E3[19]. CE applies MDM-E3 for both scenario analysis and as part of CE's regular energy-economy-emissions forecasting service. It is well-suited for the analysis:

- the model covers the entire UK economy, identifying 87 economic sectors and recognising the interdependencies between them (i.e. supply chains); this representation is fully consistent with official UK economic statistics
- the model has a full representation of the energy system, both in physical flows of energy and monetary terms, with two-way linkages with the economy:
  - the model contains behavioural equations to explain final energy demand for more than 20 final energy users
  - the model includes a representation of the UK's power sector by generating technology to explain changes in electricity supply
  - energy-related emissions are projected as a consequence of energy use
- the model is a dynamic model, with its behavioural parameters estimated on official UK data. Such a specification allows for non-equilibrium outcomes and path dependency, e.g. the possibility of sustained levels of unemployment in the medium-to-long term, which is a feature of CE's latest economic forecasts

MDM-E3 is used regularly to assess the relationships between economic development and the energy system and, conversely, the impact of energy and carbon reduction policies on the economy.

[19] Multisectoral Dynamic Model, Energy-Environment-Economy: http://www.mdm-e3.com/

3 Baseline and Scenario Description

3.1 Introduction

This research is based on a comparison of four alternative scenarios for spending EU ETS and carbon floor price revenues

The government could introduce a number of fiscal measures to stimulate the economy in the short to medium term. The scenarios described below outline some of those possible options. If the government were to introduce a fiscal stimulus, it is likely that it would introduce a combination of stimulus measures rather than individual measures. However, for comparison purposes, the scenarios represent the impact of individual measures.

The scenario analysis is also divided into two sets:

- an analysis of investing in all fuel poor homes (EE-All)
  - and a comparison scenario investing the same amount in a general government investment programme such as roads, railways, schools, etc. (GK-All)
- an analysis of targeted investing in fuel poor homes, with the investment being made only in homes that can be treated for £10,000 or less (EE-T), and four comparison scenarios with the same fiscal stimulus:
  - a general government spending programme (G)
  - a general government investment programme (GK-T)
  - a VAT reduction scenario (VAT)
  - a fuel duty reduction scenario (FUEL)

The scenarios are compared against a baseline (B) which does not include a fiscal stimulus.

The direct stimulus through the additional spending in the scenarios (EE-T, GK-T, and G) and the reduction in tax revenue (VAT and FUEL) is of equal value, allowing a direct economic comparison between the different spending and tax options. By comparing the scenario outputs it is possible to assess the relative impacts of each of the programmes on both the economy and the environment (emissions), for a given level of initial stimulus.

A third set of analyses is also considered (discussed in Section 3.3):

- energy efficiency investment – early action taken but restricted to homes that can be treated for £10,000 or less (EE-EA)
  - and a comparison scenario investing the same amount in a general government investment programme such as roads, railways, schools, etc. (GK-EA)

In this set of scenarios, the entire carbon revenue is spent each year, but limited to £10,000 per household, allowing the households (that can be treated with this amount) to be removed from fuel poverty more quickly, and taking advantage of the current surplus capacity in the economy. The OBR forecast, which forms the baseline for calibrating the MDM model, is that this current ‘output gap’ will persist until at least 2015.

The next section of this chapter describes the baseline that was used. The following sections describe the policy scenarios.

3.2 Baseline scenario

The baseline is designed to be a neutral forward looking assessment that is internally consistent

A forward-looking, *ex ante*, assessment requires a baseline forecast with which to compare the different policy scenarios. While this may not necessarily be a forecast of future developments, it is required to provide a neutral viewpoint for the purposes of comparison. Although many of the model-based results are presented as (percentage) difference from baseline, the values in the baseline are important themselves, providing, for example, an indication of remaining home energy efficiency improvements and the number of available workers in the relevant industry. It is therefore important that a robust and credible baseline is established.

The requirements for the baseline in the MDM-E3 model include:

- annual time series
- detailed sectoral disaggregation
- complete National Accounts coverage
- energy consumption by user and fuel

These figures must also be consistent with the baseline projections used in the bottom-up analysis, as described in Section 2.2, which requires projections of household income and energy prices.

The baseline figures are taken from government projections

The baseline scenario for this exercise was constructed using historical data from the Office for National Statistics (ONS), economic projections from the OBR and energy projections from DECC. For later years, where no official projections are available, figures are taken from CE's MDM-E3 model. Data that incorporate the latest quarterly estimates published by ONS were used for the years up to and including 2011.

Economic projections

For the years 2012-16, growth rates were taken from OBR projections[20] for all the components of final expenditure, income, employment, labour force, wages and inflation. These growth rates were applied to the latest historical data to create a series of projections and the OBR forecast was updated to take into account the most recent figures.

The baseline uses the November 2011 OBR projections, which are consistent with the energy projections used

The OBR projections used in the baseline were the set published in November 2011, to ensure consistency with the energy projections from DECC (see below), which were also published in Autumn 2011. However, it is noted that more recent OBR projections are available, with slightly different GDP figures (the GDP level was up 0.3% based on revisions to 2010 GDP levels).

The OBR's economic outlook reflects the weak growth assumptions that were anticipated in response to the euro crisis. It estimates 0.7% GDP growth in 2012, with a return to the long-run trend of 3% in 2015. It anticipates that household consumption will rise steadily over the next five years, reflecting progressively rising incomes and a return to the 2.0% target rate of CPI inflation by 2014. Growth in business investment is anticipated to exceed 12% in 2015 and 2016, indicating a sturdy recovery in the long run.

The OBR forecast horizon is 2016 but projections from MDM-E3 are used to extrapolate this to 2027 (see Table 3.1 and Table 3.2).

Table 3.1: Baseline Scenario: Economic Projections

BASELINE SCENARIO: ECONOMIC PROJECTIONS

[20] See http://budgetresponsibility.independent.gov.uk/category/topics/economic-forecasts/

	2010-2015 % pa	2015-2020 % pa	2020-2025 % pa
Consumption	1.1	2.5	2.4
Investment	5.5	5.7	4.1
Government expenditure	-1.4	1.2	2.2
Exports	4.9	4.3	4.1
Imports	3.0	4.2	4.3
GDP	1.9	2.9	2.7

Notes : Figures show annual average percentage growth rates
Sources : OBR and own calculations.

Table 3.2: Baseline Scenario: Employment and Earnings Projections

BASELINE SCENARIO: EMPLOYMENT AND EARNINGS PROJECTIONS

	2010-2015	2015-2020	2020-2025
	000's	000's	000's
Employment	536	1064	1291
	% pa	% pa	% pa
Average earnings (nominal)	3.2	4.4	4.4

Notes : Figures show absolute change in employment (000's over 5yr period) and annual percentage change in average earnings.
Sources : OBR and own calculations.

Energy and emissions

DECC's published energy forecast[21] was used to project future baseline growth in energy demand. Growth rates were taken for energy demand by sector and carrier for the years 2011-30.

Energy demand forecasts were taken from DECC's central price and central policy forecast and are consistent with the CCC projections used in the bottom-up analysis

The DECC central price and central policy forecast takes into account current climate change policy and, to establish the forecast for 2011-22, it includes assumptions on how the UK is expected to perform in the first three carbon budgets. The projections for 2023-30 are based on the assumption that no additional climate policy initiatives are formed during this period. The DECC projections are based on central GDP growth and price estimates that are consistent with the OBR forecast.

The DECC central price and central policy forecast includes a carbon price that is consistent with the carbon price used in the assessment of available carbon revenue. The impacts on energy demand and emissions of the carbon price are therefore captured in the baseline and each scenario.

The baseline projections of energy demand are summarised in Tables 3.3-3.6.

[21] See DECC http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx#2011-projections

Table 3.3: Baseline Scenario: Total Final Energy Demand, by Carrier

BASELINE SCENARIO: TOTAL FINAL ENERGY DEMAND, BY CARRIER

	2010 GWh	2015 GWh	2020 GWh	2025 GWh	2030 GWh
Electricity	323,189	313,069	316,530	332,204	356,331
Gas	618,286	536,085	481,116	487,636	510,884
Petroleum	742,374	716,628	696,525	719,151	734,646
Solid / manufactured fuels	34,666	32,032	27,741	26,257	26,639
Renewables	29,687	52,183	111,837	95,066	93,493
Total	1,748,202	1,649,997	1,633,749	1,660,314	1,721,993

Sources : DECC.

Table 3.4: Baseline Scenario: Total Final Energy Demand Growth, by Carrier

BASELINE SCENARIO: TOTAL FINAL ENERGY DEMAND GROWTH, BY CARRIER

	2010-2015 % growth pa	2015-2020 % growth pa	2020-2025 % growth pa	2025-2030 % growth pa
Electricity	-0.6	0.2	1.0	1.4
Gas	-2.8	-2.1	0.3	0.9
Petroleum	-0.7	-0.6	0.6	0.4
Solid / manufactured fuels	-1.6	-2.8	-1.1	0.3
Renewables	11.9	16.5	-3.2	-0.3
Total	-1.1	-0.2	0.3	0.7

Notes : Figures show annual average percentage growth rates.
Sources : DECC.

Table 3.5: Baseline Scenario: Final Energy Demand, by Sector

BASELINE SCENARIO: FINAL ENERGY DEMAND, BY SECTOR

	2010 GWh	2015 GWh	2020 GWh	2025 GWh	2030 GWh
Industry	331,269	342,234	344,383	337,443	335,122
Transport	647,675	657,396	668,789	677,691	696,210
Domestic	551,842	438,111	418,415	441,917	469,587
Public Administration	67,587	78,078	76,441	75,295	79,329
Commercial	139,328	123,479	114,906	117,036	130,697
Agriculture	10,501	10,699	10,815	10,932	11,048
Total	1,748,202	1,649,997	1,633,749	1,660,314	1,721,993

Sources : DECC.

Table 3.6: Baseline Scenario: Final Energy Demand Growth, by Sector

THE BASELINE SCENARIO: FINAL ENERGY DEMAND GROWTH BY SECTOR

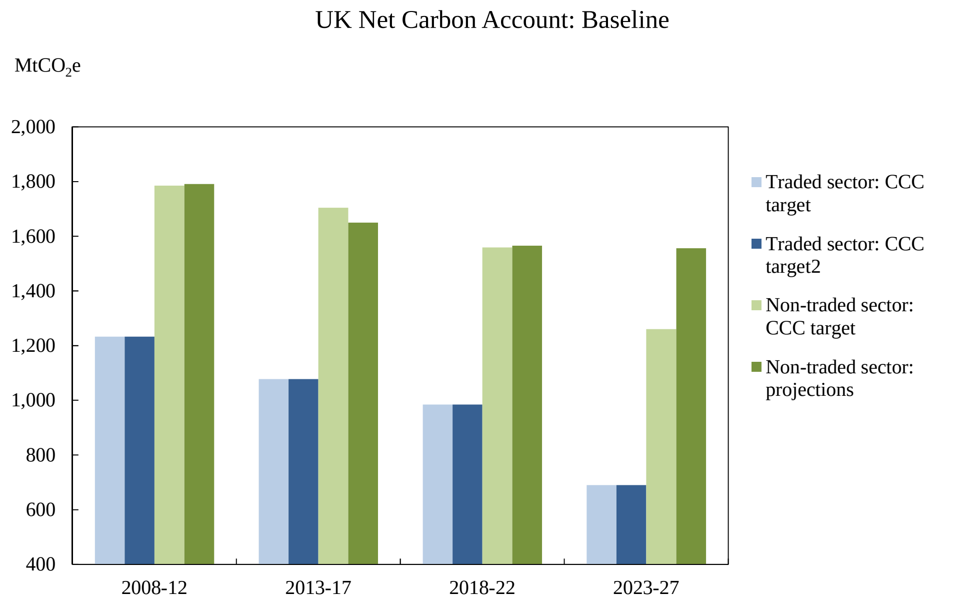
	2010-2015 % growth pa	2015-2020 % growth pa	2020-2025 % growth pa	2025-2030 % growth pa
Industry	0.7	0.1	-0.4	-0.1
Transport	0.3	0.3	0.3	0.5
Domestic	-4.5	-0.9	1.1	1.2
Public Administration	2.9	-0.4	-0.3	1.0
Commercial	-2.4	-1.4	0.4	2.2
Agriculture	0.4	0.2	0.2	0.2
Total	-1.1	-0.2	0.3	0.7

Notes : Figures show annual average percentage growth rates.
Sources : DECC.

The baseline energy projections imply that the fourth carbon budget will be missed

The DECC energy projections can be used to assess the net carbon account in future budget periods. The net carbon account has been calculated using DECC's energy inputs but CE's projection of non-CO_2 GHG emissions and non-energy CO_2 emissions. The projections suggest that the carbon budgets will be met in each of the first three periods, but missed in the fourth period, see Figure 3.1.

Figure 3.1: UK Net Carbon Account: Baseline



Source(*s*): DECC, NAEI, Cambridge Econometrics.

3.3 Energy efficiency investment scenario

How the energy efficiency scenario is constructed

This scenario considers the economic impacts of investing ETS auction and carbon floor price revenues from carbon policies into domestic energy efficiency, specifically focusing on fuel poor households.

