JOSEPH ROWNTREE FOUNDATION

REPORT

DISTRIBUTION OF CARBON EMISSIONS IN THE UK: IMPLICATIONS FOR DOMESTIC ENERGY POLICY

Ian Preston, Vicki White, Joshua Thumim and Toby Bridgeman, Centre for Sustainable Energy. Christian Brand, Environmental Change Institute, University of Oxford

The report looks at the distribution of carbon emissions and abatement opportunities of households in England, and the implications for energy and climate change policy impacts.

The UK government has a target to reduce greenhouse gas emissions by 80% on 1990 levels by 2050. In addition there are statutory targets to ensure that no household is in fuel poverty by 2016. An understanding of how current and proposed policy approaches to meeting these targets are likely to impact differentially on domestic energy consumers is fundamental to ensuring policies are both fair and effective.

This research project uses advanced modelling techniques to develop and analyse the datasets needed to support and further understanding of:

- the distribution of carbon emissions – from energy consumed in the home and through personal travel by car, public transport and aviation – across households in Great Britain;
- the impact of existing government energy and climate policies on consumer energy bills and household emissions in England;
- the potential for an alternative approach to reducing emissions in the domestic sector through a wide-scale retrofit of the housing stock.

MARCH 2013
WWW.JRF.ORG.UK

INSPIRING SOCIAL CHANGE

CONTENTS

List of tables

EXECUTIVE SUMMARY

The Climate Change Act 2008 established a long-term framework to tackle climate change with legally binding emissions reduction targets. It requires a reduction of at least 34% in UK greenhouse gas emissions by 2020, and at least 80% by 2050 (compared to 1990 levels).

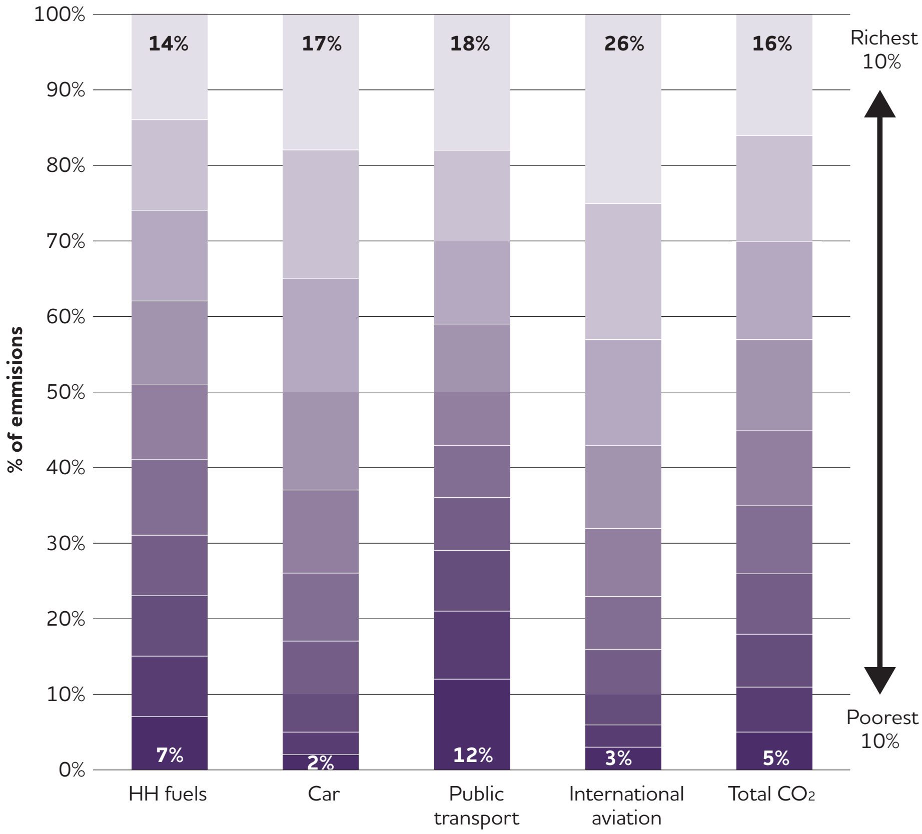
In the next decade there is a serious risk that the most significant social impacts of climate change in the UK will result not from climate change itself, but from the distributional consequences of the policies chosen to respond to the issue. Understanding these consequences – and the options for moderating them – is therefore central to 'the development of socially just responses to climate change in the UK' (JRF, 2009).

Given the above legally binding targets, it seems surprising that the government has not commissioned the collation and management of data that captures the full distribution of carbon emissions from householders. This study seeks to address this significant issue by developing a nationally representative dataset that covers the full spectrum of household emissions from energy consumed in the home and personal travel by private vehicle, public transport and aviation. The study then uses this dataset to evaluate the potential distributional impacts on householders in England of different energy and climate change policies to assess their fairness and effectiveness as responses to climate change mitigation in the UK.

Distribution of household emissions

In terms of understanding fairness, it is important to take the pre-existing distribution of household emissions into account. Household emissions are strongly correlated with household income, as Figure 1 illustrates. Put simply, higher income households are responsible for a disproportionate share of total domestic sector emissions, and this becomes starker if emissions from driving and international flights are included in the analysis. The richest emit twice that of the poorest 10% of households in terms of household energy consumption. The inclusion of transport emissions suggests that the richest 10% of households are actually emitting more than three times the carbon emissions of the poorest 10%. This has important implications for the distributional consequences of current climate change policies. Where policies increase domestic energy prices, the impact is likely to be regressive: while the poor consume (and thus emit) less, the costs of energy represent a far higher proportion of their income. In contrast, taxes on private transport, while politically more sensitive, might be expected to be less regressive, as those with higher incomes emit substantially more from travel than those on lower incomes.

Figure 1: Proportion of household emissions attributed to each disposable income decile by emissions source



Effectiveness of government policy

The average annual household energy bill in 2011 was £1,175. The average household energy bill in 2020, without any policies in place, would be £1,285. In other words, without the benefits of sustainable energy measures and allowing for increased energy costs, the bill would be £110 higher than in 2011. The average annual household energy bill in 2020, with government policies applied, appears, at £1,180, to be only slightly higher than baseline (2011) levels and is *lower*, by some £105 (or 8%) on average, than the 'no policy' 2020 energy bill (see Table 1). This suggests, therefore, that existing UK government energy and climate change policies will result in a net reduction in the average household energy bill in 2020. However, this impact depends largely on whether a household is expected to benefit directly from policies – for example, receiving financial support for installing energy efficiency measures or renewables in the home. Households not benefiting directly – some 55% of households in our modelling analysis – may expect to see an increase in household energy bills in 2020 of just under £50 on average as a result of policy.

Table 1: Overall impact of policies on actual annual household energy bills in 2020 (England only)

	Overall	Households: no support	Households: receiving support
Baseline bill (2011)	£1,175	£1,219	£1,043
2020 bill without policies[a]	£1,285	£1,270	£1,302
2020 bill with policies	£1,180	£1,318	£1,012
Impact of policies	–£105	£47	–£290
% change due to policies	–8%	4%	–22%
Change in bill on baseline	£4	£99	–£31
Count of households	21,380,077	11,716,921	9,663,156
% of households	100%	55%	45%

Note: [a] the bill in 2020 allows for changes in energy costs as a result of changes to wholesale costs for fuels, investment in the network infrastructure and other supplier costs (including profit).

The current government policies are designed to deliver the necessary 34% reduction in carbon emissions on 1990 levels by 2020. However, there is little leeway for the underperformance of policies or measures. Table 2 sets out the projected emissions savings based on current policy with and without assumptions regarding improvements in the energy efficiency of consumer products ('products policy'). This shows that current policies are only expected to meet the government's existing 2020 targets of a 34% reduction on 1990 levels of 128 $MtCO_2$ if assumptions regarding policy impacts, particularly products policy (that is, the increased efficiency of lighting and appliances), are borne out. If not, there will be a shortfall of approximately 8 $MtCO_2$.

Table 2: Carbon emissions from household fuel use

	Total ($MtCO_2$)	Reduction vs. 1990 ($MtCO_2$)	Reduction vs. 1990 (%)
1990 emissions from household fuel use	128	–	–
Survey baseline (2007)	111	17	13%
2020 total with all current policies applied	83	45	35%
2020 total excluding products policy	91	37	29%
2020 Committee on Climate Change target	83	45	35%

Distributional impacts of government policy

Several factors influence the distributional impacts of a policy or group of policies. These include the overall implementation costs, which types of household are most likely to benefit, and the way in which the implementation costs are recovered (for example, per unit of energy, per customer or via taxation). Figure 2 illustrates the income distribution of the impact of current government policies on English household energy bills in 2020.

This gives the costs per annum of three average energy bills for each income decile:

- in the absence of carbon reduction policies;
- with current government policies to reduce emissions, with the exception of products policy (i.e. assumed improvements in energy efficiency standards for appliances are excluded from the model);
- with current government policies to reduce emissions, including products policy.

As we saw in Table 1, while the overall impact of policies shows a net reduction in bills in 2020 compared with the 'no policy' option, some households will be benefiting disproportionately by receiving support or measures under certain policies, while others do not receive any of the benefits but still pay towards the policy cost through their bill. The distributional impact shown in Figure 2 suggests that higher income households are likely to benefit – in absolute financial terms – to a greater extent than lower income households when assumptions about products policy are included. In the absence of products policy assumptions, higher income households still see a reduction on their 2020 energy bill, while lower income households experience a net increase in their bill compared with the 'no policy' scenario. Thus, government policies appear most likely to benefit those households contributing most to emissions. This reflects modelling assumptions about take-up rates for renewables (expected to be higher among richer households owing to the capital costs of investment) and the policy costs passed through to electricity: lower income households are more likely to use electricity to heat their homes, which tends to be more costly than gas.

Figure 2: Average household energy bill without policies and with policies in 2020 by disposable household income decile

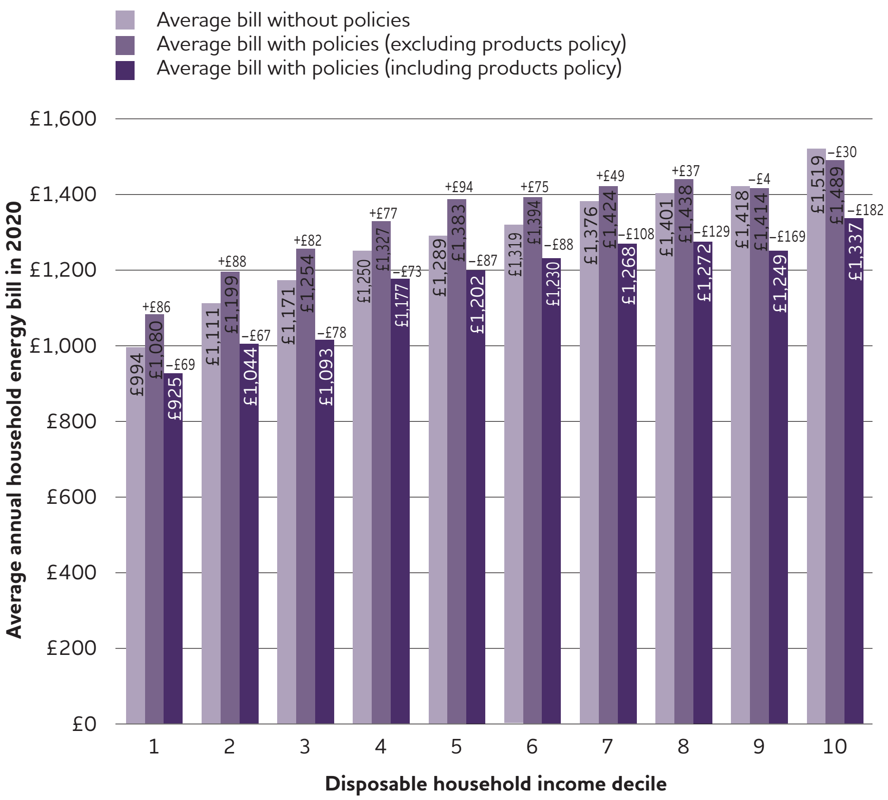
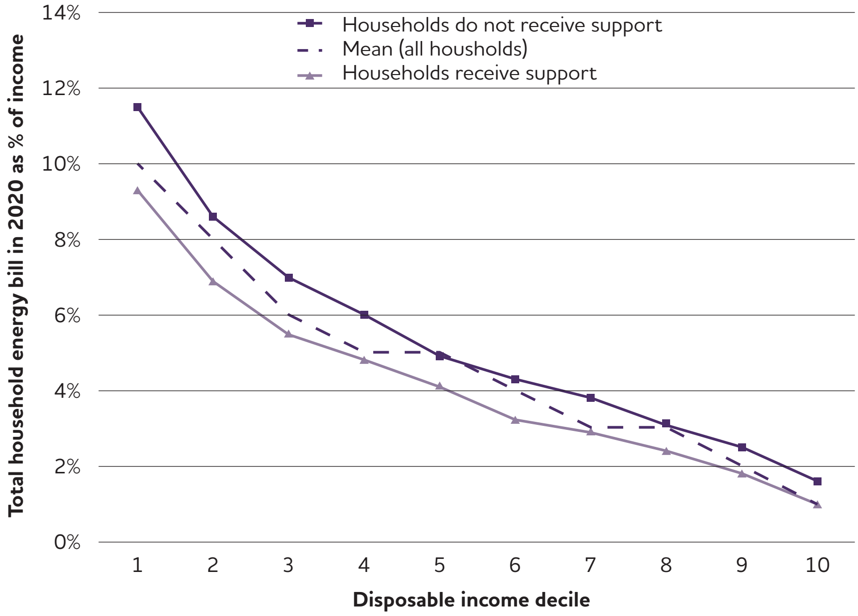


Figure 3 shows a householder's total energy cost as a proportion of their income – that is, the burden on their total expenditure. The chart shows that, on average, energy costs represent a far higher proportion of income for poorer households (around 10.5% of disposable income) than for the wealthiest households (just 1.3%). This is clearly a double injustice, with the wealthiest standing to gain the most, while the cost of purchasing energy itself represents a far smaller proportion of their household budget.

Figure 3: Total actual household energy bills in 2020 as a proportion of income, by disposable income decile and those that receive support (England)



An alternative approach

The analysis of existing government policy not only shows an unfair distributional impact, but also raises questions about effectiveness in meeting emissions reductions targets. As part of this research project, an alternative policy scenario was therefore modelled. Termed the 'maximum CO_2 abatement' policy, this scenario is based on every house in England installing the optimum combination of housing energy performance improvements (from a selection of the major energy efficiency, heating and renewable energy measures available) while attempting to avoid the regressive distributional impacts of the government's current approach. The modelling results identified a potential to reduce household CO_2 (carbon dioxide) emissions by 41% on 1990 levels by 2020 (Table 3). This is significantly higher than the projected reduction for current policies of 35% by 2020 (see Table 2).

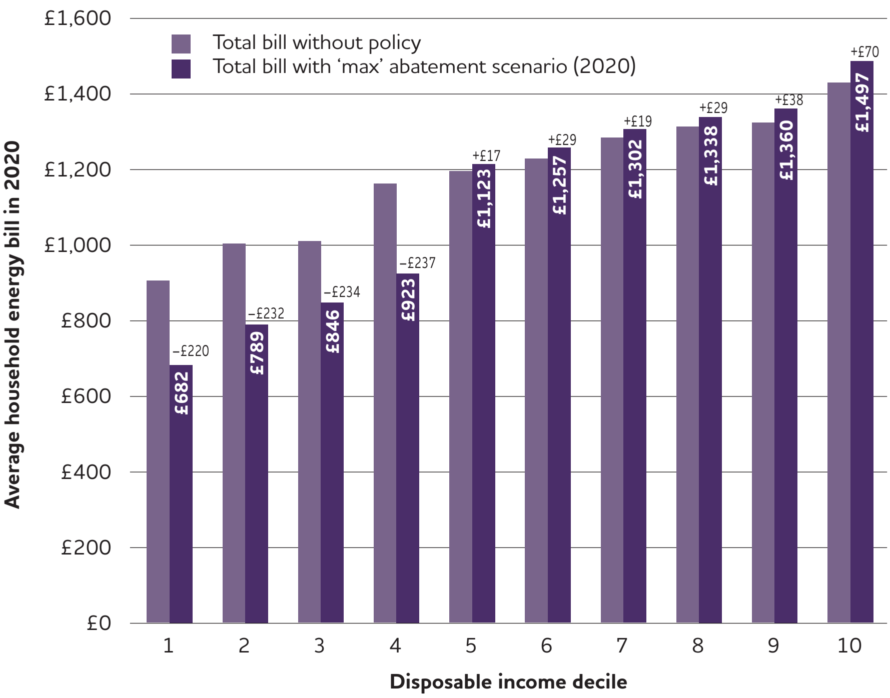
Table 3: Headline impacts on household emissions in 2020 and 2030 of an alternative policy approach to retrofitting the housing stock

	Total $MtCO_2$ emitted	Reduction vs. 1990 ($MtCO_2$)	Reduction vs. 1990 (%)
2020 alternative policy approach	69	59	41%
2030 alternative policy approach	52	77	60%

The modelling assumes measures are rolled out across the housing stock for completion in 2030. This optimisation of housing improvements results in carbon reductions of around 77 million tonnes of CO_2 by 2030, compared with 45 million tonnes from existing policies by 2020. However, cost recovery for such an ambitious and capital-intensive policy needs to be carefully designed to avoid regressive impacts. The analysis assumes that around £114 billion of the £293 billion total cost of the retrofit policy would be recovered by a Green Deal charge on energy bills for the fifth income decile and above, with the remaining £179 billion recovered from a combination of income tax, upstream carbon pricing mechanisms, and savings from means testing of the Winter Fuel Payment. While this cost is high, the programme would deliver long-term sustained benefits once the retrofit is complete from 2030, and support a reduction in fuel poverty levels. In addition, the apparently high cost needs to be considered in the context of the routine expenditure on fuel bills (and their associated carbon emissions) which the investment programme would displace.

Figure 4 shows how this investment programme reduces fuel bills for many households compared with bills without the investment. This alternative policy approach can achieve a progressive distributional outcome. Note that this looks only at the impact on energy bills – further work is required to assess the distributional impact of household contribution to policy costs from the other sources of funding, though these sources were selected based on the likelihood that they will be broadly progressive overall. This scenario includes the government's assumptions on efficiency savings resulting from products policy.

Figure 4: Distributional impacts of alternative policy approach by disposable income deciles (effect on energy bills)



Conclusions

This study set out to assess the fairness and effectiveness of current energy policies linked to climate change and, in doing so, to identify who benefits from and who pays for government energy and climate policies. The current mix of government policies has the potential to meet our carbon emission reduction targets and also to protect the average consumer from the impacts of rising fuel prices. However, current approaches to reducing household emissions appear to be less than fair in terms of the income distribution of their costs and benefits. In essence, richer households emit more than their 'share' of carbon, but contribute less than their share to the policy costs of cutting emissions.

The overall picture of policy impacts on domestic energy consumers has been described as both progressive and regressive – that is, on average we stand to benefit, but the poor, less so. The impact of the current set of policies at an individual household levels varies substantially, depending on whether or not the household benefits from the policy. In particular, the domestic Feed-in Tariff (FIT) could prove to be highly regressive if deployed to the scale suggested by the Department of Energy and Climate Change's (DECC) most recent impact assessment.

The performance of the set of policies reviewed here is key to the delivery of both emissions and bill savings: if measures or policies underperform, then domestic energy bills could rise across all income deciles. At present the 7% interest rate offered by the Green Deal Finance Company is higher than that offered by high street lenders, which is unlikely to stimulate demand from financially aware householders. The research also raises questions about the likelihood of the modelled savings from the Green Deal translating to actual reductions in energy bills.

There are also questions about the likelihood that existing policies will successfully deliver the required emissions reductions. From the analysis undertaken in this study, we can conclude that the current raft of government energy and climate change policies is likely to reduce household emissions, but this reduction is not certain and will not necessarily occur within the scale required. Government policy could be likened to a house of cards: removing one card could be catastrophic for the overall result.

If we are to achieve the current set of carbon reduction targets with the planned policies, we need to do more to support their implementation. For example, in the short term there need to be additional drivers for take-up of energy efficiency measures, such as:

- mandatory standards for rented homes from 2013 rather than 2018;
- council tax rebates for those that improve their homes;
- subsidised interest rates for Green Deal loans;
- reductions in stamp duty based on pre-sale improvements to property energy efficiency.

In the longer term, this study has shown that a more ambitious programme of work is needed to deliver carbon emissions reductions in the domestic sector beyond 2020 to meet the climate change targets of an 80% reduction on 1990 levels by 2050. The maximum annual carbon saving available from installing the major energy efficiency, heating and renewable energy measures in the English housing stock is of the order of 77 $MtCO_2$, significantly more than the 45 $MtCO_2$ annual savings expected from current policy.

This would cost around £293 billion, an amount that could be raised from a combination of a Green Deal charge for wealthier householders, income taxation, carbon revenues and means testing of Winter Fuel Payments, with progressive results. Fuel poverty, under the existing definition, would stand to fall from 3.5 million in 2010 to 2.4 million in England in 2030.

Increasing housing works would also have the effect of stimulating jobs and economic growth. Under the maximum CO_2 abatement scenario, based on the changing rates of installation for each measure, the workforce would need to rise to approximately 150,000 full-time equivalent (FTE) staff, thus creating a further 120,000 jobs. The annual expenditure on sustainable energy measures is £22 billion in 2020, with £9 billion of this being Gross Value Added[1] or economic value for the UK.

The current landscape for energy and transport policy is one of a regressive distribution of measures and costs. The challenge is therefore to encourage the progressive deployment of a housing retrofit scenario in an environment where emissions are reduced and low-income households are not unduly burdened. The above implications for avoided spending on fuel, and the opportunity to create jobs and wider economic activity, provide an additional rationale for a retrofit scenario that stimulates far deeper cuts in emissions.

1 INTRODUCTION

In the next decade there is a serious risk that the most significant social impacts of climate change in the UK will result not from climate change itself, but from the distributional consequences of the policies chosen to tackle and respond to the issue.

Understanding these consequences – and the options for moderating them – is therefore central to 'the development of socially just responses to climate change in the UK' (JRF, 2009).

Background

It is only in the last few years that researchers have begun to focus on this issue, and while their findings are beginning to feed into national policy-making, some fundamental aspects have not yet been addressed.

Work by the Centre for Sustainable Energy (CSE, 2008a) and Druckman and Jackson (2008) sought to address some of the limitations of existing datasets to facilitate more detailed and accurate analyses of the distributional impacts of climate change policies. The Expenditure and Food Survey (EFS, now the Living Costs and Food survey (LCF)) was used to create a core dataset of household emissions and associated demographic information, building on previous work by Dresner and Ekins (2004). Since then a number of other studies have used LCF data to explore the distribution of carbon emissions from both direct and indirect sources (for example, Gough, *et al.*, 2011).

CSE has also done further work developing the dataset, since used by the Department of Energy and Climate Change (DECC), through CSE's Distributional Impacts Model for Policy Scenario Analysis (DIMPSA) model, to assess the net costs on household energy bills of climate change policies. DECC (2010a and 2011a) now provides an evaluation of the distributional impacts of UK climate change policies alongside its yearly annual energy statements.

However, this approach still lacks essential components required to understand the true distributional consequences of UK climate policies, namely:

1 The dataset does not reflect household transport or aviation emissions, thereby ignoring key sources of carbon emissions with potentially significant distributional characteristics.
2 It omits detailed housing condition data, preventing an accurate assessment of the measures available to improve the energy efficiency of dwellings and reduce household energy consumption, and therefore potentially reduce negative distributional consequences of policy proposals.

As a result, investigation of the social impacts of climate policies remains partial in coverage and broad brush; results are cautious and underestimate the full range of potential effects. Policy responses are therefore likely to be crude and poorly targeted.

This project seeks to address this knowledge gap by developing, analysing and disseminating the information and tools required to enhance understanding in this increasingly important area. This will enable a wider range of researchers, policy analysts and policy-makers to explore the distributional impacts of their proposals.

This study aims to address point (1) above by developing a comprehensive dataset that includes household emissions from personal travel by private vehicle, public transport and aviation, in addition to emissions resulting from the consumption of energy in the home. While all these aspects may have been analysed in isolation previously, this is the first time such data will have been available in a single dataset for combined analyses. The results presented in this report therefore aim to show how emissions from all these sources are distributed across households in Great Britain.

To address point (2) above, this study adopts a second phase, bringing together further data sources to enable analysis of actual household energy consumption and resulting emissions alongside opportunities for energy efficiency and renewable energy measures. This therefore provides new avenues for analysing the distributional impacts of government policies on household energy bills and the opportunities to improve the sustainability of the housing stock (and thereby reduce emissions to support climate change mitigation policies). Due to data limitations, this phase of the analysis is limited to England only.

Aims, objectives and key stages

This project aims to:

- assess the fairness and effectiveness of current UK climate change policies;
- support the development of a more socially just approach to reducing direct emissions from the domestic sector.

In order to fulfil these aims, the main objectives of this study are to:

- reveal, in detail, the distribution of carbon emissions across households in Great Britain, taking account of the consumption of energy in the home and travel by private vehicle, public transport and aviation;
- explore the distributional consequences across households in England of a wide range of current, proposed and possible future policies designed to mitigate household energy carbon emissions. The impact of policies is explored in terms of actual energy consumption in the home, and associated emissions and energy bills.

Outline of key stages

This study addresses the two objectives above through two distinct phases, drawing on several different data sources, as outlined below.

Phase 1: Objective 1

1. Use national survey data to build a dataset representative of carbon dioxide (CO_2) emissions from the consumption of household fuels (for heat and power) and all personal travel used for leisure or commuting purposes (including by private vehicle, public transport, domestic and international aviation) by households in Great Britain (separate document: Technical Report 1).
2. Analyse the dataset developed in (1) to explore the distribution of household carbon emissions from all direct sources (Chapter 4 and separate document: **Project Paper 1**).
3. Explore the relationship between emissions from personal travel and accessibility to services and public transport (separate document: **Project Paper 2**).

Phase 2: Objective 2

4. Develop a dataset representative of the English housing stock to include data on household energy requirements and actual household energy consumption to model and show the distribution (opportunities, costs and benefits) of measures to reduce household carbon emissions ('abatement' measures) (separate document: **Technical Report 1**).
5. Use the dataset developed in (4) to model and reveal the distributional impacts (costs and benefits) of existing government climate and energy policies on household energy consumption and associated bills for households in England (Chapter 5).
6. Model an alternative policy scenario to explore the potential for, and likely distributional impacts of, retrofitting the housing stock, while minimising the cost implications for householders (Chapter 6).
7. Consider the implications of the policy impacts revealed in (5) and (6) for fuel poverty in England, using both the existing and proposed new definition of fuel poverty (Chapter 7).
8. Provide a final analysis to contribute to the discussion of policy and social justice implications by exploring the distributional impacts of a personal carbon allowance system that includes household-level emissions from personal travel (separate document: **Project Paper 3**).
9. Provide conclusions and recommendations on the overall fairness and effectiveness of government energy and climate change policies in the context of impacts on domestic energy consumers and household emissions (Chapter 8).