To determine the number of households that can benefit from recycled carbon revenues, and the associated energy savings that can be realised, the level of investment required to get households out of fuel poverty is first estimated. For this purpose the UK housing stock was classified into archetypes based on the dwelling type (e.g. detached, semi-detached, terrace, flat), wall construction (solid, cavity) and heating fuel (gas, electricity). For each archetype, sub-archetypes were defined to cover a range of starting energy efficiency performance levels or SAP scores.

The modelled archetypes are representative of 98% of the total properties in the 2009 EHS dataset for which data on fuel poverty are available.

Technical modelling was carried out for each of the archetypes and sub-archetypes using SAP 2005 software, starting with a very poor SAP rating (EPC B and G) and incrementally adding suitable energy efficiency measures. The sequence of measures was optimised to ensure that the most cost-effective measures are installed first; although consideration was also given to the hassle factor of installing a measure.

The results from the technical modelling of key archetypes were then used to generate 'Cost Curves' based on the capital costs of the measures and the relative improvement that they make to the SAP score. The capital costs are based on the EST Housing Energy Model[22] and are the total installed costs for the measures.

Cost curves are then applied to each fuel poor household in the EHS data, taking into account its starting SAP score (corrected to take account of energy efficiency improvements due to ECO and other policy instruments) and the ‘Target SAP’ score, to work out the level of investment required.

Estimating the available revenues

For this study, two main sources of carbon revenues were analysed. These are the auctioning of carbon allowances under the EU ETS and the introduction in the UK of the Carbon Price Floor (CPF) mechanism, a policy setting a minimum cost of carbon which is due to come into force in the UK in 2013[23].

The key input parameters are summarised in Table 3.7.

Table 3.7: Key Input Parameters for Carbon Revenue Estimates

KEY INPUT PARAMETERS FOR CARBON REVENUE ESTIMATES		
Carbon price forecasts:		
Data Source	**Start Year**	**End Year**
DECC Projections (central)	2013	2027
Emission Trend Data:		
Sector	**Data set**	
Power Sector	DECC Annual Growth/Decline in Power Sector	
Other	DECC Annual Growth/Decline in Industrial Sector	

Based on these inputs, the total combined revenue from the EU ETS and CPF mechanism from 2013 to 2027 (the end of the fourth carbon budget) is projected to be £63.1bn in real terms. Of this, around £52.1bn (82%) is projected to be raised from the EU ETS and £11bn (18%) from the CPF.

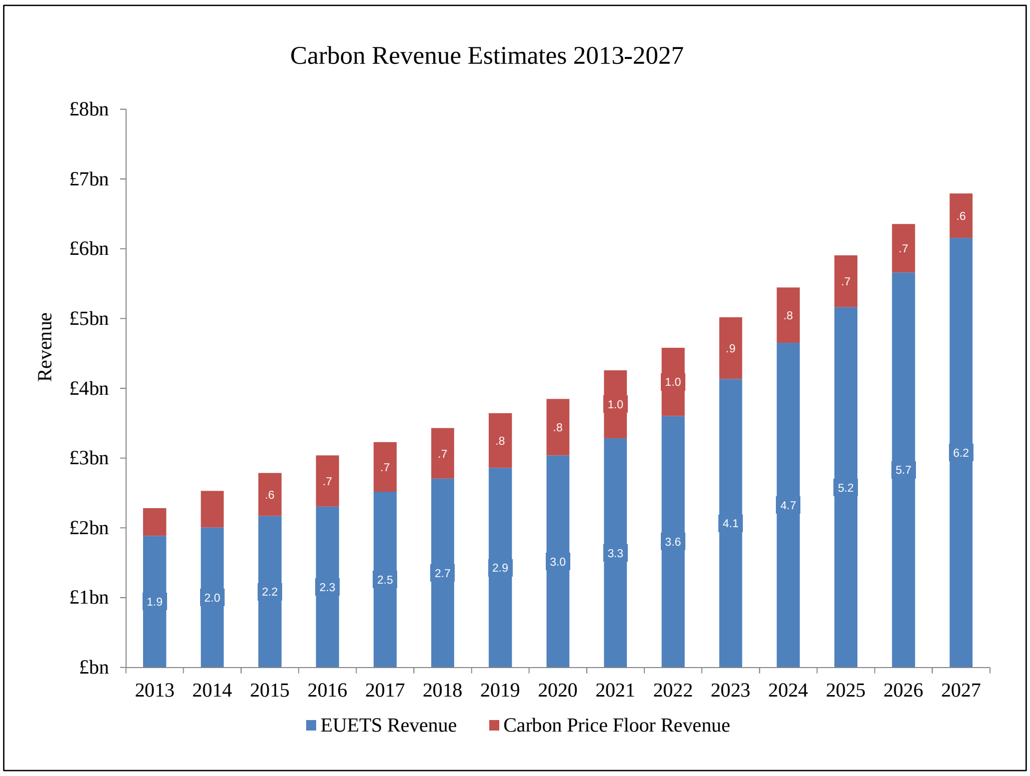
Annual calendar year revenues increase over the forecast period. Revenues begin at £2.3bn in 2013 and projected revenue for the final year, 2027, is £6.8bn.[24] Revenues are presented in real terms in Figure 3.2.

[22] EST Housing Energy Model assumptions: www.energysavingtrust.org.uk/uk/Publications2/Local-authorities/Strategy-development/The-Energy-Saving-Trust-Housing-Energy-Model-assumptions

[23] The CFP introduces a minimum cost of carbon for large electricity producers. A tax rate is set on top of the cost for an allowance under the EUETS. The carbon price will begin at £16/tCO_2 in 2013. It will rise by £2/tCO_2 per annum until 2020. From 2020-30 the price will increase by £4/tCO_2 per annum.

[24] It should be noted that market analysts do not forecast anticipated carbon prices much beyond 2020, the end of Phase III of the EU ETS and that the figures are government projections of anticipated prices.

Figure 3.2: Carbon Revenue Estimates 2013-2027



It is assumed that Phase IV of the EU ETS (2020-27) would not be subject to radical change in terms of present proposals for allowance auctioning (specifically with regards to sectors prone to carbon leakage) and in terms of sectors and emissions covered.

Generating energy consumption trends in the UK housing stock

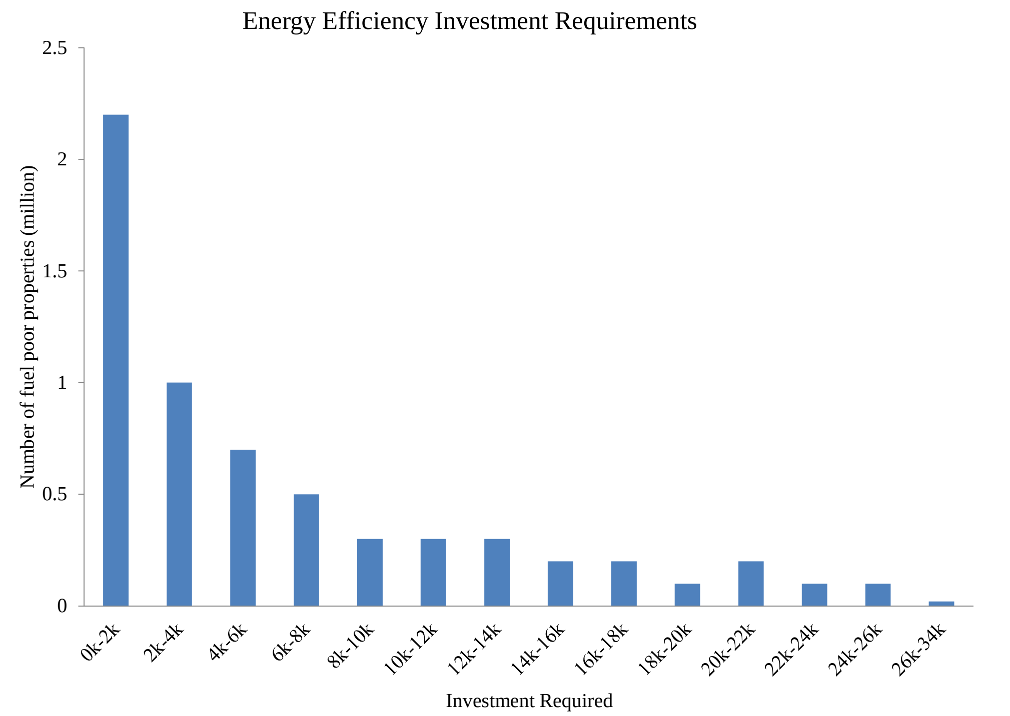
The distribution of investment across fuel poor homes required to improve the energy efficiency rating to the required SAP target is wide-ranging. Approximately 75% of homes in fuel poverty can be treated for less than £10,000, with an average cost of around £3,200. By contrast, the remaining 25% have an investment requirement between £10,000 and £36,000, which increases the average investment requirement across all fuel poor homes to £6,500. See Figure 3.3[25].

The analysis therefore assesses the impact of two scenarios for investing in energy efficiency:

- Energy Efficiency Investment: energy efficiency investment in fuel poor homes with investment requirements of less than £10,000 (EE-T) and no investment in the remaining 25% of homes
- Energy Efficiency Investment All: energy efficiency investment in all fuel poor homes (EE-All)

[25] See also Section 2.2 for further details.

Figure 3.3: Energy Efficiency Investment Requirements



Source: Energy Bill Revolution

In each of these scenarios, the investment cost is less than the carbon revenue available; around 35% of the available revenue is required to invest in the fuel poor homes which require less than £10,000, while nearly 95% of the revenue is required to invest in all fuel poor households. In each scenario, the investment cost was evenly spread across the time period, such that 35% of annual revenues are spent in the EE-T scenario, while 95% of annual revenues are spent in the EE-All scenario. In the case of the EE-T scenario, there is therefore considerable scope to invest earlier, by using all of the carbon revenue as it becomes available. There is therefore a third scenario:

- Energy Efficiency Investment Early Action: energy efficiency investment in fuel poor homes with investment requirements of less than £10,000 as the carbon revenue becomes available (EE-EA)

Table 3.8 shows the annual investment (for selected years) in each scenario, the number of households treated and the revenue available. The level of investment required to get households out of fuel poverty, and the carbon revenues available, is used to estimate the number of fuel poor homes that can be upgraded each year. As shown in Table 3.8, our analysis suggests that if all the carbon revenue was invested between 2013 and 2020 some 6.8m fuel poor homes could be removed from fuel poverty.

Table 3.8: Investment Requirements

INVESTMENT REQUIREMENTS				
	2015	2020	2025	2027
	£m	£m	£m	£m
Revenue Available	2,786.6	3,847.0	5,906.6	6,794.8
Households Treated	‘000s	‘000s	‘000s	‘000s
EE-T scenario	821.2	2,679.2	5,403.9	6,825.0
EE-All scenario	1,094.9	3,572.2	7,205.2	9,100.0
EE-EA scenario	2,375.4	6,825.0	6,825.0	6,825.0
Investment Required	£m	£m	£m	£m
EE-T scenario	963.4	1,330.0	2,042.0	2,349.1
EE-All scenario	2,617.7	3,613.8	5,548.5	6,382.8
EE-EA scenario	2,786.6	889.1	0.0	0.0
Investment Required (% of revenue)	%	%	%	%
EE-T scenario	35	35	35	35
EE-All scenario	94	94	94	94
EE-EA scenario	100	23	0	0

Sources : Own calculations.

The energy savings estimates were translated into MDM-E3 model inputs

The energy savings from the investment (as shown in Table 3.9), broken down by fuel type, were calculated as an input to the MDM-E3 model, using the figures generated on the average energy savings required in fuel poor households.

The (pre-measures) energy demand figures in the EHS dataset are based on modelled energy consumption as opposed to actual energy consumption. Therefore allowance was also made in the input data for comfort take. This is because fuel poor homes are more likely to under-heat their homes compared to modelled energy consumption levels (although actual energy spend is generally lower than that predicted by SAP methodology, particularly for older housing stock). Once energy efficiency measures are installed, the expected energy savings may therefore not be realised as fuel poor households can now afford to heat their homes more adequately. The proportion of energy savings from energy efficiency measures that are not realised as carbon savings due to households heating homes for longer or to a higher temperature is referred to as ‘comfort take’. Programmes such as CESP that are targeted at low income areas, where a higher proportion of fuel households live, allow for a 40% comfort take when predicting CO_2 savings. A similar comfort take factor was used for the purpose of this analysis.

The energy savings and investment were translated into inputs suitable for the MDM-E3 model and are shown in Table 3.9. The scale of the exogenous energy savings increases each year in relation to the baseline scenario and, by 2027, the additional energy savings in the central energy efficiency scenario (EE-T) is equivalent to 5.5% of total household final energy demand in the baseline.