Report structure

As outlined above, this project incorporates several key stages of modelling to create two separate datasets used in the final analysis. An overview of the methodology is presented in Chapter 3 of the report.

The report focuses principally on exploring the fairness and effectiveness of government policies to tackle climate change in terms of the impact on domestic energy consumers and energy consumed in the home. A summary of the results from each stage of the analysis is presented in its own chapter to support the key messages and conclusions drawn in this context. However, some additional analysis has been undertaken, utilising the datasets developed through this study, to explore in more detail the distribution of household emissions from all sources, including transport. Supplementary appendices, published as separate documents alongside this report, provide additional detail on these analyses and are listed in Appendix 2. A full, detailed report on the datasets and methodology applied in this study is also available as a separate document which can be downloaded from CSE's website (see **Technical Report 1**, via Appendix 2).

This report and accompanying outputs are therefore structured as follows:

- Chapter 2: Policy context
- Chapter 3: Methodology and approach
- Chapter 4: Distribution of household carbon emissions in Great Britain
- Chapter 5: Distributional impacts of government climate change and energy policies on domestic energy consumers
- Chapter 6: Modelling an alternative housing stock retrofit policy scenario
- Chapter 7: Policy modelling implications for fuel poverty
- Chapter 8: Conclusions
- Chapter 9: Gaps and further work
- Appendix 1: Policy modelling assumptions
- Appendix 2: Supplementary project documents (web links)

2 POLICY CONTEXT

The Climate Change Act 2008 established a long-term framework to tackle climate change. The Act aims to encourage the transition to a low-carbon economy in the UK through unilateral, legally binding emissions reduction targets.

It requires a reduction of at least 34% in greenhouse gas emissions by 2020 and at least 80% by 2050 (on 1990 levels). The Climate Change Act also led to the creation of the Committee on Climate Change (CCC), an independent, expert body to advise the government on the level of carbon budgets – that is, on caps to carbon emissions and on where cost-effective savings can be made.

Tackling climate change: UK emissions reduction targets

The carbon budgets each run for a five-year period. The first three carbon budgets were set in statute in 2009, and run from 2008–12, 2013–17, and 2018–22. The fourth, running from 2023–27, was set in law at the end of June 2011.[2]

Box 1: UK carbon budgets

A 'carbon budget' is a cap on the total quantity of greenhouse gas emissions emitted in the UK over a specified time.

Under a system of carbon budgets, every tonne of greenhouse gas emitted between now and 2050 will count. Where emissions rise in one sector, corresponding reductions will have to be achieved in another to ensure the overall cap is maintained.

Four carbon budgets have now been set to cover five-year periods: 2008–12; 2013–17; 2018–22; 2023–27.

The carbon budgets therefore set the trajectory for achieving the UK's unilateral, legally binding targets for a reduction in greenhouse gas emissions of at least 34% by 2020 and at least 80% by 2050 (as set out in the Climate Change Act 2008).

$MtCO_2e$ by budget	First carbon budget (2008–12)	Second carbon budget (2013–17)	Third carbon budget (2018–22)	Fourth carbon budget (2023–27)
Legislated (five-year) budgets	3,018	2,782	2,544	1,950
Average annual budget	604	556	509	390
Average annual reduction on 1990	180	227	274	393
Average annual percentage reduction from 1990	23%	29%	35%	50%
Total 1990 baseline UK greenhouse gas emissions	783.1			

Source: DECC, 2011b, Annex B: Carbon budgets analytical annex; Table B1: UK's legislated carbon budgets ($MtCO_2e$)

The Carbon Plan (DECC, 2011b) sets out the UK's plans for achieving the emissions reductions committed in the first four carbon budgets up to 2027. By achieving these, the government will be on course to reduce UK emissions by 80% from 1990 levels by 2050. These targets reflect the increasingly urgent need to reduce carbon emissions, and the UK carbon reduction policy framework is likely to have to become increasingly aggressive if we are to achieve them.

Transport policy

In the UK, although economy-wide emissions reductions of 18% were achieved between 1990 and 2007, domestic transport emissions increased by 11% over the same period, reaching 135 $MtCO_2$ in 2007, comprising 24% of total UK domestic emissions (CCC, 2009). The largest share of UK transport emissions is from road passenger cars at 86%, followed by buses at 4%, rail at 2% and domestic aviation at 2%. Importantly, these transport emissions totals do not include an estimated 38 $MtCO_2$ from international aviation, which, if accounted for, would increase the contribution of transport to total UK emissions (Jackson, *et al.*, 2009). Therefore, without a significant contribution from the transport sector, the 80% reduction target for 2050 is unlikely to be achieved. If aviation were included in our carbon budget, the challenge for reducing transport emissions would be even starker.

The conventional transport policy response to this issue focuses on supply-side vehicle technology efficiency gains and fuel switching. In the UK, electric vehicles (EVs) are seen as an essential part of decarbonising our road transport system, with the CCC envisaging 1.7 million in use by 2020 and 10 million by 2030 (CCC, 2010). The WWF-UK report (2011) stretch target calls for 26.3 million EVs by 2030, which would result in additional electricity demand of 29,000 GWh (around 20% of current supply (DECC, 2010b)).

However, currently (by 2012) only 611 pure electric fuelled cars have been bought, alongside 1,220 total alternatively fuelled vehicles, with a larger number (15,170) of hybrid vehicles (SMMT, 2012).

Many of the technological responses that are required to reduce transport emissions are not yet commercially mature, or require major infrastructure investment. This has therefore reinforced the notion that the transport sector can only make a limited contribution to the total CO_2 emissions reduction, particularly in the short term (Koehler, 2009; Stern, 2006).

There is, however, a growing evidence base, or even just a renewed appreciation of existing evidence, of the potential for behaviour change in travel to deliver plausible and cost-effective emissions reductions (see Gross, *et al.*, 2009). Achieving high levels of accessibility to shops, markets, employment, education, health services, and social and community networks is essential for health, quality of life and social inclusion (Woodcock, *et al.*, 2007). An increase in the use of public transport, combined with a decrease in the use of private cars, could reduce traffic congestion and, more importantly, CO_2 emissions, as public transport generally causes lower CO_2 emissions per passenger kilometre than private cars. A sustainable model for transport policy also requires integration with land-use policies. These may be somewhat limited within the bounds of existing cities, but as cities grow and new cities are built, urban planners must put more emphasis on land use for sustainable transport in order to reduce congestion and CO_2 emissions. Sustainable land-use policy can direct urban development towards a form that allows public transport as well as walking and cycling to be at the core of urban mobility.

While this report focuses principally on understanding the impacts of climate change policies in the residential sector, household emissions from personal travel by all modes (private vehicle, public transport and aviation) are included in the analysis of the distribution of household emissions presented in Chapter 4.

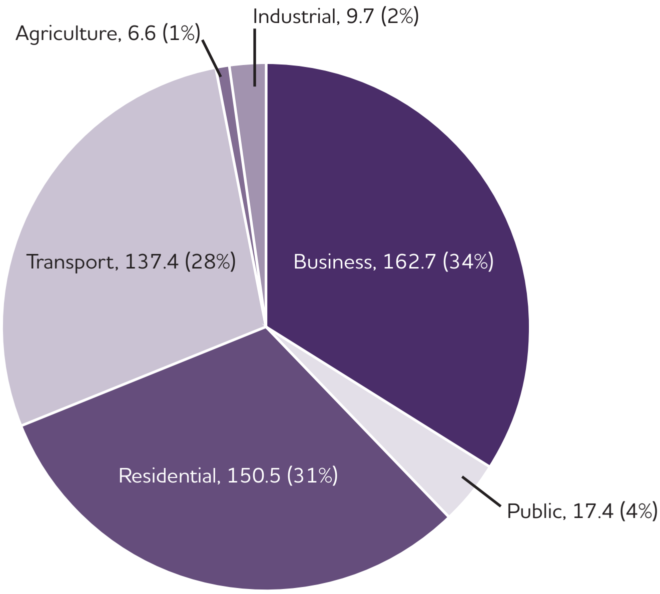
A separate document presents some analysis exploring the relationship between travel emissions and accessibility to public transport and local services. The analysis shows that accessibility in relation to a household's location had only a marginal effect on explaining the variation in total land-based transport CO_2 emissions. The overriding drivers of higher emissions were higher socio-economic status,[3] larger household size and also the household reference person being in full-time or part-time employment. The results suggest that, in isolation, improving accessibility to public transport is unlikely to reduce emissions associated with car use. (See **Project Paper 2:** Exploring accessibility to public transport and local services and its role in determining travel CO_2 emissions in Great Britain, via Appendix 2: Supplementary project documents.)

Domestic energy policy

In 2010 the residential sector accounted for some 31% of the UK's carbon emissions (see Figure 5). A number of policies aim to reduce emissions from the consumption of energy in the home. These include policies targeted 'upstream' (aimed at decarbonising the supply of energy) and at households directly (at point of use in the home, such as by improving the thermal efficiency of dwellings). Refer to the 'Policy glossary and overview' on pages 128–32 for the different policies.

In 2010 the residential sector accounted for some 31% of the UK's carbon emissions.

Figure 5: 2010 UK CO_2 emissions estimates by end user ($MtCO_2$)



Source: DECC (2010b). Final UK Figures (last updated 29 March 2012); Table 4: Estimated emissions of carbon dioxide (CO_2) by National Communication source category, type of fuel and end-user category, 1970–2010

Until relatively recently, UK government policies to reduce household emissions and alleviate fuel poverty have focused on providing grant-based financial support for the installation of energy efficiency measures – typically loft and cavity wall insulation, and heating replacement.

The Warm Front Scheme has been the government's principle means of tackling fuel poverty in England since 2001 (funded through general taxation) but will end in 2013.[4] Similar schemes operate in Wales (under the name Home Energy Efficiency Scheme) and Scotland (Warm Deal). Warm Front has offered funding to low-income households (according to certain means-tested benefits eligibility criteria) for heating and energy efficiency measures in England. In Wales (Arbed – strategic energy performance investment programme) and Scotland (Energy Assistance Package), public finances will continue to be used to support energy efficiency schemes for their own fuel-poor householders.

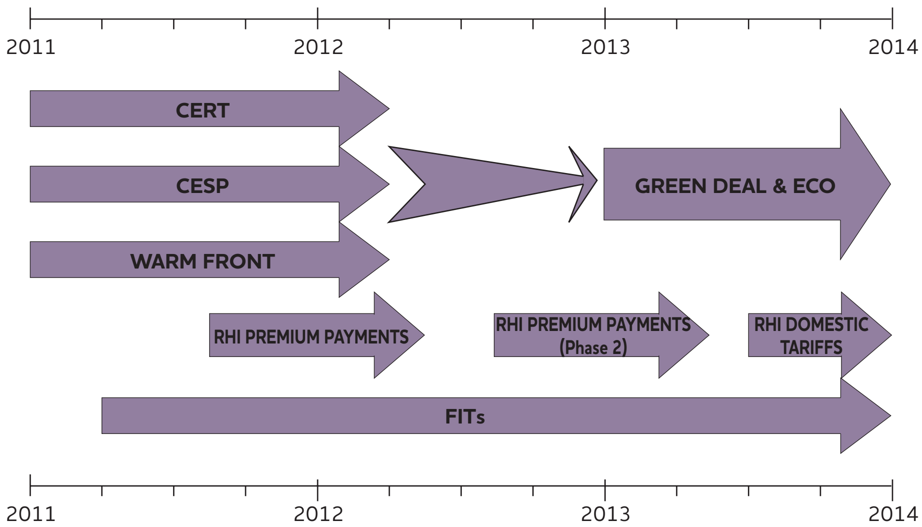
The Decent Homes Programme (2001–10) was the government's programme aimed at improving the condition of homes for social housing tenants and vulnerable households in private sector accommodation in England. The programme included measures to make people's homes warmer, which have improved the energy efficiency of social housing. The Decent Homes Standard, required for social housing, sat alongside a stream of funding that was linked to local authorities transferring their stock to a registered social landlord (RSL).

Alongside (and indeed preceding) these government-funded schemes, policies have been in place to obligate energy suppliers to achieve targets for improving home energy efficiency. The Energy Efficiency Standards of Performance (EESOP) were introduced in 1994 and have since been superseded by the Energy Efficiency Commitment (EEC-1 in 2002–05 and EEC-2, 2005–08) and latterly by the Carbon Emissions Reduction Target (CERT, 2009–12). These policies have translated into a range of financial offers from energy suppliers (operating in Great Britain and with a customer base over a specified threshold) to support householders installing energy efficiency measures.

The Community Energy Saving Programme (CESP) was introduced in 2010, placing a further obligation on energy suppliers (and generators) to support the installation of measures in areas of deprivation, with particular emphasis on solid wall insulation.

However, in more recent years the policy environment for supporting energy efficiency retrofit in the domestic sector has been undergoing significant change (see Figure 6); a change that at least in part reflects the changing economic and political environment in the UK.

Figure 6: Household energy policies in the UK – current policy timeline



In 2010 came the introduction of the Feed-in Tariff (FIT), a scheme introduced under the powers of the Energy Act 2008 and aimed at providing financial incentives for the installation of small-scale (<5 MW) low-carbon electricity generation technologies. A similar policy aimed at providing financial return for the generation of small-scale renewable heat – the Renewable Heat Incentive (RHI) – was launched in November 2011 for the non-domestic sector and will be expanded to the domestic sector from summer 2013. Preceding this, an initial phase, the Renewable Heat Premium Payment (RHPP) scheme, was introduced in 2011, offering short-term, grant-based 'vouchers' for the installation of domestic renewable heat technologies.

In October 2012 the government launched its new flagship scheme – the Green Deal – which paves the way for a very different approach to financing the installation of energy efficiency, heating and renewable energy measures in the UK's housing stock.

The Green Deal, together with the Energy Company Obligation (ECO), replaces the CERT commitment and Warm Front Scheme as the government's new flagship initiative to underpin the installation of energy efficiency improvements in the domestic sector. It sets out a framework to enable private firms to offer consumers energy efficiency improvements to their homes, community spaces and businesses at no upfront cost, and recoup payments through a charge in instalments on the energy bill (tied to the property, not the householder). Green Deal finance will only be available where the *expected* financial savings are equal to or greater than the costs attached to the energy bill, known as 'the Golden Rule'. Where the Golden Rule is not met (if the cost of the work outweighs the savings), or people need extra financial help, energy companies will be able to offer additional support to top up the loan under the ECO.

There are two elements of the ECO: Carbon Saving (which includes the Carbon Saving Communities obligation) and Affordable Warmth. The ECO is intrinsically linked to the Green Deal and involves energy suppliers providing funds that will be used to support: lower income and vulnerable households where the Green Deal is less likely to work (under the 'Affordable Warmth Group'); and action on 'hard-to-treat' properties where recommended measures are less likely to meet the Golden Rule (under the Carbon Saving Obligation).

The Energy Act 2011 represents the most recent government legislation designed to support household emission reductions. It provides for some of the key elements of the government's Climate Change Plan, namely Electricity Market Reform, mandatory energy efficiency standards in the private rented sector, the Green Deal and the ECO. The Energy Act provides specific powers to ensure the ECO works alongside the provision of Green Deal finance for those households containing vulnerable people on low incomes and in hard-to-treat housing.

The UK government policies contained in the Climate Change Act 2008 and the Energy Act 2011 to reduce CO_2 emissions do not impact UK households uniformly. Each policy has a different delivery model, is targeted at different household types and has varying levels of associated costs and benefits. Where policies are not paid for through general taxation, the costs are passed on to consumers (domestic and non-domestic) through their energy bills. Household characteristics interact with various aspects of the design, implementation and uptake of such policies to determine the way individual households, and groups of similar households, pay for these costs and/or stand to benefit. For example, the FIT generates a revenue stream for households able to overcome the capital barriers to take advantage of the opportunity presented by the policy. However this revenue (the cost of the policy) is recovered through the electricity bills of all households. If higher income households take up the FIT at a greater rate than lower income households – as might be expected given the capital costs of technology installation – then the FIT can be expected to have a regressive distributional impact. That is, wealthier households benefit from the policy while poorer households bear a disproportionate amount of the policy costs. Chapter 5 of this report looks in detail at the distributional impacts of existing government energy and climate change policies across households in England.[5]

The UK government policies contained in the Climate Change Act 2008 and the Energy Act 2011 to reduce CO_2 emissions do not impact UK households uniformly.

Fuel poverty

Alongside the level of spend on energy *actually* consumed in the home, government legislation dictates consideration of householders' spend *required* to keep adequately warm. The Warm Homes and Energy Conservation Act 2000 required the publication of a strategy setting out policies to ensure that, as far as reasonably practicable, no-one lives in fuel poverty. A household is defined as 'fuel poor' if it needs to spend more than 10% of its income on fuel in order to maintain an adequate level of warmth. Fuel poverty is therefore based on *modelled* spending on energy, rather than on *actual* spending.

The government's UK Fuel Poverty Strategy (DECC, 2001) set an interim objective of eradicating fuel poverty in vulnerable households as far as reasonably practicable by 2010. Under the terms of the Warm Homes and Energy Conservation Act, no household should be in fuel poverty as far as reasonably practical by 2016.

The 2010 target has not been met. Some 2.8 million vulnerable[6] households and 3.5 million households in total across England were classed as fuel poor in 2010, equating to some 4 million and 4.75 million in the UK respectively (DECC, 2012a).

At the Spending Review in October 2010, the government announced it would commission an independent review of the fuel poverty target and definition. The terms of reference for the Fuel Poverty Review (DECC, 2012a) were 'to consider fuel poverty from first principles: to determine the nature of the issues at its core, including the extent to which fuel poverty is distinct from poverty more generally, and the detriment it causes'.

Based on the findings, the Fuel Poverty Review aimed to develop possible formulations for a future definition and any associated form of target that would best address the underlying causes identified; help government focus its resources and policies on those who need most support; measure the cost effectiveness of different interventions in contributing to progress towards any target; and develop practical solutions.

The Hills Review (Hills, 2012) concluded with a proposed 'low income, high cost' (LIHC) definition of fuel poverty, using the wording of the Warm Homes and Energy Conservation Act, such that 'a person is to be regarded as living "in fuel poverty" if he is a member of a household living on a lower income in a home which cannot be kept warm at reasonable cost'.

The LIHC indicator of fuel poverty applies the following thresholds:

- the low-income threshold, which defines those households that are in income poverty after excluding their required fuel costs;[7]
- the energy cost threshold, which is set at the median of total energy costs for a household (equivalised for household size).

The LIHC definition also includes an additional method of measuring fuel poverty – the 'fuel poverty gap' – which provides a measure of the severity of fuel poverty. This is the amounts by which the assessed energy needs of fuel poor households exceed the threshold for reasonable costs. The government ran further consultation on the proposed new definition from September to November 2012, the outcome of which is pending.

The impacts of domestic energy policies

Designing policies to address the issues of both climate change and fuel poverty poses a significant challenge. It is therefore essential that we understand the social distributional impacts of existing and proposed energy and climate policies on households in the context of their impact on fuel poverty. Then, we can feed this understanding back into the policy design process, which is a fundamental requirement if we are to implement policies that:

- reduce (or at the very least, avoid exacerbating) the hardship faced by fuel-poor households;
- are fair, and are seen to be fair, which is a likely precondition for successful carbon reduction policies.

This necessitates modelling both the impact of policies on actual household energy bills and the impact in fuel poverty terms – that is, on the 'required' energy bill. To model the latter, detailed information is needed about the physical characteristics of the property. To date, dataset limitations have prevented such analysis: a limitation that this study seeks to address. Our analysis therefore explores both the 'fairness' of policy (who benefits and who pays?) and the 'effectiveness' in meeting government targets (both for delivering carbon emissions reductions and reducing fuel poverty).

The report is structured to address each of the following questions:

- **Who emits most?** An analysis of the distribution of carbon emissions across households in Great Britain, including emissions from the consumption of household fuels and personal travel (including international aviation).
- **Who benefits from and who pays for energy and climate policies?** An analysis of the impacts on energy bills of existing government energy and climate change policies and alternative policy options for households in England.
- **How can we maximise carbon emissions reductions in the English housing stock?** An analysis of where emissions savings could be made in the household sector and how the costs of this can be recovered fairly.
- **How do policies impact on the fuel poor?** An analysis of the impacts of existing policies, and the likely impacts of an alternative policy scenario, on household required spend on fuel (using the existing and proposed new definition of fuel poverty) for households in England.

Throughout the report we focus particularly on the implications of policies for 'vulnerable' households. We have not adopted one single definition of 'vulnerable', but rather explore the distributional impacts of policies on people, considering a range of key socio-demographic characteristics including income, age, household composition (e.g. lone parents, single, elderly), location (urban vs. rural) and fuel-poverty status.

3 METHODOLOGY AND APPROACH

Perhaps surprisingly, given the urgency of the need to reduce carbon emissions to meet our legal targets, there is at present no unified dataset representing household carbon emissions from all direct sources.[8]

This research project seeks to address this gap by drawing on data from a number of different nationally representative surveys and combining these to create a single 'synthetic', representative dataset.

Overview

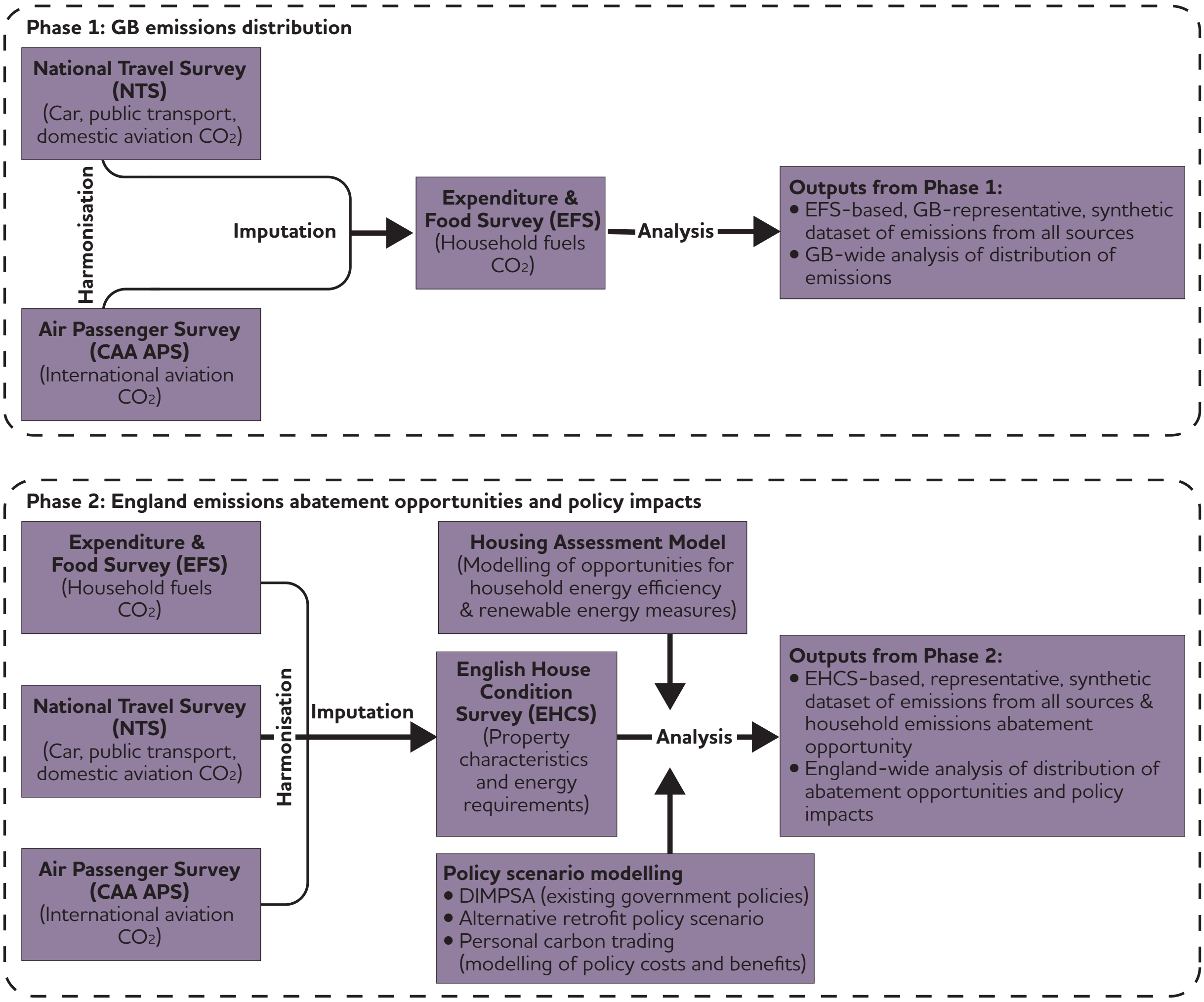
The project methodology comprises two distinct phases, illustrated in Figure 7 and summarised below. A more detailed description of the method employed in this study is included in a separate document (**Technical Report 1**, via Appendix 2).

Phase 1: Distribution of emissions

The first phase of this study seeks to present detailed analysis of the distribution of carbon dioxide emissions from the consumption of household fuels and all personal travel (by car, public transport, and domestic and international aviation) by households in Great Britain, by drawing on several different data sources. The Expenditure and Food Survey (EFS) is used to derive estimates of CO_2 from the consumption of household fuels (based on expenditure data in the survey). Additional data is imputed to this EFS dataset from two further surveys (the National Travel Survey and the Civil Aviation Authority Air Passenger Survey, see below) to provide information on emissions from personal surface travel and aviation.

This dataset is then analysed to reveal the distribution of emissions across GB households by a range of socio-demographic descriptors available in the EFS dataset. As far as we are aware, this is the first integrated analysis of emissions from all these sources based entirely and directly on nationally representative survey data. The analysis provides new evidence and insight

Figure 7: Methodological approach



into who is responsible for emitting how much carbon dioxide, and identifies the relative contributions of different aspects (energy consumption in the home, private road travel and aviation) of household carbon emissions. Some headline results from this analysis are presented in Chapter 4, with the full and detailed results presented in a separate report (see **Project Paper 1:** The distribution of household CO_2 emissions in Great Britain, via Appendix 2).

Phase 2: Distribution of policy impacts and abatement opportunities

The second phase of the project is designed to create a second synthetic dataset, again representative of household carbon emissions (from all sources described above), but to include data on opportunities for households to reduce their household energy emissions. To model and analyse these opportunities (for example, the potential for different types of insulation or renewable energy measures, referred to as the household 'abatement opportunity'), detailed information is needed about the physical characteristics of the property. The English House Condition Survey (EHCS) is therefore used as the 'core' dataset for this phase of the project (and analysis is therefore limited to England only). However, the EHCS dataset does not include data on actual household fuel consumption necessary to model the impact of policies (rather it provides data on modelled household energy requirements). Data on CO_2 resulting from all energy actually consumed in the home is therefore imputed from the EFS, with the additional data on emissions from personal travel again imputed from the two travel surveys (as in Phase 1). The resulting dataset therefore contains all the detailed property characteristics and socio-demographic data within the EHCS, along with imputed estimates of actual household emissions from the consumption of household fuels and all personal travel. This dataset is used to analyse the distributional impacts of government climate policies and households' opportunities to reduce their emissions through the installation of the key energy efficiency, heating and renewable energy measures.