Table 3.9: Household Energy Savings

HOUSEHOLD ENERGY SAVINGS				
Energy Efficiency Investment (EE-T)	2015	2020	2025	2027
Levels	GWh	GWh	GWh	GWh
Electricity savings	270.8	968.1	2,124.0	2,840.1
Gas savings	2,495.4	7,816.3	16,522.3	21,243.4
Total energy savings	2,766.2	8,784.4	18,646.3	24,083.5
Compared to baseline	%	%	%	%
Electricity savings	0.3%	1.0%	2.1%	2.7%
Gas savings	0.8%	2.5%	5.1%	6.4%
Total energy savings	0.7%	2.2%	4.4%	5.5%
Energy Efficiency Investment in All Fuel Poor Households (EE-All)	2015	2020	2025	2027
Levels	GWh	GWh	GWh	GWh
Electricity savings	383.9	1,372.8	3,012.4	4,024.8
Gas savings	3,372.9	10,571.1	22,370.8	28,741.9
Total energy savings	3,756.8	11,943.9	25,383.2	32,766.7
Compared to baseline	%	%	%	%
Electricity savings	0.4	1.5	3.0	3.8
Gas savings	1.0	3.4	6.9	8.7
Total energy savings	0.9	3.0	6.0	7.5
Energy Efficiency Investment – Early Action (EE-EA)	2015	2020	2025	2027
Levels	GWh	GWh	GWh	GWh
Electricity savings	784.7	2,465.9	2,465.9	2,465.9
Gas savings	7,198.4	19,903.2	19,903.2	19,903.2
Total energy savings	7,983.1	22,369.1	22,369.1	22,369.1
Compared to baseline	%	%	%	%
Electricity savings	0.8	2.7	2.5	2.3
Gas savings	2.2	6.4	6.1	6.0
Total energy savings	1.9	5.6	5.3	5.1

Sources : Own calculations.

3.4 Comparative scenarios

The government spending scenario

The government spending scenario (G) incorporates £63.1bn additional government final consumption over the years 2013-27, compared to the baseline. The MDM-E3 model includes four government spending sectors; public administration/defence, education, health and care/social work. These sectors typically have high employment ratios, so results from this scenario would be expected to have a large positive effect on employment. However, this might be partly offset by the relatively high wages in these sectors compared to the construction sector.

As expenditure on domestic services accounts for the largest part of government consumption, it is expected that the expenditure would have little impact on import demand.

The additional government spending was set to be equal to the investment requirement in the energy efficiency scenarios and was split so that each of the government sectors received the same proportional increase in expenditure. Table 3.10 shows that the additional spending in the scenario in 2027 was approximately 0.6% higher than total government expenditure in the baseline.

Table 3.10: Government Spending Scenario Overview

GOVERNMENT SPENDING SCENARIO OVERVIEW

	2010 £m	2015 £m	2020 £m	2025 £m	2027 £m
Baseline spending	320,054	298,319	315,904	352,974	369,250
Additional spending	0	963	1,330	2,042	2,349
Total spending in scenario	320,054	299,282	317,234	355,016	371,599

Notes : Figures show annual government spending in baseline and scenario, 2008 prices.
Sources : OBR and own calculations.

The government investment scenario

The government investment scenario was selected as a comparison scenario for all three energy efficiency scenarios, such that in each set of scenarios the investment is equivalent. Table 3.10 shows the difference in investment for each of the three government investment scenarios:

- government investment to match EE-T scenario (GK-T)
- government investment to match EE-All scenario (GK-All)
- government investment to match EE-EA scenario (GK-EA)

The central government investment scenario (GK-T) includes approximately £0.8-2.4bn pa extra government investment in the public administration, education and health sectors in addition to that in the baseline scenario. The extra investment in 2027 is approximately equal to 6.2% of government investment in the baseline. It is possible that the extra government investment will lead to an increase in output and employment in the construction and engineering sectors, as a result of large-scale building projects undertaken by the government as part of their investment programme.

The investment in the GK-All scenario is much higher, reflecting the higher investment requirements of EE-All to which the scenario is matched. By contrast, investment in the equivalent early action government investment scenario is low in 2020 (the final year of energy efficiency investment) and zero in the years to follow.

Table 3.11: Government Investment Scenarios Overview

GOVERNMENT INVESTMENT SCENARIOS OVERVIEW	2010 £m	2015 £m	2020 £m	2025 £m	2027 £m
Baseline investment	32,507.7	26,048.8	33,722.3	36,682.4	37,942.0
GK-T scenario					
Additional investment	0.0	963.8	1,330	2,042.2	2349.7
Total investment in scenario	32,507.7	27,012.6	35,052.3	38,724.6	40,291.7
GK-ALL scenario					
Additional investment	0.0	2,618.1	3,613.9	5,548.7	6383.3
Total investment in scenario	32,507.7	28,666.9	37,336.2	42,231.1	44,325.3
GK-EA scenario					
Additional investment	0.0	2,787	889.2	0.0	0.0
Total investment in scenario	32,507.7	28,835.8	34,611.5	36,682.6	37,942.6

Notes : Figures show annual government investment in baseline and scenario, 2008 prices.
Sources : OBR and own calculations.

The VAT reduction scenario

For the VAT reduction scenario, the funding used for energy efficiency investment in the EE scenario is used to pay for a reduction in the standard rate of VAT. By 2020 this translates to a VAT rate of approximately 19.8% which, following the profile of expected carbon revenues, falls to around 19.7% by 2022 through to 2027. This scenario would be expected to reduce consumer prices and therefore increase household expenditure.

The administrative costs and political will associated with changing the rate of VAT on an annual basis to the rates shown in Table 3.12 (e.g.19.7%) undermines the plausibility of this scenario as a real world policy option, but the results still provide a sensible comparison to the other scenarios.

Table 3.12: VAT Reduction Scenario Overview

VAT REDUCTION SCENARIO OVERVIEW					
	2010	2015	2020	2025	2027
	%	%	%	%	%
VAT rate in baseline	17.5	20.0	20.0	20.0	20.0
VAT rate in scenario	17.5	19.8	19.8	19.7	19.7
	£ m	£ m	£ m	£ m	£ m
VAT revenue in baseline	95,964	128,182	162,324	205,412	226,596
VAT revenue in scenario	95,964	126,967	160,503	202,240	222,778

Notes : Figures showing VAT revenue are in nominal prices.
Sources : Cambridge Econometrics.

The fuel duty reduction scenario

In the fuel duty reduction scenario, the stimulus money is used to reduce the level of fuel duty on diesel and petrol used by road transport. Although reducing the rate of fuel duty will increase the demand for diesel and petrol, overall this would lead to additional revenue to spend on other items, and a reduction in business costs should increase UK competitiveness. This might be partially offset by increases in imports of crude oil.

Table 3.13: Fuel Duty Reduction Scenario Overview

FUEL DUTY REDUCTION SCENARIO OVERVIEW					
	2010	2015	2020	2025	2027
	pence/litre	pence/litre	pence/litre	pence/litre	pence/litre
Fuel duty rate in baseline	60.0	71.1	87.5	105.1	114.0
Fuel duty rate in scenario	60.0	67.7	81.7	95.0	101.5
	£m	£m	£m	£m	£m
Fuel duty revenue in baseline	27,013	30,788	36,320	44,411	47,981
Fuel duty revenue in scenario	27,013	29,575	34,518	41,173	44,018

Notes : Figures showing fuel duty revenue are in nominal prices, fuel duty rate in pence/litre.
Sources : Cambridge Econometrics.

3.5 Sensitivity Analysis on the Direct Rebound Effect

The direct rebound effect from comfort-taking in the central EE-T scenario is assumed to be 40%, which is in line with central estimates from the literature (see Section 3.3). For some cases, and particularly fuel poor homes, it is argued that the direct rebound effect could be even higher, perhaps 60% or even 80%.

There are four sensitivities to assess the impact of the direct rebound effect on the macroeconomic results, these are:

- 0% direct rebound effect (EE-0)
- 20% direct rebound effect (EE-20)
- 60% direct rebound effect (EE-60)
- 80% direct rebound effect (EE-80)

The energy saving inputs for each MDM-E3 scenario are described in Table 3.14 alongside the central energy savings for the EE-T scenario that includes a 40% direct rebound effect.

Table 3.14: Household Energy Savings for the Direct Rebound Effect Sensitivity Analysis

HOUSEHOLD ENERGY SAVINGS FOR THE DIRECT REBOUND EFFECT SENSITIVITY ANALYSIS

	2015	2020	2025	2027
Levels	GWh	GWh	GWh	GWh
Total energy saving (EE-T)	2,766.2	8,784.4	18,646.3	24,083.5
Total energy saving (EE-0)	4,605.9	14,634.6	31,080.9	40,127.9
Total energy saving (EE-20)	3,684.7	11,707.7	24,864.7	32,102.3
Total energy saving (EE-60)	1,842.3	5,853.8	12,432.3	16,051.1
Total energy saving (EE-80)	921.2	2,927.0	6,216.2	8,025.6
Compared to baseline	%	%	%	%
Total energy saving (EE-T)	0.7	2.2	4.4	5.5
Total energy saving (EE-0)	1.1	3.6	7.3	9.2
Total energy saving (EE-20)	0.9	2.9	5.9	7.4
Total energy saving (EE-60)	0.4	1.5	2.9	3.7
Total energy saving (EE-80)	0.2	0.7	1.5	1.8

Sources : Own calculations.

4 Results

4.1 Key findings

The EE scenario increases GDP, reduces CO_2 emissions and alleviates fuel poverty

The key findings can be summarised as follows:

- Of the main scenarios (see below), the central energy efficiency scenario (EE-T) has the largest positive impact on GDP, relative to the baseline. This is because in addition to the investment or spending stimulus, there is reduction in the nation's net imports through a shift from imported energy to domestically produced goods and services.
- All of the stimulus scenarios lead to a modest increase in GDP, the investment scenarios (GK-T and EE-T) boost demand for the construction sector (and its associated supply chain), while in the government spending scenario (G) the demand for government services increases; the reduction in taxes (fuel duty or VAT) improve UK cost competitiveness (as businesses have lower energy costs) and lead to increases in consumer spending.
- The EE-T scenario leads to a reduction in household energy bills: around 6.8m homes are removed from fuel poverty by 2027 with an average reduction in fuel bill of £212 pa (after rebound effects). The more ambitious energy efficiency scenario would result in fuel poverty being eliminated from 87% of the population.
- Around 52,000 jobs could be created by 2027 in the EE-T scenario compared to the baseline, around 13,500 more than the GK-T scenario. Around 130,000 jobs could be created in the more ambitious energy efficiency scenario (EE-All), roughly 24,000 more than the government investment scenario (GK-All).
- In the EE-All scenario whereby all fuel poor households receive an investment stimulus, the economic stimulus is greatest, but it has similar GDP results to general government investment of an equivalent amount. This is because of diminishing returns and the reduced efficiency gains of each additional pound spent compared to the EE-All scenario.
- The early action scenario suggests that 75% of households in fuel poverty in the baseline could be removed from fuel poverty by 2020, and that the investment would yield a higher return to UK GDP than using the funds for the other stimulus options, including general government investment.

Overview of key scenarios

This chapter presents the outcomes of the economic modelling in MDM-E3 and provides a comparison of the five main scenarios, compared to each other and to the baseline (B):

- the energy efficiency investment scenario (EE-T)
- the government spending scenario (G)
- the government capital spending scenario (GK-T)
- the VAT reduction scenario (VAT)
- the fuel duty reduction scenario (Fuel)

Comparisons between the scenarios are made in Section 4.2 and Section 4.3, while Section 4.4 gives a specific analysis of the employment results.

In Section 4.5, we provide a discussion of the results for the early action scenarios:

- the energy efficiency early action scenario (EE-EA)

- the equivalent 'early action' government investment scenario (GK-EA)

The remaining sections of the chapter discuss the impact of energy efficiency investment on energy demand and emissions; the economic results in England, Scotland, Wales and Northern Ireland; the potential for an impact on healthcare costs, and the results of the sensitivity analysis on different rates of comfort taking.

4.2 The impact of energy efficiency investment compared to general government investment

The scenario in which all households are lifted from fuel poverty has the most positive result from GDP, but this is because the investment stimulus is larger than in the central scenarios (i.e. there are less revenues left over to spend on other activities). Furthermore, as Table 4.1 shows, there is little difference in results between the scenarios in which the investment is used for energy efficiency and the scenario in which it is used for general government investment, particularly in the short term.

Table 4.1: GDP and Expenditure Components, 2015

GDP AND EXPENDITURE COMPONENTS, 2015

	EE-T	GK-T	EE-All	GK-All
	%	%	%	%
GDP	0.08	0.08	0.20	0.21
Consumption	0.03	0.03	0.08	0.07
Investment	0.40	0.40	1.07	1.13
Exports	0.01	0.01	0.01	0.02
Imports	0.04	0.05	0.13	0.14
Government Spending	0.00	0.00	0.00	0.00

Notes : 2008 prices. Scenario results are presented as percentage difference from baseline.
Sources : OBR and MDM-E3 calculations.

Table 4.2: Employment, 2015

EMPLOYMENT, 2015

	EE-T	GK-T	EE-All	GK-All
	'000s	'000s	'000s	'000s
	Difference from baseline			
Employment	26.6	23.6	71	64.5

Notes : Scenario results are presented as absolute difference from baseline.
Sources : OBR and MDM-E3 calculations.