Each of the datasets used in this study is described further below, with a brief overview of how survey data has been used to derive estimates of household carbon emissions. Full details on the methodology applied in compiling the final datasets used in the analysis are included in separate documents (see Appendix 2: Supplementary project documents).

Creating the datasets

The two phases of this study require different input datasets. To understand the distribution of household carbon emissions resulting from consumption of energy in the home and personal travel, a dataset is needed to represent CO_2 emissions from the consumption of energy in the home, private road transport, public transport,[9] and aviation at the household level.

To model the likely impacts of government energy and climate policies on household energy bills and fuel poverty levels (Phase 2 of this study), a quantitative representation is needed of:

- estimates of actual and required household energy consumption and how this translates into carbon emissions and energy bills;
- detailed information about housing condition and characteristics, and hence opportunities for energy efficiency, heating and renewable energy measures to reduce household carbon emissions.

The information outlined above exists within, or is derivable from, a number of different survey datasets, representative of either UK, GB or England households, as shown in Table 4 below. (Note that while the EFS and APS have UK coverage, the NTS is limited to GB only. As a result, a subset of the two former surveys to include GB only is used in this study.)

Each of the surveys listed above is undertaken independently and therefore exists as a distinct dataset. However, they are all designed to be representative of the area they cover (UK, GB or England only) through sampling and weighting design, and they each contain socio-demographic information (for example, household income, dwelling type, tenure).
Using variables common to two or more datasets, it is possible to develop imputation models to take (or rather 'impute') data from one survey into another. There are four key stages in the multiple imputation approach:

1. **Derive carbon emissions estimates from survey data:** taking survey data such as actual household expenditure on heating fuels (in the EFS), or annual distance travelled by private car for leisure purposes (in the NTS), methods were developed to apply relevant carbon emissions factors (using the 2010 Defra CO_2 emissions factors available at the time of the study[10]) to give an estimate of annual emissions at the household level (see Table 4).

Table 4: Summary of surveys used to derive emissions estimates

Survey	Input (raw survey data)	Output
Expenditure and Food Survey (EFS)	Expenditure on all household fuels	Annual consumption of all household fuels (kWh) and associated CO_2 emissions ($kgCO_2$) for GB households
National Travel Survey (NTS)	Private vehicle mileage Distance travelled – public transport Distance travelled – domestic flights	Annual CO_2 emissions from all personal (non-business) travel by private vehicle, public transport and domestic aviation for GB households
CAA Air Passenger Survey (APS)	Start airport, destination airport (international only) and flight class for all GB leisure passengers	Distance travelled and associated CO_2 emissions from (non-business) international aviation for GB households
English House Condition Survey (EHCS)	Physical property characteristics needed to assess the thermal performance and energy requirements of a dwelling	Estimates of household energy requirements and associated carbon emissions and costs – and therefore fuel poverty status – for households in England

2 **Survey harmonisation:** before the imputation can be undertaken, the surveys need to be 'harmonised'. This essentially means ensuring that key concepts used in each of the surveys are defined and measured in the same way. For example, income can be defined as disposable, gross and so on, but must be defined in the same way if it is to be used to impute data from one survey dataset to another. The full technical report on the survey harmonisation process, including a list of which variables were harmonised, is available as a separate document via Appendix 2.

3 **Use multiple imputation techniques** to impute carbon emissions data from one survey to another. This process involves developing predictive models where the 'predictor' variables include the harmonised socio-demographic variables. Several different imputation models had to be developed for the purpose of this study – one for each of the variables imputed to (a) the EFS (Phase 1 of this study) and (b) the EHCS (for Phase 2). Table 5 shows which variables were imputed to the EFS and EHCS, respectively. Each of these represents an imputation model in itself.

4 **Post-imputation adjustments** to match original survey sum totals ('re-grossing').[11] The multiple imputation process imputes data to replicate the distribution of emissions in the source dataset, based on harmonised variables in the surveys. However, the imputed values will not necessarily sum to give the same total as derived from the donor survey (owing to survey weightings). While this issue is immaterial in terms of the distribution of emissions, it is of fundamental importance for the modelling of policy impacts. The team therefore developed a methodology to adjust the imputed values in the resulting surveys (that is, the EFS in Phase 1 and EHCS in Phase 2) such that the sum totals of the imputed values correspond with those of the original surveys (for the equivalent population – GB for the EFS, England only for the EHCS).

Table 5: Variables imputed to the EFS and EHCS datasets

Phase 1: EFS-based dataset	Phase 2: EHCS-based dataset
Variables imputed from the NTS: • CO_2 public transport – commute • CO_2 public transport – leisure • CO_2 private vehicle – commute • CO_2 private vehicle – leisure • CO_2 domestic aviation	Variables imputed from the NTS: • CO_2 public transport – commute • CO_2 public transport – leisure • CO_2 private vehicle – commute • CO_2 private vehicle – leisure • CO_2 domestic aviation • Number of cars/vans
Variables imputed from the APS: • CO_2 international aviation (non-business) • A variable to flag non-flying households • Number of short-haul flights to Europe in past year • Number of long-haul flights further than Europe in past year	Variables imputed from the APS: • CO_2 international aviation (non-business) • A variable to flag non-flying households • Number of short-haul flights to Europe in past year • Number of long-haul flights further than Europe in past year
	Variables imputed from EFS: • CO_2 from heat load • CO_2 from power load • Total number of appliances in household

Box 2: Modelling emissions from domestic aviation

The estimates for emissions from domestic flights have been derived from the National Travel Survey 'long-distance journey' dataset (National Travel Survey, 2012). The sample representing domestic flights is small, hence these results have to be treated with some caution. As only a very small proportion of the population appears to take any domestic flights (and this contributes less than 1% of the total emissions mix in the dataset), the household level mean appears negligible, to the point of being somewhat meaningless (see Table 10 in the following section on the distribution of emissions). In reality, a high proportion of households will have zero emissions from domestic aviation (those that never take domestic flights) while a small proportion of the population will have much higher annual emissions from flying within the UK.

The 'final' datasets

The methodology developed and applied in this study was designed with the specific aim of creating two distinct datasets, representative of household carbon emissions in Great Britain and England respectively. Some key statistics describing the final datasets used in the analysis in this study are shown below.

Table 6 shows the number of households represented in each dataset (the 'weighted count'); the sum total of emissions across all households in the dataset (that is, representing the population of GB or England); and average (per household) estimates of carbon emissions. The two datasets are synthetic to the extent that data has been imputed from external sources, and they represent different timeframes; hence they cannot be considered directly comparable. However, some conclusions can still be drawn from the results: for example, the figures are indicative of the proportional contributions to emissions from each country in Great Britain. A comparison of the estimated figures for emissions from household fuels shown below suggests Scotland and Wales contribute some 19% of the total mix. This is slightly higher than the 15% total domestic energy consumption derivable from DECC's tables of 'Total sub-national final energy consumption: 2007 in GWh' (2011c). However, the figures in Table 6 represent carbon emissions, not energy (kWh). Coal – a carbon-intensive fuel – is more prevalent in Wales and Scotland with total GWh consumption in these two countries representing over 30% of the Great Britain total (DECC, 2011c).

Table 6: Household emissions estimates from survey modelled data

	GB EFS dataset (2004–07)		**England EHCS dataset (2006–07)**	
	Sum ($MtCO_2$)	**Household mean ($kgCO_2$)**	**Sum ($MtCO_2$)**	**Household mean ($kgCO_2$)**
Household fuels total	137	5,675	111	5,190
Private car total	64	2,644	57	2,657
Public transport total	7.3	302	6.6	307
Domestic aviation	0.8	33	0.4	17
International aviation	29	1,182	24	1,124
Total emissions	238	9,836	199	9,296
Weighted count of households ('000)[a]	24,207		21,380	

Note: [a] annual survey weight adjusted to allow for multiple years in the dataset

Table 7 shows further comparison of our modelled emissions estimates (as shown in Table 6) with totals derived from survey data used in this study. The UK sectoral emissions estimates published by DECC (2011d) are shown in the right-hand column of the table. It should be noted that no attempt has been made to reconcile the two, given the very different methodologies ('bottom-up' versus 'top-down'), purposes and population they represent. This is particularly an issue for international aviation: the DECC figures used for comparison here represent 'Emissions from international aviation and shipping estimated from refuelling from bunkers at UK airports and ports (whether by UK or non-UK operators)' whereas our modelling uses survey data of UK passengers travelling for leisure purposes only.

What the figures clearly show, however, is that emissions from household fuels make up over half (about 57%) of the total emissions mix being explored in this study; hence this is the main area of focus. Table 8 and Table 9 show the average and range[12] of incomes in each disposable decile for the EFS and EHCS datasets respectively. These are shown for reference, as all sections of this report present results by different income groups.

Table 7: Emissions estimates derived from survey data compared with national figures

$MtCO_2$	Source survey	Years	GB	England	National UK data (2007)	Source and notes[13]
Household fuels	EFS	2004–07	137.4	111	149.8	DECC (a): Residential combustion, by final user
Private car	NTS (vehicle)[a]	2002–06	64	56.8	74.3	DECC (a): Passenger cars & motorcycles, by source
Public transport	NTS (journey)[a]	2002–06	7.3	6.6	6.4	DECC (a): Buses and rail, by source
Domestic aviation	NTS (LDJ)[a]	2002–06	0.73	0.36	2.3	DECC (a): Domestic aviation, by source (cruise, landing, take-off)
International aviation	CAA APS	1999–2008	26.7	24	35.4	DECC (b): CO_2e from UK international aviation bunkers

Source: DECC (2011d) (a) Table 4: Estimated emissions of carbon dioxide (CO_2) by National Communication source category, type of fuel and end-user category, 1970–2010. Values shown are for 2007.
DECC (2011d) (b) Table 8: Greenhouse gas emissions arising from use of fuels from UK international aviation bunkers. Values shown are for 2007.
Note: [a] the NTS survey includes a number of different datasets. The 'vehicle', 'journey' and 'long-distance journey' (LDJ) datasets were used to obtain the necessary data as indicated here. Full details are provided in the separate project technical report (**Technical Report 1**) via Appendix 2.

Table 8: Income deciles in the EFS dataset – households in Great Britain

Disposable income decile	EFS (2004–07)			
	Count of households ('000)	N %	Mean	Range
1	2,421	10%	£5,070	£0–7,179
2	2,420	10%	£8,895	£7,180–10,537
3	2,421	10%	£12,158	£10,538–13,894
4	2,421	10%	£15,726	£13,895–17,685
5	2,421	10%	£19,731	£17,686–21,818
6	2,420	10%	£24,052	£21,819–26,394
7	2,421	10%	£28,926	£26,935–31,682
8	2,420	10%	£35,023	£31,683–38,841
9	2,421	10%	£44,019	£38,842–50,846
10	2,420	10%	£74,060	£50,847–1,885,978
Total	**24,207**	**100%**	**£26,765**	

Table 9: Income deciles in the EHCS dataset – households in England only

Disposable income decile	EHCS (2006–07)			
	Count of households ('000)	N %	Mean	Range
1	2,138	10%	£6,130	£2,366–7,955
2	2,138	10%	£9,231	£7,956–10,556
3	2,137	10%	£11,915	£10,557–13,420
4	2,139	10%	£14,998	£13,421–16,758
5	2,138	10%	£18,416	£16,759–20,152
6	2,138	10%	£22,093	£20,153–24,169
7	2,138	10%	£26,302	£24,170–28,739
8	2,137	10%	£31,727	£28,740–35,270
9	2,139	10%	£40,096	£35,271–46,348
10	2,137	10%	£70,508	£46,349–359,578
Total	**21,380**	**100%**	**£25,141**	

4 DISTRIBUTION OF HOUSEHOLD CARBON EMISSIONS IN GREAT BRITAIN

Using the new and comprehensive dataset developed in Phase 1 of the project, a detailed analysis has been undertaken to explore the distribution of carbon emissions across households in Great Britain.

Chapter summary: key points

- Household emissions are strongly correlated with income:
  - In Great Britain, the richest 10% of households emit some three times that of the poorest 10%.
  - The top 10% of earners are responsible for 16% of total household emissions including the emissions from energy use in the home and all personal travel by car, public transport and aviation. This is over three times that of the poorest 10% of households, which contribute 5% to total household emissions from these sources.
- The distribution of emissions is more polarised for transport emissions than for energy consumption in the home:
  - Consumption of energy in the home: on average the highest income decile emits just over twice that of the lowest income decile.
  - Private road travel: the highest income decile emits seven to eight times that of the lowest income decile.
  - International aviation: the highest income decile emits some ten times that of the lowest income decile.

- Emissions from public transport, however, show a flatter distribution across income deciles:
  – Public transport: the highest income decile emits around 1.5 times that of the lowest income decile.
- In addition to income, other household characteristics associated with higher than average carbon emissions include: houses containing multiple adults; couples (with or without children); middle-aged households (aged 35–60 years); households using oil to heat their home; and properties in rural areas.
- These findings, which highlight the number of factors (beyond income) that influence household carbon emission levels, have fundamental implications for how energy and climate policies will impact (disproportionately) on different segments of the population. They also help in identifying the highest emitting groups, which could be targeted first with emissions reduction policies and measures.
- While the general pattern in household and transport emissions across income deciles is clear (higher income = higher emissions), there is also significant variation of emissions within income deciles – for example, where low-income households in larger homes tend to consume more energy.

Analysis

As far as we are aware, this is the first integrated analysis of emissions based entirely and directly on nationally representative survey data to include emissions associated with consumption of energy in the home (household fuels); private road travel (for leisure and commuting purposes[14]); public transport usage (for leisure and commuting purposes); and domestic and international aviation. The analysis provides new evidence and insight into who is responsible for emitting how much carbon dioxide, and identifies the relative contributions of different aspects of consumption to household carbon emissions.

Results are presented to show the relative contribution to total household emissions from all direct sources by different socio-demographics, including: income, household composition, age, number of cars in the household, settlement type and heating fuel type.

In addition, one-way analysis of variance (ANOVA) is used to reveal any significant differences between groups as defined by: income; tenure; number of workers in the household; employment status; age; socio-economic group; settlement type; car ownership; and domestic heating fuel. The results show the degree to which these different variables can be said to explain or predict variations in CO_2 emissions. A summary of the key findings from this analysis are presented in this section of the report, with the full set of results presented in detail in a separate paper (via Appendix 2: Supplementary project documents). Being based on the EFS dataset, all results in this section apply to households in Great Britain and emissions from energy used in the home reflect actual consumption of fuels (rather than estimates of energy need).

Mean annual carbon dioxide emissions from all sources included in this study are around 9.8 tCO_2 per year for households in Great Britain. Emissions from the use of energy in the home account for nearly three fifths of these emissions, while emissions from private car use make up over one quarter.

Results

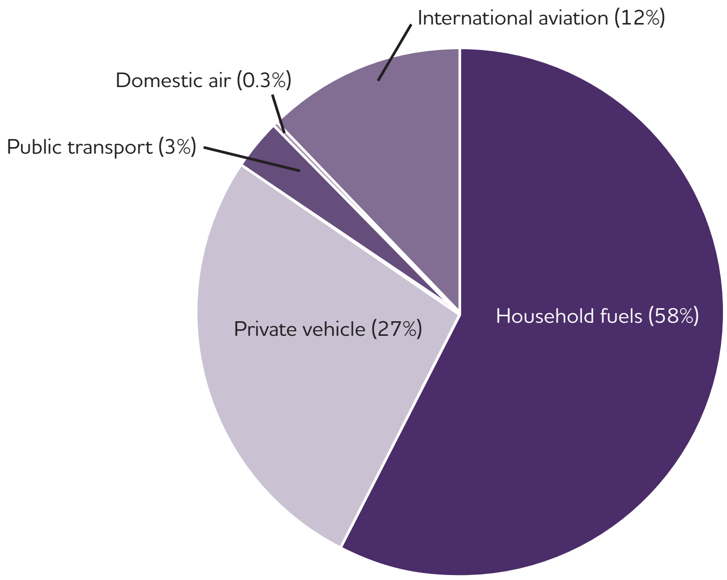
Mean annual carbon dioxide emissions from all sources included in this study[15] are around 9.8 tCO_2 per year for households in Great Britain (see

Table 10). Emissions from the use of energy in the home account for nearly three fifths (58%) of these emissions (see Figure 8), while emissions from private car use make up over one quarter (27%). Across the dataset population as a whole, international aviation accounts for 12%. However, the proportional contribution of these different sources to household emissions (as shown in Figure 8) varies across different household types and socio-demographics, as illustrated and discussed below.

Table 10: Make-up of sum total and mean annual household emissions from all direct sources in the GB EFS dataset

EFS imputed dataset	Sum total ($MtCO_2$)	Household mean (tCO_2)
Household fuels total	137	5.7
Private car total	64	2.6
Public transport total	7.3	0.3
Domestic aviation	0.8	0.033
International aviation	29	1.2
Total	**238**	**9.8**
Weighted count of households ('000)	24,207	

Figure 8: Proportion of total annual household emissions from each source (based on GB EFS data)



Distribution of emissions by income decile

Mean annual household CO_2 emissions are strongly correlated with income:

- Households within the highest disposable income decile have mean total CO_2 emissions more than three times those of households within the lowest income decile (see Figure 9).
- Emissions from private road travel and international aviation account for a high proportion of this differential: international aviation emissions of the highest income decile are more than ten times those of the lowest income decile, while emissions from private vehicle travel are around

seven to eight times higher. (Note that in Figure 9 domestic aviation is shown in the legend, but as this makes up such a small proportion of total household emissions it is barely discernable on the graph.)

Figure 9: Mean annual household CO_2 emissions from all sources by disposable household income decile (GB EFS dataset)

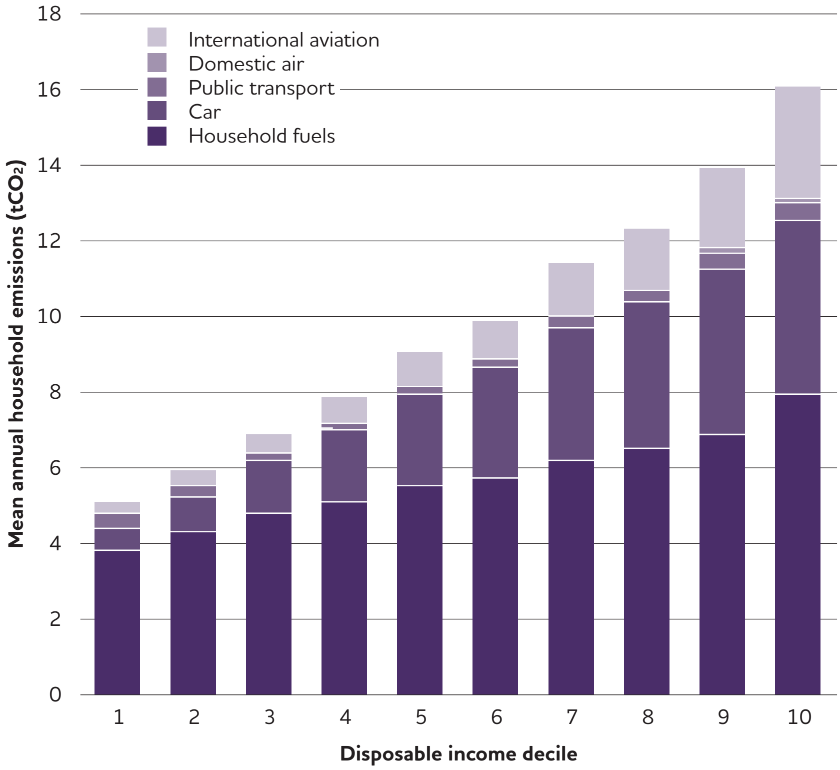


Figure 10 further highlights the disproportionate spread of emissions across income deciles:

- In Great Britain, the top 10% of earners are responsible for 16% of total household emissions (including the emissions from energy use in the home and all personal travel by car, public transport and aviation). This is over three times that of the poorest 10% of households, which contribute 5% to total household emissions from these sources.

The distribution of emissions is more polarised for emissions from private travel (road and aviation):

- The richest 10% of households emit 17% of the total emissions from private road travel and 26% of emissions from international aviation, compared with 2% and 5% for the poorest 10% of households respectively.

Despite the analysis showing that the overall trend in emissions increases from low to high income, Figure 11 shows that significant variations remain in emissions within income deciles. That is, the highest emitting poor households have emissions that are comparable with the mean emissions of wealthy households. This finding is consistent with previous analysis (CSE and Hirsch, 2012) of household energy consumption and emissions, which has shown a clear group of low-income, high-consuming households.

Figure 10: Proportional contribution of each income decile to total household emissions from different sources (GB households)

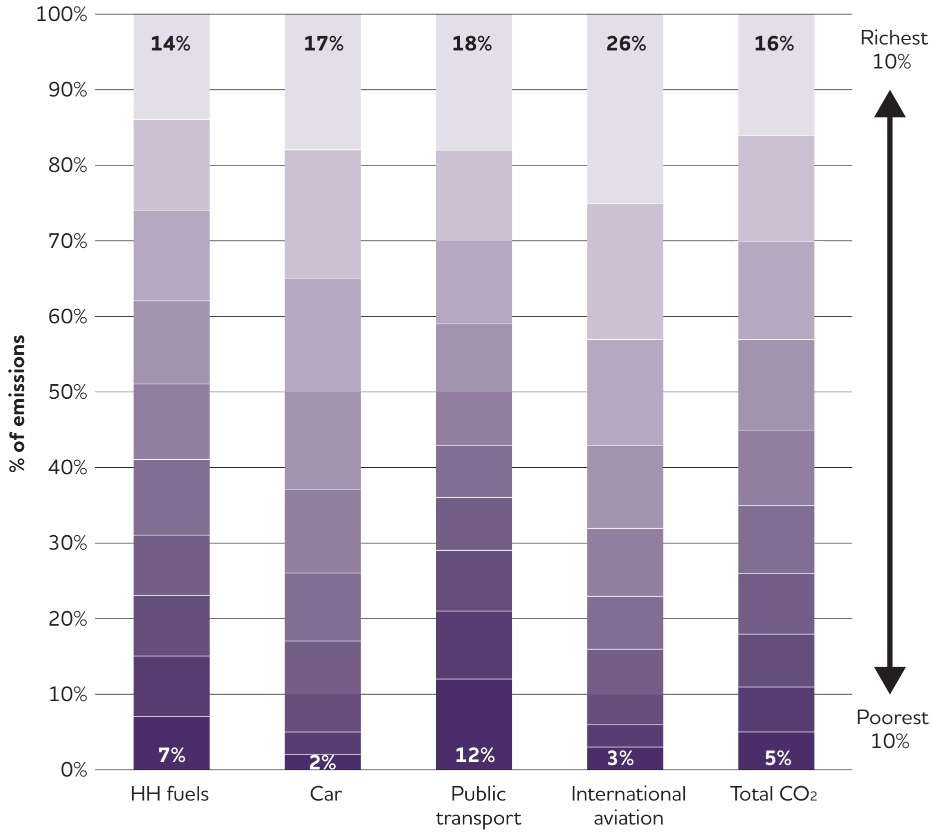
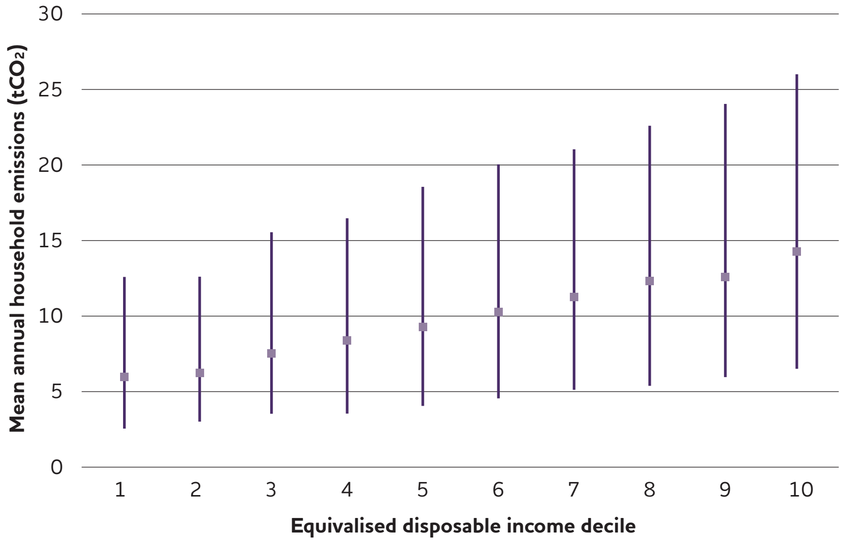


Figure 11: Mean annual total CO_2 emissions from all sources by equivalised household disposable income decile with 95% range of sample



Distribution of emissions by other socio-demographics

Households with three or more adults, and couples (with or without children) have significantly higher emissions on average than other household types (see Figure 12). Mean CO_2 emissions are lowest in single-pensioner households, which have notably lower transport-related emissions than other household types.

Mean household total CO_2 emissions show an increase and then decrease over the age bands (see Figure 13), with a peak in the middle years (household reference person (HRP) aged 35–60 years). This trend in emissions across life course is likely to reflect underlying differences in income and command over resources associated with age, as well as social differences in household size and composition.