The increased spending can lead to quite large increases in employment. The demand-side stimulus (GK-All) could create around 65,000 jobs. The EE-All scenario could create a further 6,000-7,000 jobs, as a result of increased spending power for consumers.

In the longer term, as the efficiency impact accumulates with each annual investment in energy saving measures, the impact on GDP in the EE scenarios increases relative to the equivalent standard government investment. This is a direct result of increasing efficiency in the economy and reducing household spending on imported fuel.

Table 4.3: GDP and Expenditure Components, 2027

GDP AND EXPENDITURE COMPONENTS, 2027

	EE-T	GK-T	EE-All	GK-All
	%	%	%	%
GDP	0.16	0.13	0.38	0.36
Consumption	0.08	0.06	0.20	0.17
Investment	0.62	0.57	1.60	1.54
Exports	0.00	0.03	0.01	0.09
Imports	0.09	0.12	0.28	0.32
Government Spending	0.00	0.00	0.00	0.00

Notes : 2008 prices. Scenario results are presented as percentage difference from baseline.
Sources : OBR and MDM-E3 calculations.

As a result of the increasing impact of the efficiency, employment also increases with an extra 129,400 jobs in 2027 compared to 105,200 in the traditional government investment scenario. The difference between the two of 24,200 is due to the permanent improvement in the energy efficiency of UK homes resulting in lower needs to import gas (and hence permanently higher GDP).

Table 4.4: Employment, 2027

EMPLOYMENT, 2027

	EE-T	GK-T	EE-All	GK-All
	'000s	'000s	'000s	'000s
	Difference from baseline			
Employment	52.0	38.5	129.4	105.2

Notes : Scenario results are presented as absolute difference from baseline.
Sources : OBR and MDM-E3 calculations.

The targeted energy efficiency scenario does relatively better (compared to the equivalent government investment scenario) than the scenario in which all fuel poor households receive the investment required to bring them out of fuel poverty. The reason for this is that the costs to bring the final 25% of homes out of fuel poverty are very high and result in relatively less savings (and reductions in fuel imports).

Indeed, from a microeconomic perspective, it might be deemed too expensive to invest over £10,000 in homes for energy bill reductions of £200-£300 per annum. A simple cost benefit analysis would suggest that these measures would be too expensive and that other investment options might be preferable. However, there are still arguments in favour of this additional investment, such as social equality factors (improvements in quality of life and health), energy security concerns, and legal bounds to constrain carbon emissions. Even capped investment, however, would reduce the energy bill burden of fuel poor homes.

4.3 A comparison against other fiscal stimulus options

Macroeconomic results

The five scenarios all have a modest positive impact on GDP, as a result of the stimulus from the extra funding (see Table 4.1) since any reduction in GDP caused by the carbon price is captured in the baseline. However, the mechanisms through which the increases in GDP come about vary substantially between the scenarios.

In the EE and GK scenarios, the primary driver is through higher investment (in energy efficiency and government services), while the VAT and fuel duty scenarios mainly boost household consumption. The G scenario increases final government expenditure. All of these lead to an increase in jobs (see Table 4.2) and boosts to household incomes, leading to a further increase in consumption and investment.

The key difference is in the change of imports. In all scenarios there is an increase in imports, due to an increase in imports of consumer products. However, in the energy efficiency scenario this is somewhat offset by reduced imports of fossil fuels; higher rates of energy efficiency thus lead to a better outcome for overall GDP.

The results for employment in Table 4.2 reflect this pattern. The investment scenarios generally lead to higher increases in employment (and corresponding reductions in unemployment, as labour supply is assumed as constant), because of the large share of manual labour in the investment sectors. The investment scenarios have a greater impact on employment because the jobs created in construction are comparatively lower paid than jobs created in health and education, with employment increasing by 26,600 jobs in 2015 in the energy efficiency investment scenario.

Table 4.5: GDP and Expenditure Components, 2015

GDP AND EXPENDITURE COMPONENTS, 2015

	EE-T	G	GK-T	VAT	FUEL
	%	%	%	%	%
					Difference from base
GDP	0.08	0.06	0.08	0.05	0.05
Consumption	0.03	0.02	0.03	0.08	0.08
Investment	0.40	0.03	0.40	0.04	0.03
Exports	0.01	0.00	0.01	0.00	0.01
Imports	0.04	0.04	0.05	0.03	0.03
Government Spending	0.00	0.32	0.00	0.00	0.00

Notes : 2008 prices. Scenario results are presented as percentage difference from baseline.
Sources : OBR and MDM-E3 calculations.

Table 4.6: Employment, 2015

EMPLOYMENT, 2015					
	EE-T	G	GK-T	VAT	FUEL
	'000s	'000s	'000s	'000s	'000s
	Difference from base				
Employment	26.6	10.2	23.6	6.9	2.8

Notes : Scenario results are presented as absolute difference from baseline.
Sources : OBR and MDM-E3 calculations.

The modelled increase in employment compares consistently to other energy efficiency investment programmes. In 2009 the German KfW eco-refurbishment programme stimulated nearly €8bn of private and public sector investment in energy efficiency building, leading to 128,000 jobs. This is similar to our finding that around £1bn of investment in 2015 would stimulate 26,600 jobs in the EE-T scenario, while £2.6bn of investment would stimulate 71,000 jobs in the EE-All scenario.

In the longer term the macroeconomic results for each of the government spending and investment scenarios are broadly similar, and result in an estimated 0.12% increase in annual GDP (by 2027) compared to the baseline, but the energy efficiency scenario increases GDP more (comparatively) because of the efficiency savings. This is also reflected in the long-term employment impact. The macroeconomic results of the VAT and Fuel Duty scenarios are slightly worse, since they lead to bigger increases in imports than the other scenarios.

Table 4.7: GDP and Expenditure Components, 2027

GDP AND EXPENDITURE COMPONENTS, 2027					
	EE-T	G	GK-T	VAT	Fuel
	%	%	%	%	%
			Difference from base		
GDP	0.16	0.12	0.13	0.11	0.10
Consumption	0.08	0.06	0.06	0.22	0.21
Investment	0.62	0.06	0.57	0.09	0.10
Exports	0.00	0.00	0.03	0.02	0.03
Imports	0.09	0.10	0.12	0.12	0.15
Government Spending	0.00	0.64	0.00	0.00	0.00

Notes : 2008 prices. Scenario results are presented as percentage difference from baseline.
Sources : OBR and MDM-E3 calculations.

Table 4.8: Employment, 2027

EMPLOYMENT, 2027					
	EE-T	G	GK-T	VAT	Fuel
	'000s	'000s	'000s	'000s	'000s
	Difference from base				
Employment	52	25.4	38.5	19.2	18

Notes : Scenario results are presented as absolute difference from baseline.
Sources : OBR and MDM-E3 calculations.

Sectoral results

The fiscal stimulus has a small positive impact on industry output for almost all sectors in each of the five scenarios.

In the government spending scenario (G), output in the government services sector increases as a result of the direct increase in expenditure in this area. However, output in the other sectors is largely unaffected by the additional spending.

Gross output in the construction sector increases by 0.5% of GDP relative to the baseline in the EE-T scenario as a result of the investment stimulus. The impact is also evident in the employment figures. Employment in the construction sector increases by 13,000 and 18,000 in the GK-T and EE-T scenarios respectively (in 2015).

Table 4.9: Gross Output by Broad Sector, 2015

GROSS OUTPUT BY BROAD SECTOR, 2015					
	EE-T	G	GK-T	VAT	Fuel
	%	%	%	%	%
Agriculture	0.03	0.00	0.01	0.06	0.06
Mining & quarrying	0.02	0.00	0.03	0.01	0.01
Manufacturing	0.06	0.02	0.10	0.04	0.04
Utilities	-0.11	0.04	0.05	0.07	0.05
Construction	0.51	0.04	0.41	0.05	0.03
Distribution	0.05	0.02	0.05	0.05	0.04
Transport & storage	0.05	0.03	0.05	0.05	0.04
Hotels & catering	0.05	0.02	0.03	0.07	0.05
Communications	0.04	0.04	0.07	0.03	0.02
Business services	0.06	0.03	0.06	0.05	0.03
Government services	0.02	0.23	0.01	0.02	0.01
Other services	0.03	0.04	0.02	0.04	0.02

Notes : Scenario results are presented as percentage difference from baseline.
Sources : MDM-E3 model calculations.

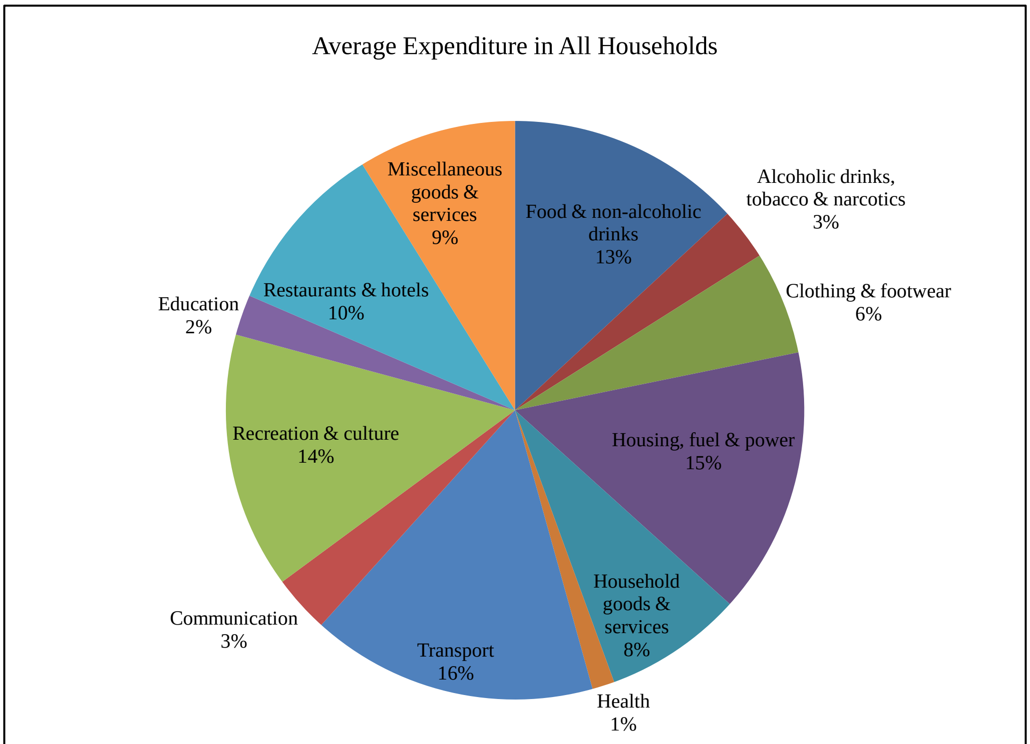
The knock-on effect of the increase in output in the construction sector is an increase in output and value added in the manufacturing sectors of 0.1%, as demand for building materials and energy efficient products increases. In the energy efficiency scenario, there is a small decline of 0.1% in output in the utilities sector, as a consequence of the large reduction in energy demand.

The main difference between the energy efficiency scenario and the government investment scenario is the reduction in consumer spending on gas as a result of the energy efficiency investment. For every £1 spent on gas, around 4p is collected through net taxes (VAT receipts), around 12p is spent on labour in the gas supply sector, 46p is spent on material and services consumed by the gas supply sector (i.e. is allocated to other sectors) and around 38p is spent on gas which, at the margin, is imported.

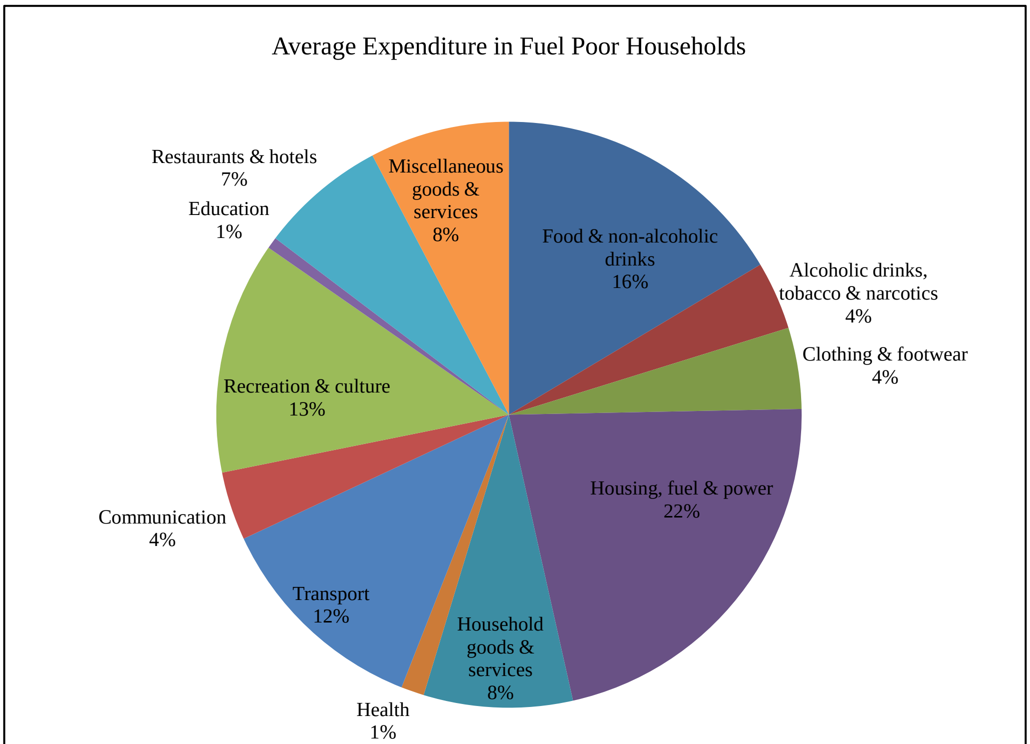
Consumer spending

Consumer spending varies across income groups. Since this analysis focuses on the impact of reducing energy expenditure in fuel poor households this allows additional expenditure on other items. The impacts on consumer spending increases were tailored in the energy efficiency investment scenarios to reflect the spending patterns of the two poorest income quintiles (which we take as a proxy for fuel poor homes). See Figure 4.1.