Figure 12: Mean annual household CO_2 emissions from all sources by household type (GB EFS dataset)

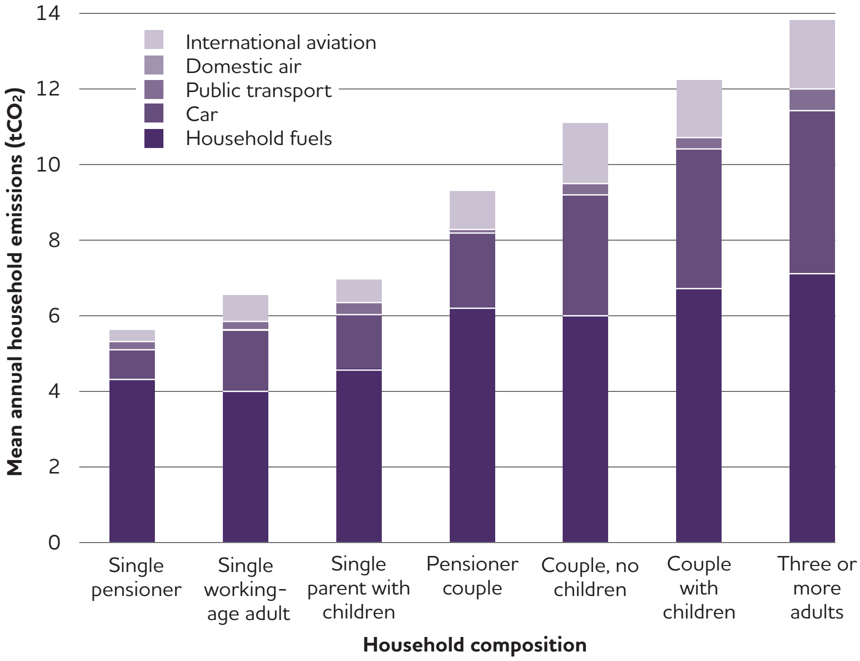
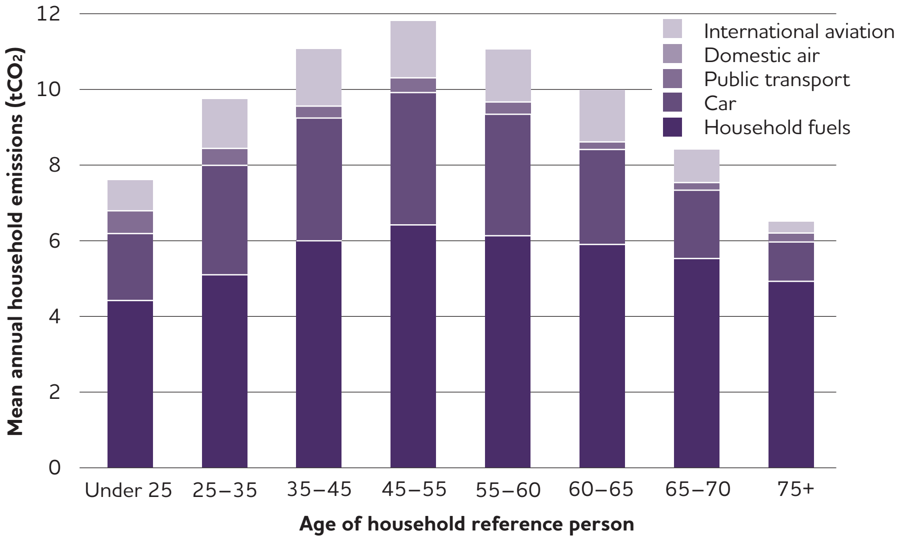
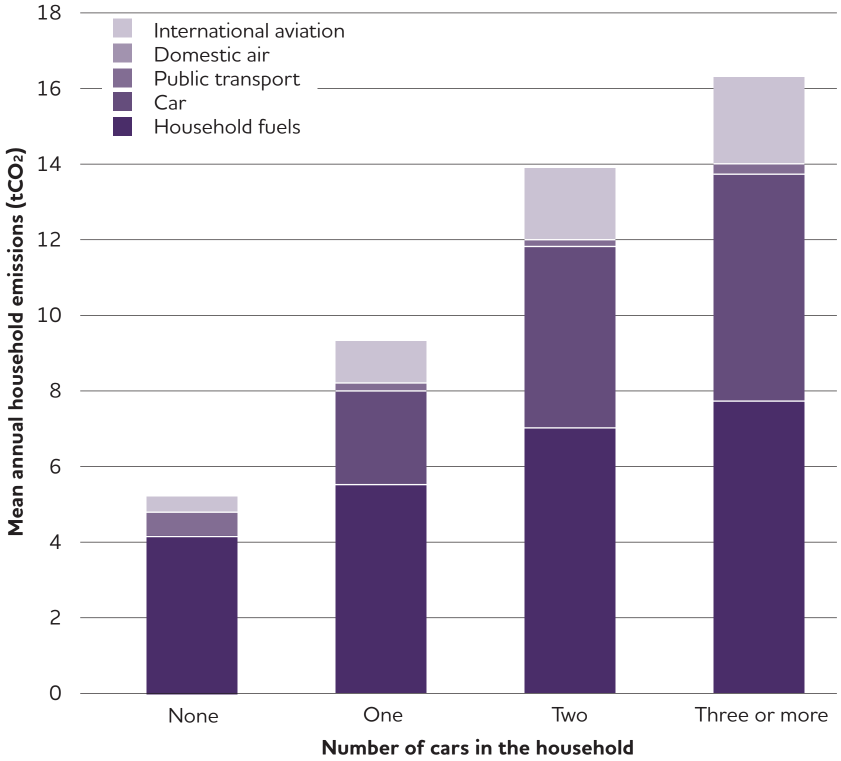


Figure 13: Mean annual household CO_2 emissions from all sources by age of HRP (GB EFS dataset)



There is a strong and clear relationship between car ownership and average household carbon emissions: as the number of cars in the household increases, so too do average emissions levels (see Figure 14). While the difference observed in mean *total* emissions by car ownership is mainly attributable to emissions from private vehicles,[16] as would be expected, further univariate[17] analysis shows car ownership is also a strong predictor of emissions from other sources (notably aviation and domestic fuel). These variations in other emissions sources associated with levels of car ownership are likely to reflect the indirect impacts of other socio-economic differences (and especially inequalities in household income) that are also associated with car ownership.

Figure 14: Mean annual household CO_2 emissions from all sources by number of cars in household (GB EFS dataset)



Analysis by domestic heating fuel shows average household emissions are significantly higher for households using oil to heat their home and lowest for electrically heated households (Figure 15). This can be primarily associated with the variation in carbon emissions of different household fuels (oil is far more carbon intensive), but it is also likely that domestic fuel type is a proxy for a wide range of socio-economic inequalities within the population, including income, property size and type, which will affect patterns of household energy consumption. Furthermore, some heating fuel types are more common in specific areas/property types. For example, oil is more common in rural areas where there is no mains gas (which may explain, in part, why car emissions also appear higher, but public transport emissions appear lower, for oil-heated properties) and electric heating is more common in city centre flats – which will typically be smaller and hence have a lower heating demand. The latter also correlates with the lower car emissions and higher public transport emissions that appear associated with this heating fuel type.

Figure 15: Mean annual household CO_2 emissions from all sources by heating fuel type (GB EFS dataset)

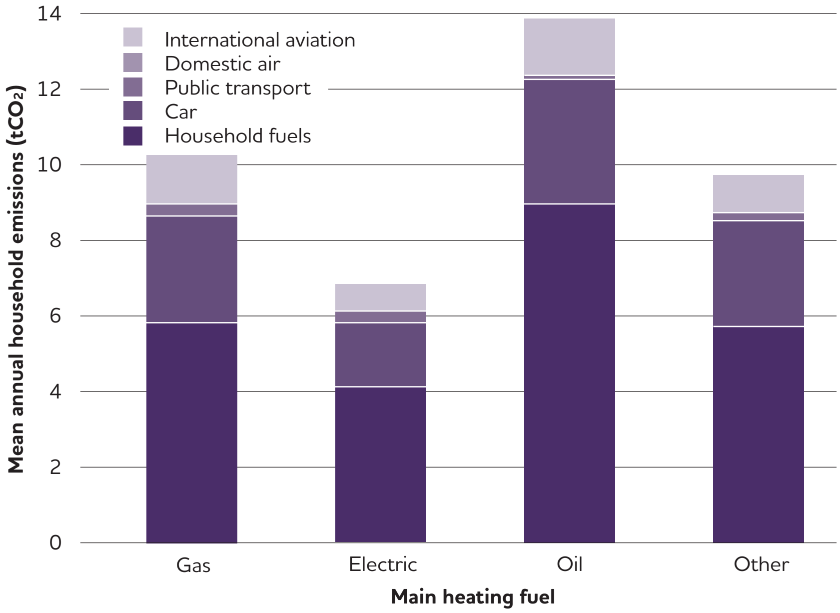
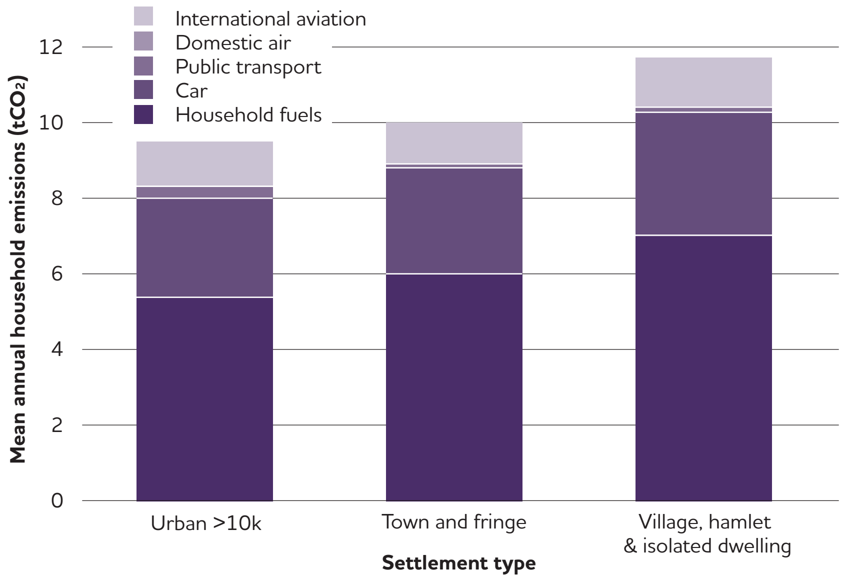


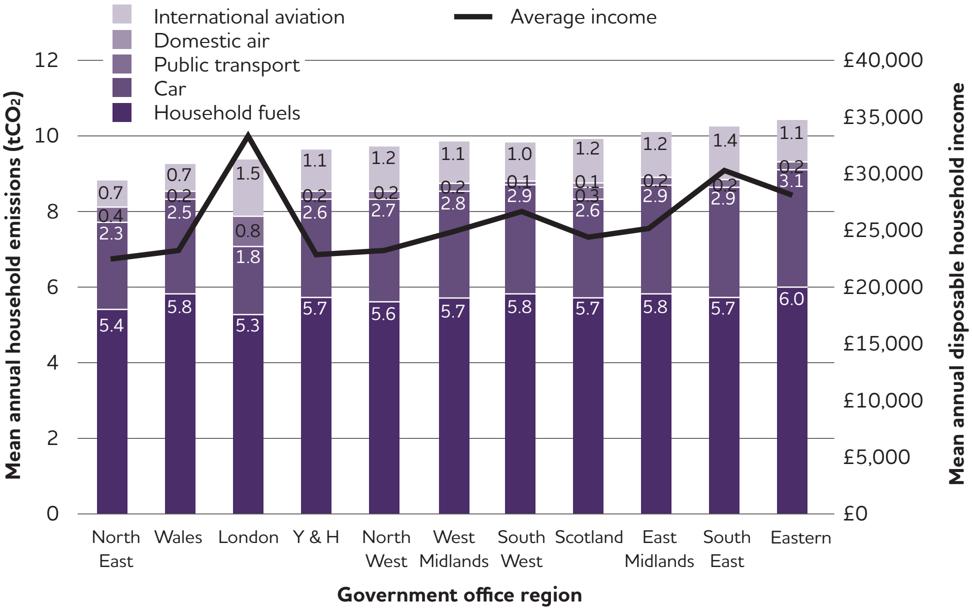
Figure 16: Mean annual household CO_2 emissions from all sources by settlement type (EFS dataset, England and Wales only)[18]



Differences in mean household carbon dioxide emissions between urban and rural[19] areas appear modest relative to other socio-demographic variations (see Figure 16). These differences are nonetheless significant, with rural household CO_2 emissions being one fifth higher than urban households. Emissions from domestic fuel use appear to vary more substantially by settlement type than for other social dimensions, with rural household fuel CO_2 being around 25% higher than in urban dwellings.

Analysis by region shows little variation in average household emissions (from all sources) across different parts of Great Britain (Figure 17). However, the results do evidence patterns that we would expect to see. For example, households in London have the lowest emissions from car travel on average but the highest average, for public transport and international aviation; Scotland has the highest average emissions for domestic aviation.

Figure 17: Mean annual household CO_2 emissions from all sources by region (GB EFS dataset)



The chart also shows that there appears to be an interesting interaction effect with income. While the general trend in emissions across the different regions follows that of income (that is, an increase in average income, as illustrated by the line and right-hand axis on Figure 17, equates to an increase in emissions, as illustrated by the stacked bars and left-hand axis), London is a clear anomaly. Income is higher in London on average than in all other regions (masking a very wide distribution, with extremes of wealth and poverty), but this does not correspond with higher emissions overall. This reflects the somewhat unique characteristics of the city. There is a higher proportion of smaller properties (17% one-bed[20]), giving lower than average emissions from household fuels. The presence of the underground and bus systems, and accessibility to airports offering international flights, are likely to be important factors since public transport and aviation emissions are higher, while emissions from travel by private vehicle are lower.

Discussion

The analysis presented above helps in understanding the central question, 'Who emits most?' In general, it is higher income households, middle-aged people, people living in rural areas and people that are dependent on oil for their home energy who emit most. While household fuel emissions account for the majority (approximately 60%) of total household emissions from all sources (as analysed in this study), much of the *variation* in emissions that we see across different socio-demographic groups actually arises from private vehicle and (to a lesser extent) aviation emissions. Emissions associated with public transport usage appear negligible in comparison and the 'social patterning' (the distribution across different socio-demographic descriptors) of emissions from this source is much less pronounced.

With well over half of all household emissions arising from the consumption of energy in the home, achieving reductions in domestic carbon emissions will depend to a significant extent upon relatively long-term improvements in the energy efficiency of the housing stock. However, emissions associated with domestic energy use appear relatively *inelastic* with regard to demographic and socio-economic differences within the population (that is, there is less notable difference in household fuel emissions compared with aviation and private vehicle usage across different socio-economic groups). This has important implications for the distributional consequences of current energy policies: where these affect domestic energy prices (where policy costs are passed on and recovered through consumer energy bills), the impact is likely to be regressive.[21] In contrast taxes on private transport might be expected to be less regressive, as those with higher incomes emit substantially more from travel than those on lower incomes.