Figure 4.1: Spending Patterns



Source: ONS, Family Spending 2010



Source: ONS, Family Spending 2010

4.4 The impact of energy efficiency investment on jobs

Many studies claim large impacts of investment programmes on jobs. This section of the report discusses the employment findings in this study and why these might differ to engineering or 'bottom-up' based studies.

Definitions used in jobs figures

The following five terms are often used to describe the various types of job estimates:

- direct jobs: these are the jobs created with a policy intervention
- indirect jobs: these are the jobs created as a result of the multiplier effects of the policy intervention
- induced jobs: these are the jobs induced from the other impacts of the behaviour change induced by a policy intervention
- whole economy jobs: this term describes all the jobs created in the economy (direct, indirect and induced) as a result of the investment, including any that arise from other effects that are triggered from the investment, for example, an increase in competitiveness
- net jobs: this term describes the difference in jobs that is created as a result of taking up one investment option rather than another

The increase in jobs described in this report is for the whole economy. By comparing the jobs created by investing in energy efficiency to other equivalent stimulus measures (as represented by the other scenarios), we can determine the 'net jobs' associated with the energy efficiency investment programme.

In the Energy Bill Revolution Campaign Report[26], it was suggested that between 30,000 and 50,000 (annual FTE) direct jobs could be created through the investment of between £2.3bn pa and £6.2bn pa (2013-27) with a further 90,000 to 150,000 indirect jobs. The direct jobs were calculated by assessing the number of person days required for each measure installed as a result of the investment.

By contrast, in the comparable EE-All scenario around 130,000 whole economy jobs could be created by 2027. Based on the results of the equivalent government investment it is possible to attribute about 105,000 of the jobs to the investment stimulus and around 25,000 jobs to the impact of reducing consumer spending on gas, and increasing consumer spending on other items. The job estimates of the top-down approach encompassed in the economic modelling use average wages and relationships between industrial output and industrial employment to calculate employment increases. It could be argued that the top-down methodology understates employment in the construction sector, since the installation of energy efficiency measures might be more labour intensive in that sector than as a whole. However, the similarity between the overall jobs numbers from two very different analytical methods reinforces the robustness of this result.

It is worth noting that the jobs accruing from the investment stimulus are transitory and would not be maintained once the investment programme came to an end, but, the extra jobs created as a shift in consumer spending would persist. However, if this investment were coupled with additional stimulus building on Green Deal, the construction stimulus could persist for some time.

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[26] Energy Bill Revolution Campaign Report, Camco. See: http://www.energybillrevolution.org/wp-content/uploads/2012/02/Energy-Bill-Revolution_full-report.pdf

The whole economy jobs figure presented for the EE-T is lower (52,000), because the investment requirement is considerably less (see Table 4.8).

Although this is a top-down macroeconomic assessment, the initial inputs are similar to those presented in the report to the Energy Bill Revolution Campaign Report. Table 4.10 presents a breakdown of the direct jobs associated with this type of investment.

Table 4.10: Breakdown of Direct Jobs by Investment Measure

BREAKDOWN OF DIRECT JOBS BY INVESTMENT MEASURE	
Type of measure	% of direct jobs
Cavity wall insulation	6.2
Loft insulation	7.2
Internal insulation	8.3
External insulation	3.7
Floor insulation	6.3
Insulated doors	2.1
Primary pipework insulation	4.3
Double glazing	26.7
Triple glazing	1.9
Reduced infiltration measures	9.5
Draught proofing	2.2
Low energy light bulbs	0.7
Heating controls	3.8
Foam insulated DHW cylinder	8.3
Condensing boiler replacement (gas)	7.8
Heat Pump	1.0

Sources : Report to the Energy Bill Revolution and own calculations.

4.5 The impact of early action

The early action scenario brings forward investment into fuel poor homes as the carbon revenue is made available (rather than only using 35% of it each year, as reflected in the central scenarios). The impact on the economy by 2020 is more relevant for this scenario since all the investment is undertaken, and annual energy savings realised, by 2020.

The results for employment and GDP suggest that early action would be more beneficial to the economy (than the EE-T scenario) by 2020 since the energy efficiency savings are realised sooner, and that energy efficiency investment still yields higher returns to general government investment. Moreover, this course of action would remove 75% of homes (6.8m) from fuel poverty by 2020.

Table 4.11: GDP and Expenditure Components, 2020

GDP AND EXPENDITURE COMPONENTS, 2020		
	EE-EA	GK-EA
	%	%
GDP	0.16	0.11
Consumption	0.15	0.12
Investment	0.42	0.34
Exports	0.01	0.02
Imports	0.07	0.13
Government Spending	0.00	0.00

Notes : 2008 prices. Scenario results are presented as percentage difference from baseline.
Sources : OBR and MDM-E3 calculations.

Table 4.12: Employment, 2020

EMPLOYMENT, 2020		
	EE-EA	GK-EA
	'000s	'000s
Employment	67.0	46.1

Notes : Scenario results are presented as absolute difference from baseline.
Sources : OBR and MDM-E3 calculations.

4.6 The impact of efficiency investment on fuel bills and emissions

Household energy demand is reduced by 5.4% by 2027

By the last year of the annual investment programmes (2027), household energy demand across all UK households is reduced by around 5.4% in the EE-T scenario compared with the baseline, with a larger relative fall in gas consumption among the fuel poor households that are treated. By 2027, there is an average energy bill saving of 12%, when compared to the baseline.

Table 4.13: Household Energy Demand, 2027

HOUSEHOLD ENERGY DEMAND, 2027			
	B	EE-T	2027
	GWh	GWh	% diff
Electricity	106,468.4	103,917.2	-2.4
Gas	329,596.1	308,509.2	-6.4
Total	436,064.5	412,426.4	-5.4

Sources : DECC and own calculations.

Energy bills fall substantially as a result of the energy efficiency investment

The reduction in energy consumption drives the economic results. After the energy efficiency measures have been installed, annual household energy expenditure is reduced by around £1.4bn in 2008 prices. This translates to an average annual saving of £212 (2008 prices) for each of the 6.8m households lifted out of fuel poverty. However, that saving is after the rebound effect. Overall, the energy efficiency measures deliver energy bill savings of £350 pa (2008 prices), but we assume that households will spend some 40% of this on increased comfort through heating (warmth). Table 4.14 shows how this assumption affects fuel bills.

Table 4.14: Average Fuel Bill Savings in Treated Households, 2027

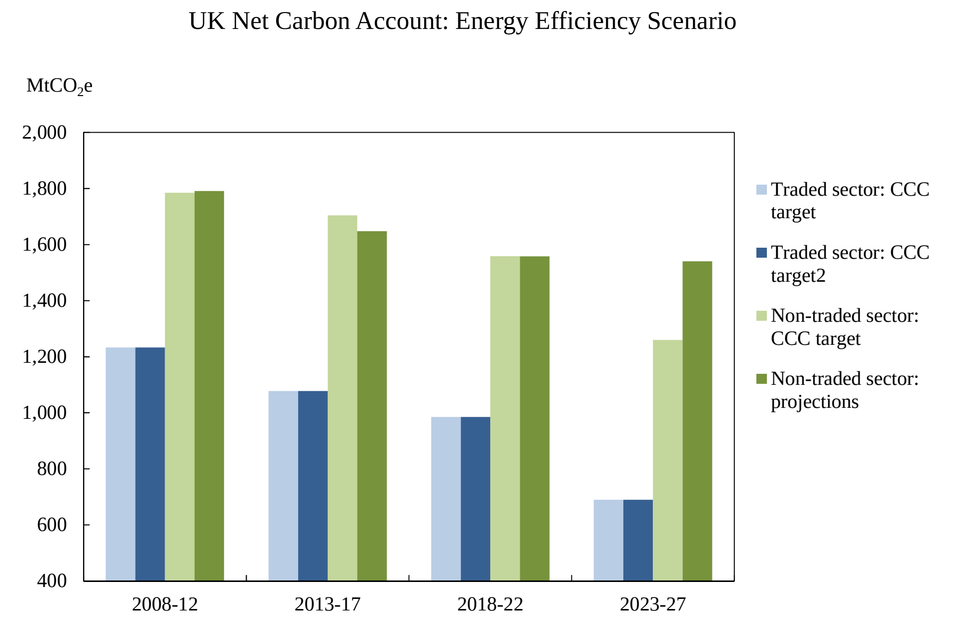
AVERAGE FUEL BILL SAVINGS IN TREATED HOUSEHOLDS, 2027						
	EE-T	EE-All	EE-0	EE-20	EE-60	EE-80
	£'s	£'s	£'s	£'s	£'s	£'s
Average savings (nominal)	349	356	577	464	233	116
Average savings (2008 prices)	212	216	350	282	141	70

Notes : Nominal prices. Scenario results are presented as absolute difference from baseline.
Sources : MDM-E3 model calculations.

CO_2 emissions

CO_2 emissions are reduced in the energy efficiency scenario, driven mainly by reductions in the consumption of natural gas in households. In total, UK CO_2 emissions (gross of EU ETS emissions trading) are reduced by 1.1%, and household emissions are reduced by around 5.6% by 2027. The overall impact on the net carbon account is therefore modest, and the reduction is not sufficient to meet the fourth carbon budget (see Figure 4.2).

Figure 4.2: UK Net Carbon Account: Energy Efficiency Scenario



Source(s): DECC, NAEI, Cambridge Econometrics.

4.7 The impacts in the Devolved Administrations

The MDM-E3 model has a regional component and so impacts on the economies of Devolved Administrations in the UK can be considered. However, the bottom-up technology analysis feeding into the MDM-E3 model, which considers the number of fuel poor households requiring investment, the investment required and the resulting energy savings, is undertaken at the UK aggregate level. Therefore these results simply reflect the sector composition of the different devolved administrations. In most of the scenarios the distribution of impacts is relatively evenly distributed (see Table 4.15). However, the government spending scenario reflects the larger share of government services in total value added in Wales, Northern Ireland and to a lesser extent Scotland, compared to England. The table highlights results for EE-T in 2015. In this scenario and in this year all the proceeds for carbon taxes are being spent on alleviation of fuel poor homes where costs are less than £10,000 per home.

Table 4.15: Total Value Added by Devolved Administration, 2015

TOTAL VALUE ADDED BY DEVOLVED ADMINISTRATION, 2015

	EE-T	G	GK-T	VAT	Fuel
	%	%	%	%	%
	difference from baseline				
England	0.08	0.07	0.08	0.04	0.03
Wales	0.08	0.09	0.08	0.04	0.03
Scotland	0.08	0.08	0.08	0.04	0.03
Northern Ireland	0.08	0.09	0.08	0.04	0.03
UK total	0.08	0.07	0.08	0.04	0.03

Sources : Own calculations.

A similar pattern emerges for employment, with very little regional variation in each scenario. The small differences reflect the variations in labour productivity in the regions.

Table 4.16: Employment by Devolved Administration, 2015

EMPLOYMENT BY DEVOLVED ADMINISTRATION, 2015

	EE-T	G	GK-T	VAT	Fuel
	%	%	%	%	%
	difference from baseline				
England	0.08	0.03	0.07	0.02	0.01
Wales	0.09	0.04	0.08	0.02	0.01
Scotland	0.08	0.03	0.07	0.02	0.01
Northern Ireland	0.09	0.04	0.07	0.02	0.01
UK total	0.08	0.03	0.07	0.02	0.01

Sources : Own calculations.

4.8 The impact of improved energy efficiency on health

A cold home can be very damaging to the physical and mental health of its occupants, and the association between poor housing and ill health is now well established. Older people, children and disabled people are particularly vulnerable to the risk of health problems as a result of living in fuel poverty. In this section of the report, the cost to society of fuel poverty and cold homes is considered in terms of the impact on utility, wellbeing and health, as well as the impact on National Health Service (NHS) costs.

The impact of energy efficiency savings on wellbeing and health outcomes has not been quantified due to the inherent difficulty in measuring these variables. However, it is likely that health outcomes would improve considerably due to improved levels of comfort; either as a direct result of the efficiency improvements, or through additional comfort taking made affordable by energy efficiency improvements. Warmer and drier homes are likely to have a positive impact on individuals' health outcomes.

Impact on the NHS

Investment in energy efficiency measures in fuel poor households is also likely to reduce NHS spending on cold-related illnesses, and there is an extensive literature on this topic. Research commissioned by the Chartered Institute of Environmental Health (CIEH) in 2008 estimated that the treatment of cold-related illnesses and conditions costs the NHS approximately £1bn pa[27]. This is a substantial financial drain; however, this figure is likely to include some spending on treating persons from households that are not fuel poor.

More recently, BRE has published estimates on the cost to the NHS of not reducing cold hazards in F and G rated privately rented dwellings to the average SAP level. This is estimated to be at least £145m pa[28]. However this figure is likely to be a fraction of the total costs as it relates to only privately rented dwellings in England, rather than all of the UK housing stock. Furthermore, this estimate is not specifically based on households in fuel poverty, rather it bases calculations on F and G band rated buildings. There are also households living in fuel poverty in dwellings in higher EPC bands, as well as occupants in F and G rated buildings that do not live in fuel poverty[29].

Davidson et al. have proposed a model for estimating the relationship between poor health and poor housing (as defined as housing which fails to meet minimum statutory standards for housing in England, as assessed by the Housing Health and Safety Rating System (HHSRS)) [30]. The model estimates the cost to the NHS for excess cold hazards in poor private sector housing (i.e. SAP band F and G) in England to be around £860 m pa[31].

The Chief Medical Officer's Annual Report 2009 suggests that, for every £1 spent on reducing fuel poverty, a return of 42 pence can be seen in NHS savings[32] [33].

Summary of the impact on health costs

The published reports referred to above generally solely relate to England (rather than the whole of the UK), only deal with private sector dwellings (rather than including social rented dwellings), and calculate the cost of cold hazard in specific EPC Bands (rather than just from fuel poverty). The final report of the fuel poverty review by John Hills[34] published in 2012 highlighted that at present there is a lack of a robust methodology to establish a firm link between health effects directly attributable to fuel poverty and the resulting costs to the health service. Research to date therefore suggests that the cost of fuel poverty in the UK to the NHS is likely to be in the region of £600m to £1bn pa and even this is likely to be a conservative estimate. Whilst not providing a definitive figure, this does give a rough indication of the size of the problem, especially when government spending on health for the 2012/13 financial year is set to be £130bn[35]. By contrast, this report suggests that households could be removed from fuel poverty in 75% of cases, through cost-effective investment funded by carbon revenues, of just £2-3bn pa.

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[27] *V. Mason,* Good Housing Leads To Good Health: A Toolkit for Environmental Health Practitioners, *Chartered Institute of Environmental Health (CIEH), 2008.*

[28] *V. Mason and M. Roys,* The Health Costs of Cold Dwellings, *BRE Electronic Publications, 2011.*

[29] *Centre for Sustainable Energy,* CSE's response to the Hills Review Interim Report*, 2012.*

[30] *M. Davidson, M. Roys, S. Nicol, D. Ormandy, and P. Ambrose,* The Real Cost of Poor Housing, *BRE Electronic Publications, 2010.*

[31] *Department of Health,* South East Regional Public Health Group Fact Sheet: Health and Winter Warmth - Reducing Health Inequalities*, 2009.*

[32] *C. Liddell,* Estimating the impacts of Northern Ireland's warm homes scheme 2000-2008, *University of Ulster, 2008.*

[33] see:
http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/@ps/documents/digitalasset/dh_114012.pdf

[34] J. Hills, Getting the measure of fuel poverty – Final report of the Fuel Poverty Review, *March 2012.*

[35] *HM Treasury,* Budget 2012, *London, 2012.*

4.9 Sensitivity analysis

The direct rebound effect

The direct rebound effect is the extent to which energy savings from the efficiency investment will be offset by increases in energy consumption through comfort taking, as a result of a reduction in the effective price of energy services. To reach the same level of comfort as before the energy efficiency improvements, households will spend less money on fuel bills. This reduction in the relative price of energy services due to the efficiency improvements, will result in higher demand for energy that will slightly offset the initial savings, as individuals respond to the relative price change in order to optimise their level of utility.

The size of the rebound effect will depend upon the elasticity of demand for energy services and sensitivity analysis was used to test uncertainty around the magnitude of this effect (a value of 40% was used in the central scenario, see Section 3.3). However, there have been far fewer studies relating to the size of the rebound effect in fuel poor households, which is likely to differ considerably, due to differences in consumption preferences for this specific income group compared to the average across the whole population.

For this reason, four other sensitivities for the direct rebound effect were also tested: 0%, 20%, 60% and 80%. The results of the sensitivity analysis generally do not change the relative strength of the energy efficiency investment scenario, which continues to out-perform the other scenarios in terms of GDP. However the benefits to GDP decrease as the rebound effect grows, and 80% rebound brings the results in line with the GK scenario.

The 0% direct rebound effect assumption refers to an instance where consumers make no behavioural changes or comfort taking following the energy efficiency investment. The results from this sensitivity therefore comprise the largest energy savings relative to the baseline. By 2027, total final energy demand is 2.3% lower than in the baseline and 0.8% lower than in the EE-T scenario.

In the 20%, 60% and 80% comfort taking sensitivities, final energy demand was 1.7%, 0.9% and 0.4% lower in each of the scenarios respectively, when compared to the baseline.

The economic results for the sensitivities with the lower direct rebound assumptions have the largest positive impact on the economy, due to the larger reductions in imported gas (see Table 4.14 for details of fuel bills). Consumer expenditure is directed to goods with a higher domestic content, compared to in the other scenarios and sensitivities, and therefore the results for the 0% and 20% sensitivities have a larger positive impact on GDP.

Table 4.17: GDP and Expenditure Components, 2027

GDP AND EXPENDITURE COMPONENTS, 2027					
	EE-T	EE-0	EE-20	EE-60	EE-80
	%	%	%	%	%
GDP	0.16	0.18	0.17	0.15	0.13
Consumption	0.08	0.10	0.09	0.08	0.07
Investment	0.62	0.65	0.63	0.60	0.58
Exports	0.00	0.00	0.00	0.00	0.00
Imports	0.09	0.06	0.07	0.10	0.11
Government Spending	0.00	0.00	0.00	0.00	0.00

Notes : 2008 prices. Scenario results are presented as percentage difference from baseline.
Sources : OBR and MDM-E3 calculations.

Table 4.18: Employment, 2027

EMPLOYMENT, 2027	EE-T	EE-0	EE-20	EE-60	EE-80
	'000s	'000s	'000s	'000s	'000s
Employment	52	58.2	55.1	49.1	45.9

Notes : Scenario results are presented as absolute difference from baseline.
Sources : OBR and MDM-E3 calculations.

5 Concluding Remarks

5.1 Concluding remarks

The research provides evidence of economic benefits for investing in fuel poor households beyond the social and environmental benefits

This research shows that investing the revenues from the EU ETS and carbon floor price in improving the energy efficiency of fuel poor homes has many benefits. The analysis shows that energy efficiency investment has advantages over a set of alternatives that were tested, namely:

- **Economic benefits**: Investing the money in improving the homes of fuel poor households has a better outcome on growth and employment than the alternative options modelled.
- **Social benefits**: Between 75% and 87% of the households that would have otherwise been in fuel poverty are removed from fuel poverty, improving the quality of millions of lives of some of the most vulnerable members of society and reducing health care costs.
- **Environmental benefits**: UK CO_2 emissions fall by more than 5% compared to baseline by 2027, contributing to the UK's legal commitment to reduce GHG emissions by 2050.

The research suggests that if all the carbon revenues are invested in energy efficiency, fuel poverty could be largely eliminated and 130,000 jobs created by 2027. However, the economic impact of such a programme, when compared with other scenarios is less conclusive. If cost effectiveness is the primary concern, the research shows that an energy efficiency programme restricted to homes that can be treated for less than £10,000 per home improved is considerably more effective than the other scenarios investigated. Of course, this does not take into account the wider social and environmental benefits of the more extensive programme.

This analysis considers the impact of using revenues from carbon pricing to fund grants to households, since it focuses on the fuel poor for whom loan schemes or partial subsidies would not be appropriate. To capture the wider population, other options could include loan guarantee schemes or interest rate subsidies which could draw in private investment in energy efficiency measures.

Key assumptions

The economic results depend on a number of factors:

- gas prices remain close to current levels and do not fall substantially
- the UK continues to import a large proportion of its natural gas requirements
- the carbon price floor remains in place to provide the revenue to fund the investment
- that consumers do not take all of the energy efficiency savings as extra comfort (e.g. a 100% direct rebound effect)

These factors are all reasonable.

- Even if wholesale gas prices were to fall by 50% the financial savings for households would still be substantial and fewer households would be in fuel poverty (both in the baseline and the scenarios).
- If the UK were able to produce more natural gas, through shale gas extraction for example, it would still be beneficial to reduce demand since it is highly unlikely that the UK could meet domestic demand through domestic production without a substantial reduction in gas demand, a reduction far beyond that outlined in these results, and imports would still be required to meet the difference.

- In terms of revenues only two-thirds of the carbon price floor and EU ETS revenues are used and so there is scope for some reduction in expected revenues, although the policy initiative proposed here could also merit funding from other sources.
- For 100% of energy efficiency savings to be taken back in comfort-taking would imply that households in fuel poverty are living far below their required comfort and would also suggest that they are not in need of extra income for anything else. The 40% direct rebound effect used in the central scenario is high, reflecting the additional comfort that fuel poor households require, but still results in a positive macroeconomic result.

At a time when the European political debate on government austerity is at a cross-roads, this research provides a case for investing in energy efficiency as an economic stimulus which yields returns for the economy, society and the environment.

Appendix: MDM-E3 Model Description

A.1 Introduction

MDM-E3 is a model of the UK energy-environment-economy system

MDM-E3[36] is maintained and developed by Cambridge Econometrics (CE) as a framework for generating forecasts and alternative scenarios, analysing changes in economic structure and assessing energy-environment-economy (E3) issues and other policies. MDM-E3 provides a one-model approach in which the detailed industry and regional analysis is consistent with the macroeconomic analysis: in MDM-E3, the key indicators are modelled separately for each industry sector, and for each region, yielding the results for the UK as a whole. MDM-E3 is one of a family of models which share the same framework, general design, methodology and supporting software; the scope of the E3ME[37] model is European; that of E3MG[38] is global.

To analyse structure, the E3 models disaggregate industries, commodities, and household and government expenditures, as well as foreign trade and investment, and incorporate an input-output framework to identify the inter-relationships between industry sectors. The models combine the features of an annual short and medium-term sectoral model estimated by formal econometric methods with the detail and structure of input-output models, providing analysis of the movement of the long-term outcomes for key E3 indicators in response to economic developments and policy changes. The models are essentially dynamic simulation models estimated by econometric methods.

MDM-E3 retains an essentially Keynesian logic for determining final expenditure, output and employment. The principal difference, compared with purely macroeconomic models, is the level of disaggregation and the complete specification of the accounting relationships in supply and use tables required to model output by disaggregated industry.

The model is dynamic, and its parameters are estimated econometrically

The parameters of the behavioural relationships in MDM-E3 are estimated econometrically over time, within limits suggested by theory, rather than imposed from theory. The economy is represented as being in a continual state of dynamic adjustment, and the speed of adjustment to changes (in, for example, world conditions or UK policies) is based on empirical evidence. There is therefore no assumption that the economy is in equilibrium in any given year, or that there is any automatic tendency for the economy to return to full employment of resources.

In summary MDM-E3 provides:

- annual comprehensive forecasts to the year 2025 for:
  - industry output, prices, exports, imports and employment at an industry level (87 industries); for household expenditure by 51 categories
  - investment by 27 investing sectors for the nine Government Office Regions, Wales, Scotland and Northern Ireland
- projections of energy demand and emissions, by 25 fuel users and eight main fuel types (in all, 11 fuels are distinguished)

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[36] Multisectoral Dynamic Model, Energy-Environment-Economy: http://www.mdm-e3.com/

[37] Energy-Environment-Economy Model of Europe: http://www.e3me.com/

[38] Energy-Environment-Economy Model at the Global level: http://www.e3mgmodel.com/

- full macro top-down and industrial bottom-up simulation analysis of the economy, allowing industrial factors to influence the macro picture
- an in-depth treatment of changes in the input-output structure of the economy over the forecast period to incorporate the effects of technological change, relative price movements and changes in the composition of each industry's output
- scenario analysis, to inform the investigation of alternative economic futures and the analysis of policy

A.2 Economy

MDM-E3 incorporates a disaggregated representation of the UK economy…

The purpose of MDM-E3 is to abstract the underlying patterns of behaviour from the detail of economic life in the UK and represent them in the form of a key set of identities and equations. In a complex system, such as the UK economic system, the abstraction is very great. In any economic model the initiatives, responses and behaviour of millions of individuals is aggregated over geographical areas, institutions, periods of time and millions of heterogeneous goods and services into just a few thousand statistics of varying reliability. The aim of MDM-E3, then, is to best explain movements in the data and to predict future movements under given sets of assumptions.

A key contribution of the approach to modelling the UK economy in MDM-E3 is the level of disaggregation. The macroeconomic aggregates for GDP, consumers’ expenditures, fixed investment, exports, imports, etc are disaggregated as far as possible without compromising the available data.

One reason for disaggregation is simply that it is necessary to answer certain questions of economic interest. Some macroeconomic questions are intrinsically structural and if they are to be answered using a model then it must be disaggregated in some way. The disaggregation of agents and products is crucial in trying to understanding the behavioural responses of heterogeneous agents as it reduces the bias encountered in estimating aggregate relationships.

…at the sectoral level…

The principal economic variables in MDM-E3 are:

- the final expenditure macroeconomic aggregates, disaggregated by product, together with their prices
- intermediate demand for products by industries, disaggregated by product and industry, and their prices
- value added, disaggregated by industries, and distinguishing operating surplus and compensation of employees
- employment, disaggregated by industries, and the associated average earnings
- taxes on incomes and production, disaggregated by tax type
- flows of income and spending between institutions sectors in the economy (households, companies, government, the rest of the world)

…as well as the regional level

Some variables are also disaggregated by Government Office Region and Devolved Administrations. This applies particularly to value added, employment, wages, household incomes and final and intermediate expenditures. Prices are not typically disaggregated by region, because of data limitations.

The model's accounting framework is consistent with international systems of national accounts

A social accounting framework is essential in a large-scale disaggregated economic model. The early versions of MDM-E3 were based on the definitions and estimation of a Social Accounting Matrix (SAM) for the UK and its associated input-output tables and time-series data. The principles of SAM have been extended and elaborated in detail in the UN's revised System of National Accounts (SNA). Accordingly we now use the SNA for the accounting framework for the data and the model.

The national accounts provide a central framework for the presentation and measurement of the stocks and flows within the economy. This framework contains many key economic statistics including Gross Domestic Product (GDP) and gross value added (GVA) as well as information on, for example, saving and disposable income.

The national accounts framework makes sense of the complex activity in the economy by focusing on two main groupings: the participants of the economy and their transactions with one another.

Units are the individual households or legal entities, such as companies, which participate in the economy. These units are grouped into sectors, for example the Financial Corporations sector, the Government sector and the Household sector. The economic transactions between these units are also defined and grouped within the accounts. Examples of transactions include government expenditure, interest payments, capital expenditure and a company issuing shares.

The national accounts framework brings these units and transactions together to provide a simple and understandable description of production, income, consumption, accumulation and wealth. These accounts are constructed for the UK economy as a whole, as well as for the individual sectors in the Sector Accounts.

Since 1998 the National Accounts have been consistent with the European System of National Accounts 1995 (ESA95). The ESA95 is the European implementation of the International System of National Accounts 1993 (SNA93) developed by the UN to ensure a common framework and standards for national accounts, including input-output analyses, sector accounts and constant-price analyses. The ESA95 was developed to reflect the changing role of government, the increased importance of service industries and the increased diversity of financial instruments. It recognises the wider scope of capital formation, by using concepts such as intangible assets.

The model identifies three main flows of economic dependence

The determination of output in MDM-E3 can be divided into three main flows of economic dependence:

- the output-investment loop
- the income loop
- the export loop

Household expenditure is principally a function of income and prices, although demographic trends are also accounted for

Consumers' expenditure is estimated at an aggregated level for each of the 12 UK regions covered in MDM-E3 and then further disaggregated to the 51 expenditure categories which relate to the COICOP classification. At the aggregate level regional consumption in real terms is predominantly a function of regional real income.

This relationship is constrained to reflect the idea that expenditure cannot outgrow income levels in the long term, although it is possible in the short term. The other key drivers of regional consumption as defined in the equations are:

- the adjusted dwellings stock
- the OAP dependency ratio
- inflation

In the short run we also consider the effects of:

- unemployment - in the literature high levels of unemployment are linked to sharp falls in consumer spending beyond the fall in consumer spending which can be explained by an associated fall in real gross disposable income that the unemployment would cause; this is explained in the literature by the uncertainty that unemployment induces across a region
- real house prices - we assume here that there is a positive (negative) wealth effect caused by increasing (decreasing) real house prices which causes consumption to increase (decrease) in the short run

Household expenditure is disaggregated by type and region

Regional consumption is then disaggregated further in the disaggregated regional equations which take the main independent variable as regional consumption, which effectively reflects the income effect on consumption (the parameter is restricted to be positive). The other explanatory variables are relative prices in the form of the price of each consumer category compared to the overall price index for all consumer items, this captures the price effect (the parameter is restricted to be negative). The OAP and child dependency ratios are also considered so as to reflect differing consumption patterns arising from changing demographic structure in the different regions.

Feedback from the energy sub-models determines consumption of energy products

For the consumption categories that represent energy products, consumption in each region is determined by applying the growth rate in UK fuel consumption (in energy units) from the fuel user 'households' (or in the case of petrol - road transport) to the real consumption of gas, electricity, coal, petrol and manufactured fuels. The fuel used by households and road transport is derived from the energy and transport sub-models described later. Disaggregated consumption is then scaled to match regional consumption at the aggregate level.

Household expenditure by expenditure category is then mapped to the 41 product categories to derive domestic consumer demand by product category.

Investment is a function of industry output

Among other elements such as social-capital formation, public and private sector dwellings and legal fees, the most important element of gross fixed capital formation is the acquisition of new buildings, plant and machinery and vehicles by industry.

Investment in MDM-E3 is treated quite differently to the neoclassical framework which relies on the production function of firms and net present welfare maximisation based on equating the user cost of capital with the marginal product of capital.

However, the neoclassical treatment leads to an unresolved conflict between the implied costless switch between capital and employment and the observation that capital stock adjustments are subject to significant time lags.

In MDM-E3 investment data are divided into 27 investing sector categories at the national level. The national investment equations depend on industry output, which is converted from the 41 industry sectors to the 27 investing sectors. The equations yield the result that an increase in output will lead to an increase in investment. Typically, the investing sectors which are most responsive to changes in output are the capital-intensive manufacturing-based investment sectors such as Transport Equipment.

The investment equations are specified in the Engle-Granger cointegrating form and therefore allow for the impact of the lagged investment and an error correction term, allowing adjustment to the long-term trend.

The level of government expenditure is an exogenous assumption in the model, and must be determined by the model operator

Assumptions for government capital spending are used to forecast gross fixed capital formation in the investing sectors relating to Health, Education and Public Administration. Government final consumption expenditure is treated exogenously in MDM-E3 and is based on the plans announced in the Comprehensive Spending Review and Budget statements.

Government revenues from taxes on income and production are inherently endogenous as they rely on consumption and incomes. This duality is an important consideration in scenario analysis. Increased tax revenues are not automatically recycled into the economy. Model operators must decide where additional revenue should be spent. If additional tax revenues are not spent they will, by definition, simply reduce the Public Sector Net Cash Requirement (PSNCR), but this has no further effects on behaviour (for example, it is not assumed that household spending responds to the prospect of higher or lower taxation in future as indicated by the extent of government borrowing in the present).

UK exports are driven by (assumed) economic activity in the rest of the world; import demand by the level of domestic demand and relative prices

MDM-E3 has assumptions for 19 world regions, covering (among other factors) activity (GDP), price levels and exchange rates. The world activity indices are the key drivers of export demand, which is estimated across the 41 product categories. The result is that an assumed change in US GDP growth will affect the products that are most traded with the US, depending on the weighting of US demand in the world demand for UK exports and the responsiveness of UK export demand to the change in the world activity index. The price of exports also affects the level of export demand. To explain historical export volumes two dummy terms for integration with the EU internal market are significant for 1974 and 1978.

Import volumes are determined by domestic demand and import prices relative to domestic prices. A capacity utilisation constraint is also considered in the short term.

Interdependencies between industries are represented in an input-output framework

Input-output supply and use tables (SUTS) provide a framework to make consistent estimates of economic activity by amalgamating all the available information on inputs, outputs, gross value added, income and expenditure. For a given year, the input-output framework breaks the economy down to display transactions of all goods and services between industries and final consumers (eg households, government) in the UK. Since 1992, ONS has used the input-output process to set a single estimate of annual GDP and ONS has published the detailed analyses in the SUTS.

The information from the regular releases of SUTS are used in conjunction with the more detailed analytical tables (last published for 1995) to construct the inputs that are required for the MDM-E3 model. An input-output table has been estimated from official data to provide the detail needed to model inter-industry purchases and sales.

The input-output coefficients derived from the SUTS allow intermediate demand to be derived for each product given the final demand at the product level of disaggregation.

Employment is determined by sector and region

The employment equations for MDM-E3 are based on a headcount measure of employment rather than on a full-time equivalent basis. The employment equations are specified by region and industry. The two main drivers of employment are gross output and the relative wage costs as measured by industry wages relative to industry prices.

Labour productivity is defined on a net output per job basis

In MDM-E3 assumptions are made for world prices and exchange rates. These are then used to determine import prices, which are one element of the cost to the UK's industries of bought-in inputs. The other element is, of course, the cost of the UK's own production. Unit material and labour costs determine industry output prices. Consumer prices, then, depend partly on import prices and partly on UK industry prices, together with taxes on products. Consumer prices have an influence on average wage rates, as do labour market factors. Average earnings and productivity are then used to determine unit labour costs. Export prices depend partly on unit labour costs in the UK and partly on world prices (reflecting the extent to which prices are set in world markets).

Interest rates and exchange rates are exogenous inputs to the model

Previous versions of MDM-E3 have sought to include endogenous treatments for interest rates and exchange rates but the inclusion of these specifications often led to increased instability within the model. Recent versions of the model therefore rely on an exogenous treatment for both exchange rates and interest rates. This has important consequences for scenario analysis. For instance, unilateral UK action on carbon taxes might push domestic consumer price inflation to a position where the Bank of England might take deflationary action by increasing the repo rate. Similarly, exchange rates do not change in response to domestic prices, the balance of payments, world prices, Treasury bill rates and so on.

Prices are formed as a mark-up on unit costs

Industrial prices are formed as a mark-up on unit costs with an allowance for the effect of the price of competitive imports, technological progress and, in the short run part of the equation, the effect of expected consumer price inflation. The supply side comes in through the utilisation of capacity as measured by the ratio of actual output to normal output.

For many of the industries the dominant effect is industrial unit costs. However, import prices can affect domestic prices in three different ways. First, by directly increasing industrial unit costs, to the extent that industry inputs are imported. Second, as competitor prices so that domestic prices tend to rise with import prices over and above any effect on costs. Third, as import prices directly affect consumer price inflation and therefore the expectation of future increases in import prices.

Import and export prices play the role of transmitting world inflation to the UK economy through its effect on export and import prices. Import and export prices are determined by world product prices, the exchange rate, world commodity prices and unit cost. For export prices in the short term there is also a supply-side effect which comes through the increases in the utilisation of capacity. A measure of technical progress is also included to cope with the quality effect on prices caused by increased levels of investment and R&D. Restrictions are imposed to force price homogeneity and exchange rate symmetry on the long-term equations.

Consumer prices are determined by import prices and industry prices and the respective weighting of imports and domestic purchases in consumers' expenditure, together with the application of product taxes.

Following a wage-bargaining model, increases in price tend to drive wages upward

The aggregate consumer price index is assumed to have a positive relationship with wages, such that an increase in prices should lead to an increase in wages. Productivity also has a positive relationship with wages: if employees in an industry are able to increase value added by increasing output for the same input then they are able to command higher wage rates.

The treatment of wages in MDM-E3 partly follows the typical wage bargaining model. The opportunity from not working as expressed by unemployment benefit has a positive relationship with wages as the benefit rate will mean that workers will want to gain sufficiently more than the available benefit transfer to justify employment. In MDM-E3, again following the wage bargaining models, unemployment levels also have an impact on wages: if unemployment is high it follows that wages will be low as there is no incentive for employers to pay an individual more when there are a large number of unemployed willing to work for a lower salary.

The retention ratio term identifies the average real take-home pay for any given salary level. The purpose of this is to simulate the characteristic of individuals operating in a way to make sure that their net pay means they are equally well off following a change in tax. If income tax increases, the retention ratio falls and wages rise to (fully or partially) compensate for the higher tax rate.

In an attempt to understand relationships between wages within one industry but across regions, or within one region but across industries, MDM-E3 also uses external industry wage rates and external regional wage rates to estimate wage rates as a system. The idea is that if wages in a region are increasing for all other industries that are not industry Y, then this should drive an increase in industry Y wages, within the specified region. This argument is then extended for one industry's wages across all the regions. If the oil and gas industry increases wage rates in all non-X regions, this will have an impact on the oil and gas industry wages in region X.

Wage bills are calculated across region and industry by multiplying the average wage by the number of full time equivalent (FTE) employees. Further key variables, such as the total wage bill, average wage, average wage for a region and average wage for an industry are also calculated.

The treatment of financial stocks and returns in the model is currently quite limited and they have no important effects.

Technological progress is represented endogenously in MDM-E3

Technological progress is often represented as exogenous, either as a residual in a neoclassical production function or by using a linear or non-linear time trend approach. Both methods have their drawbacks. The neoclassical approach is somewhat circular in its logic, ie to know a firm's production possibilities one needs to model technological progress, but in modelling technological progress one is already making an assumption about the production process. The time trend approach is also unappealing given its atheoretical background.

The approach to constructing the measure of technological progress in E3ME is adapted from that of Lee et al (1990). It adopts a direct measure of technological progress by using cumulative gross investment, but this is altered by using data on R&D expenditure, thus forming a quality adjusted measure of investment.

A.3 Energy

MDM-E3 incorporates a number of energy sub-models…

Flows in the economic model are generally in current and constant prices, prices are treated as unit-value indices, and the energy-environment modelling is done in physical units. This modelling is described in Barker et al (1995).

MDM-E3 includes a bottom-up (the ETM) sub-model to model changes in the power generation sector's use of fuels in response to policy initiatives and prices. This modelling approach has been reviewed by McFarland et al (2004) and has the advantages that it avoids the typical optimistic bias often attributed to a bottom-up engineering approach, and the unduly pessimistic bias of typical macroeconomic approaches. It was the focus of a recent Tyndall Centre project (Koehler et al, 2005) and the current research under the Energy Systems and Modelling Theme (ESMT) for the UKERC (Barker et al, 2005).

…with two-way feedback to the economy

Energy-environment characteristics are represented by sub-models within MDM-E3, and at present the coverage includes energy demand (primary and final), environmental emissions, and electricity supply. Energy demand by industries is then translated into expenditure flows for inclusion within the input-output structure to determine economic variables, so that MDM-E3 is a fully-integrated single model, allowing extensive economy-energy-environment interactions.

Energy-economy feedback is an important feature of the model with regard to policy analysis

The ability to look at interactions and feedback effects between different sectors - industries, consumers, government - and the overall macroeconomy is essential for assessing the impact of government policy on energy inputs and environmental emissions. The alternative, multi-model approach, in which macroeconomic models are operated in tandem with detailed industry or energy models, cannot adequately tackle the simulation of 'bottom-up' policies. Normally such multi-model systems are first solved at the macroeconomic level, and then the results for the macroeconomic variables are disaggregated by an industry model. However, if the policy is directed at the level of industrial variables, it is very difficult (without substantial intervention by the model operator) to ensure that the implicit results for macroeconomic variables from the industry model are consistent with the explicit results from the macro model. As an example, it is very difficult to use a macro-industry, two-model system to simulate the effect of exempting selected energy-intensive industries from a carbon or energy tax.

The energy sub-model determines final energy demand, fuel use by user and fuel, the prices of each fuel faced by fuel users, and also provides the feedback to the main economic framework of MDM-E3. Fuel use for road transport is solved using MDM-E3's Transport Sub-model. Fuel use for power generation is calculated in the electricity supply industry (ESI) sub-model, which uses a 'bottom-up' engineering treatment.

A.4 Final energy demand

The main drivers of energy demand are activity, prices and technological progress

Final energy and fuel demand by fuel user is modelled by econometric equations, which are estimated using a standard cointegrating technique. The estimation of energy demand occurs in a two-step method. Firstly, the aggregate (ie with no breakdown by fuel type) demand for energy for each end-user is determined. Typically, the key dependent variables are:

- the activity of the fuel user, usually taken to be gross output of the sector, but, in the case of households, household expenditure is used
- technological progress in energy use, which reflects both energy-saving technical progress and the elimination of inefficient technologies
- the price of energy relative to general prices
- changes in temperature

In addition, to account for the Climate Change Levy and Climate Change Agreements, we also include the 'announcement' effect of the CCL and the 'awareness' effects on participating industries of the CCAs. The estimates of these effects were derived from a study by Cambridge Econometrics for HM Customs and Excise (CE et al, 2005).

Relative fuel prices are an important determinant of fuel switching

Fuel users' demand for each fuel is estimated by splitting the estimated aggregate energy demand. To reflect the fact that fuel switching is inhibited by the existing stock of appliances and machinery used in the economy and the available infrastructure, it is assumed that fuel users adopt a hierarchy in their choice of fuels:

- choosing first electricity for premium uses (light, electrical appliances motive power, special heating applications)
- then sharing out non-electricity demand for energy between three fossil fuels (coal and coal products, oil products and gas)

The specification of these equations is similar to that of the aggregate energy equations, except that the estimated variable is the fuel share, and the explanatory variables are:

- activity
- technology measure

- three price terms - the price of the fuel type in question, the price index of its nearest competitor, and the general price index within the economy
- temperature (where relevant)

Aggregate energy demand is projected first, and then shared out to individual fuels

This method is regarded to be the most suitable given the data available and the relative quality of data at different levels of disaggregation. The aggregate energy demand equations command a higher level of confidence than the fuel share equations. The estimated fuel share equations used to split aggregate demand to yield demand for individual fuels by fuel users fit the data better than equations which directly estimate the demand of a particular fuel by an individual fuel user. This is partly due to high level of volatility in the time series data at this level of detail.

Both the aggregate energy/fuel demand equations and the disaggregated fuel share equations are specified as cointegrating equations:

- the dynamic part of the equation provides short-term responses of energy demand
- the long-term response is captured in the long-term part of the equation, adjusted for the speed of adjustment term (or error correction mechanism)

The equations for final energy demand are estimated on the data in the Digest of UK Energy Statistics (DUKES) published by DECC.

The wholesale prices of fossil fuels such as coal, oil and gas are assumptions in MDM-E3. Wholesale prices are converted to consumer/retailer prices for each fuel user by applying appropriate levies and taxes.

A.5 Emissions

MDM-E3 distinguishes 14 air emissions, including the six Kyoto greenhouse gases

MDM-E3 distinguishes 14 air emissions, including the six greenhouse gases currently regulated under the Kyoto Protocol. Emissions data are obtained from the National Air Emissions Inventory (NAEI) and the last year of outturn is typically one year earlier than the energy data, published by DECC, that are fed into the model. For example, the last year of data reported in the July 2010 edition of DUKES is 2009 but the last year of NAEI data, published in 2010, is 2008.

The NAEI data for each year are highly disaggregated and classified by fuel type and activity. The data must be aggregated to the 11 fuel types and 25 fuel users distinguished in MDM-E3 and the guiding principle is that, as far as it practicable, emissions should be classified to the industries that use the fuels associated with the emissions eg if off-road vehicles are used mainly for construction, the emissions would be allocated to the fuel user Construction.

Where available, emissions coefficients for individual fuels and fuel users are applied to the corresponding energy demands to give a first estimate of emissions. A scaling term is applied in the history to ensure that the final output matches official sources. This adjustment is held constant throughout the forecast period. Other emissions are calculated on an implied basis in the last year in which both energy and emissions data are available (2008 in the example above). These coefficients are also typically held constant for the remainder of the period (although they could for example be adjusted to reflect the adoption of emissions-abatement technologies).

Emissions from non-energy use are linked to fuel-user activity indicators or population growth and are thus not differentiated by fuel. Emissions from land use and land use change are not covered.

A.6 Power generation

Electricity generation is handled by an electricity supply industry (ESI) sub-model

MDM-E3 models the stock of power generation capacity and the annual generation of power from this stock in response to changes to demand for electricity, fossil fuel prices, carbon prices and incentives to increase the use of renewables. Changes to the power capacity stock are modelled by the electricity technology sub-model (ETM). Estimation of generation from the capacity stock is modelled by the electricity supply industry (ESI) sub-model.

An Energy Technology Model (ETM) projects the future evolution of UK generation capacity

The ETM builds on earlier work by Anderson and Winne (2004). The ETM assumes the role of the national social planner whose objective is to derive a schedule of build of new capacity to meet expected demand. It chooses to build capacity from a range of generation technologies.

The key drivers in determining the capacity build are contemporaneous and future values of:

- the required supply margin, usually expressed as a percentage on top of winter peak demand (currently this is around 18%)
- the prices of generation fuels (largely fossil fuels)
- the carbon prices of generation fuels
- the capital costs of new build
- the maintenance costs of new plant
- the payments to generators from the Renewable Obligation (RO); only eligible renewable power generation technologies attract the payment
- learning curve effects
- the build time of new plant

The ETM accounts for learning effects

The ETM considers learning effects, where the cost of building a particular type of new capacity falls as more of that capacity gets built.

The ETM uses cost minimisation of net present value (NPV) in order to determine the type of new capacity that is built. Coupled with the learning effects, this can cause the schedule of new build generated by the ETM to be dominated by one particular type of technology. This effect is tempered by constraints on the amount of new build that is permitted to occur and assumptions for the technology chosen for any existing announced new build.

The Renewables Obligation is explicitly modelled

The ETM allows the model to project the impact of the Renewables Obligation (RO) including the 'banding' of RO payments. The model considers the contemporaneous and expected future values of RO payments, which are entered as inputs.

Power generation is estimated by the electricity supply industry (ESI) sub-model. The ESI sub-model distinguishes the fuel burn and other characteristics of existing power stations and possible future stations, to allow for substitution on the basis of current fuel and carbon prices. The model adjusts these load factors up or down as more or less generation from these plants is required.

Electricity generation from the ESI sub-model operates on a cost-minimisation basis

The ESI uses cost minimisation to decide the generation mix in any given year. In some cases, however, these load factors are constrained in accordance with non-economic factors such as regulations. For example, the Environment Agency's regulations on emissions from coal and oil-fired power stations require that the load factors of plants with or without FGD should be adjusted as follows: plants without FGD have their load factor restricted while plants retrofitted with FGD operate at a higher load factor (in the ratio 2:1) than plants without FGD owned by the same power companies. The ESI also takes into account the impact of the Large Combustion Plant Directive.

There is a separate treatment for CHP

The ESI sub-model also includes a separate treatment of combined heat and power (CHP). In the CHP sub-model that has been developed, it is assumed that CHP schemes are operated before other electricity demand is taken from the grid. Hence, the demand for heat and power from CHP schemes is derived in the model before the overall demand for power. The generation from CHP schemes is then subtracted from the overall demand for electricity to be met by the generating stations attached to the grid. The use of electricity from the CHP plants shows up as increased energy efficiency in overall electricity generation (because, as the proportion of CHP-generated electricity increases, the efficiency rises).

Electricity prices are endogenously derived and depend on the relative share of each fuel used in generation of power in the year. The value of renewable certificates and any carbon price are also passed through to the wholesale price. It is assumed that 100% of the costs of generation are passed though to the wholesale price. This is consistent with evidence of the ability of power generators to pass on the cost of the Phase I EU ETS carbon price to the wholesale electricity price (Ekins, 2005). The retail price of electricity faced by end users is calculated by the model, based on historical evidence. Large industrial users can be insulated from variations in the retail price as they may have bilateral contracts with suppliers to fix the price for a number of years.

Due to their characteristics and the nature of the UK electricity market, there are real-world constraints on the extent to which nuclear and intermittent forms of generation such as wind (without back up) can service the power needs of the UK, especially the daily and seasonal peaks in UK's electricity demand. However, the electricity sub-models in MDM-E3 do not incorporate these constraints; all available technologies are treated as perfect substitutes for each other. Coupled with the cost minimisation algorithm used to determine the capacity and generation mix for power generation, the effect can be that the proportion of capacity made up by intermittent forms of generation such as wind can be overstated.

A.7 Road transport

The Transport Sub-model projects demand for vehicles, travel and fuel for Road transport

MDM-E3 now incorporates a transport sub-model to project energy demand from Road Transport. These results are used in place of the 'top-down' equations previously used, and which are still used to solve energy demand from the other final users. The projections for Road Transport are still derived from a set of econometrically-estimated equations but the degree of disaggregation is far greater, as is the number of explanatory factors considered. The treatment is sufficiently general that the other three modes of transport (air, rail and water) can also be modelled but these elements are not yet operational.

The sub-model is composed of three sets of stochastic equations to explain:

- the demand for travel, expressed in kilometres, disaggregated by vehicle type (eg Cars and taxis, Bus/coach and HGV) and network type (eg Rural A roads, Urban A roads and Motorways)
- annual purchases of new vehicles, disaggregated by vehicle type and technology (eg internal combustion engines that run on Petrol, Diesel or LPG)
- changes in the fuel efficiency of different vehicle categories, differentiated by vehicle type (eg the fuel efficiency of petrol-driven cars is allowed to differ from, and move differently to, the fuel efficiency of petrol-driven buses)

The sub-model contains a representation of the vehicle stock in which additions are determined by the second and third sets of equations and older vehicles are scrapped according to an exponential function such that the rate at which vehicles are removed from the stock increases with their age. The average fuel efficiency of the stock can thus be tracked over time and combined with the demand for travel to derive the demand for fuel in each year. The consequent emissions are calculated on an implied basis using the last year for which data on energy demand and emissions are both available.

The sub-model was designed by the Cambridge Centre for Climate Change Mitigation Research[39] (4CMR) based on a specification outlined in Johnstone (1995) and was implemented and integrated by teams at 4CMR and CE. The work was funded by the Green Fiscal Commission[40] and the UK Energy Research Centre[41].

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[39] http://www.landecon.cam.ac.uk/research/eeprg/4cmr/index.htm

[40] http://www.greenfiscalcommission.org.uk/

[41] http://www.ukerc.ac.uk/