In general terms, the results shown here suggest that substantial reductions in carbon emissions could be achieved by reducing energy consumption among those groups currently 'over-consuming' relative to the population as a whole. However, this analysis does not show how these emissions resulting from energy actually consumed in the home relate to household requirements for heat and power. Phase 2 of this project (reported in Chapter 5 onwards) therefore utilises the EHCS dataset, which provides all the information needed to assess a household's energy requirements and identify opportunities for insulation and renewable energy measures to reduce household energy demand.

5 DISTRIBUTIONAL IMPACTS OF GOVERNMENT CLIMATE CHANGE AND ENERGY POLICIES ON DOMESTIC ENERGY CONSUMERS

A key, overarching aim of this project is to increase understanding of the distributional impacts of climate policies on households in the UK. This stage of the analysis therefore seeks to address the question: 'What are the costs and benefits to households (in England) of existing and potential climate policies?'

Chapter summary: key points

- The impact of UK government energy and climate policies on household energy bills in 2020, as modelled here, shows the overall, combined impact to be a net reduction in the average annual bill of £105 (8%) below the expected bill in 2020 if these policies were not implemented.
- In the absence of existing government policies, the average fuel bill in 2020 for the lowest income decile would be some £69 higher, while the average bill of the top income decile would be over £180 higher. Thus government policies appear to reduce the average energy bill of the poorest 10% of households in England by 7% in 2020, compared with 12% on average for the richest 10% of households.

- On average, across all households, the change in the total 2020 bill for household fuels as a result of policies (that is, the 'impact') represents less than 1% of income.
- While the *impact* of energy policies on consumers' bills in 2020 represents a small proportion of income for all households, the *total household energy bill* in 2020 represents a much higher proportion of household income for poorer households, ranging from 10.5% for the lowest income decile to 1.3% for the wealthiest households.
- Furthermore, while the overall impact of policies is a net reduction on bills in 2020, some households will benefit disproportionately by receiving support or measures under certain policies, while others do not receive any of the benefits but still pay towards the policy cost through their bill.
- While the proportion of households receiving support/measures from policies is relatively uniform across the income spectrum, the distributional impact on energy bills appears less so. Around half of those on the lowest incomes (47%) who benefit directly from policies see a reduction of £170 (17%) on average on their 2020 energy bill compared with a 'no policy' scenario. The remainder of this income group (not benefiting directly from policy) see an average increase of £20 (2%) on the 'no policy' 2020 energy bill. Around half of the wealthiest 10% of households also benefit directly from policies resulting in a 2020 energy bill that is some £450 (30%) lower than the 'no policy' scenario. Households in this income group not benefiting directly (53%) have an average energy bill in 2020 that is nearly £70 (4%) higher than the 'no policy' scenario.
- Furthermore, for households that do not receive any support through policies, the average increase in their household energy bill in 2020 represents a higher proportion of household income for those in lower income deciles – a highly regressive result.
- The overall average decrease in energy bills in 2020 reflects government assumptions about the savings that will be delivered through policy measures. In particular, it reflects improvements in products efficiency (regulated requirements for minimum levels of energy efficiency in consumer products). Modelling the impact of policies in combination means that the policy costs passed through to consumers' bills are diminished by these assumed savings.
- When modelled independently of each other (one policy at a time), the impact and notably regressive nature of certain policies becomes more apparent (that is, lower income households are worse off relative to higher income households).
- On average, across all consumers, the Renewables Obligation (RO) appears to be adding the most to energy bills in 2020, while products policy contributes the greatest savings. The latter policy assumes all households benefit from reduced electricity demand due to enforced improvements in product energy efficiency. This policy does not have a cost on bills associated with it, and so represents a saving to households.
- The Green Deal and ECO are expected to add around £25 to the average energy bill in 2020, whilst the FIT appears to offer a net saving of over £30. However, this overall net saving masks significant variation in the impact on different households – some will be significantly better off, benefiting directly from the policy, while others (the majority) bear its cost (see below).
- The Green Deal, ECO and FIT all have both costs (policy cost passed through to consumer bills) and benefits (such as measures installed in the home, payment through the FIT) associated with them. The impact on an individual household therefore varies significantly,

depending on whether the household benefits directly from the policy. Modelling of the Green Deal in this study suggests some 14% of households are expected to benefit directly by 2020 and these households see an average reduction in their energy bill of over £130. Households benefiting from FIT – some 12% in this modelling scenario – see an average saving of £359 on their annual energy bill in 2020. However, the remaining 88% of the population pay for the policy at an average cost of £10 a year on their 2020 energy bill. It is important to note that the non-domestic sector also pays towards the cost of domestic FIT via its electricity consumption.

- The assumptions applied in the modelling are consistent with current government thinking where such assumptions have been made publicly available. However, in practice there is no certainty that savings, such as those assumed under products policy, or the take-up rates of measures, for example under FIT or the Green Deal, will be realised.
- If the model is run without products policy then the mean annual energy bill in 2020 would be £1,340 which represents a £55 (4%) increase over the 'no policy' bill, whereas the full policy view of the world sees bills reduce by £105 (or 8%) on average. In reality, the short-term trend for domestic energy demand over the last ten years is one of gradual decline which suggests that, despite population growth, improving heating system efficiencies and products policy are reducing usage.

Modelling existing policy impacts

This section presents the results of modelling the impacts of existing government energy and climate policies on consumer energy bills.

DIMPSA overview

The analysis principally uses CSE's Distributional Impacts Model for Policy Scenario Analysis (DIMPSA) – a tool that provides the means to simulate the impact of both policy costs (to consumers on energy bills) and benefits (through the deployment of measures and policies that deliver efficiency savings). DIMPSA has been developed with DECC, and is now used under licence by it to model the costs and benefits of policy delivery in terms of impact on domestic energy bills.

Box 3: Modelling household energy bills to 2020. Impact of fuel price rises – the 'no policy' energy bill

To assess the distributional impacts of an entire policy package, the study needs to consider the impact of the policy packages against a 'no policy' counterfactual scenario that excludes all policies in the package. The bill is estimated assuming that a householder's energy use will remain constant, while the energy costs will change as a result of changes to the wholesale energy price, network charges and other supplier margin values. The wholesale changes are based on DECC's long-term central projections for oil, gas and coal for the UK up to 2030. Figure 18 and Figure 19 show the central scenario used in this study and the alternative high and low projections for fuel prices. DECC's (2011e) work has been subject to peer review and the figures have been revised in the light of comments received. See Appendix 1: Policy modelling assumptions for further details on these costs.

The model was originally designed and built on the EFS-based dataset, using survey data on actual household expenditure on fuels to derive estimates of annual energy consumption. For the purpose of this research project, DIMPSA was adapted to run on the EHCS-based dataset developed in the project. This includes the values for actual household emissions imputed from the EFS dataset. This is the dataset used for all policy scenario modelling in this study.

The 'no policy' energy bill
In addition to modelling the impacts of policy, DIMPSA produces outputs for a 'no policy' scenario. This estimates household energy bills in the modelling year, taking account of changes in energy prices over time but excluding any costs or benefits of policies. Referred to by DECC as the 'counterfactual' energy bill, this provides a means for extracting and understanding the impact of policies on bills by acting as a comparator for other bills with policies applied.

Figure 18: Projected changes in electricity costs from 2011 to 2020

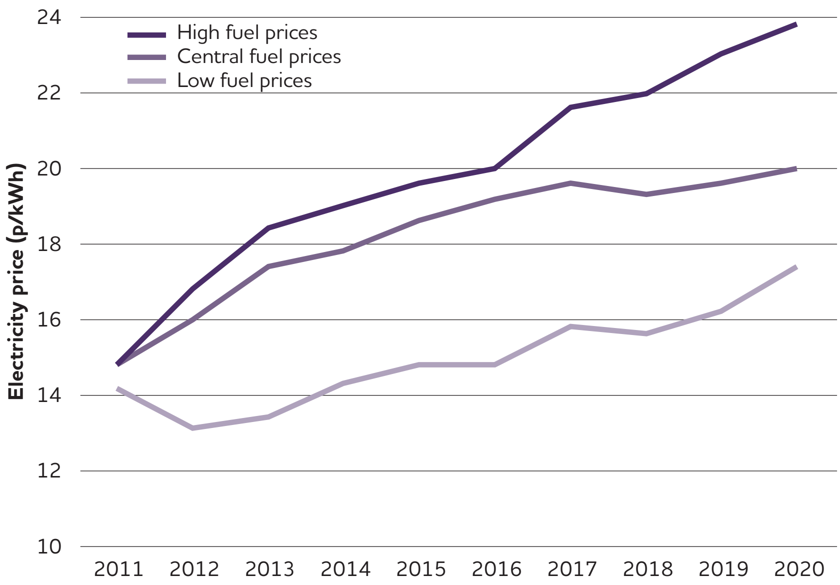
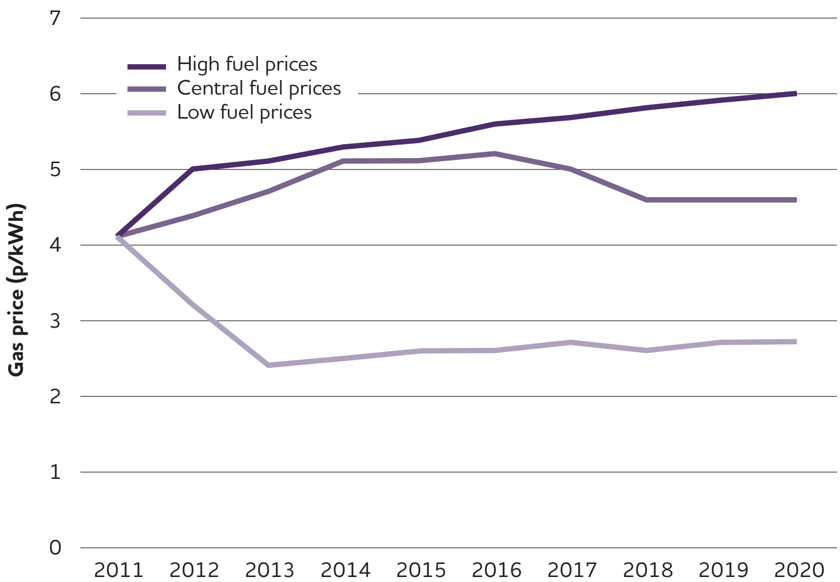


Figure 19: Projected changes in gas costs from 2011 to 2020



Modelling policies
DIMPSA models both the costs (on consumer bills) and benefits (such as installation energy efficiency measures received) of policy scenarios on households over a specified timeframe. For the purpose of this study, all modelling explores the impacts on household bills in 2020. This means that only policies that are 'live' in 2020 will represent a cost, but householders will be benefiting from any measures delivered under the completed policy. For example, CERT is due to end in 2012 and therefore costs on bills in 2020 will be zero, but any households that received measures under CERT will still see a saving on their 2020 energy bill as a result of this policy.

To model the benefits of policies, DIMPSA identifies cases (households) in the dataset that may be suitable for different insulation and renewable energy technologies that are supported by government policies. See Box 4 for a discussion of how policy benefits are assigned in DIMPSA.

Box 4: Modelling policy benefits – who gets measures?

The model identifies records in the dataset that may be suitable for sustainable energy technologies. The user can apply a number of criteria to the dataset to constrain the application of measures. Variables used include tenure, built form, central heating type, property size, occupants, age of household representative, rurality and wall type. For example, solid wall insulation will be applied only to households with uninsulated solid walls, while biomass boilers may not be appropriate in urban areas.

Policy measures are targeted at specific groups, consistent with policy design, and randomly distributed between eligible households. For example, FIT measures are targeted at a group of early adopters of technology, identified through specific household characteristics. ECO measures are targeted at a group that identifies vulnerable households through the Super Priority Group.

DIMPSA also allows the user to specify a factor for the amount of the saving that may be taken as comfort. For any heat consumption reduction measure, renewable heat pump or insulation measure, the savings are adjusted in the model used here to allow for comfort taking – for example, discounting the rate of savings by 15% of the total modelled saving in order to be consistent with the assumptions on comfort taking used in DECC's analysis within its annual energy statement (AES, 2011).

'Comfort taking' refers to the fact that some households use energy efficiency measures to make their homes warmer rather than to save energy. This is especially true for lower income households that have previously underheated their homes because energy costs were unaffordable (that is, energy bills represented a significant financial burden and a high proportion of household income). To allow comparability with DECC's previous analysis, we have assumed a standard rate for comfort taking of 15%.

In addition to modelling the potential policy benefits (the deployment of measures), DIMPSA also models the impact of policy costs on consumer energy bills. The modelling assumptions are based on a central policy costs scenario taken from the study by CSE and ACE (2012) for Consumer Focus, which examines a range of future energy costs based on varying policy success. The aforementioned work includes a detailed appraisal of the assumptions about the total costs and benefits of policies contained in

DECC's own impact assessments. Full details on the scenario policy costs are provided in Appendix 2: Policy modelling assumptions.

The total policy costs to be passed through to customers depend on two key factors:

- the customer types covered by the policy – that is, domestic, commercial or both;
- the fuel types covered – that is, electricity, gas, oil, coal or liquid petroleum gas (LPG).

For instance, the FIT applies only to electricity (see Table 11 and Table 12) but covers both domestic and commercial customers. The total policy costs are therefore split between these two customer groups (on a proportional basis, according to the total annual electricity consumption of each sector). Where a policy is applied to more than one fuel, the total cost distributed domestically is divided between the relevant fuels (according to the number of households using each fuel). Finally, policy costs may be passed on to consumers based on either a per unit basis (p/kWh, so the cost relates to annual energy consumption) or a per customer basis (a fixed cost is passed on to all consumers regardless of consumption levels). The decision on how to charge is driven by the nature of the policies themselves. The CERT policy provides measures to households and, as such, is levied on a per household (supplier account) basis. In comparison, the RO is charged on each unit of electricity sold because the policy is based on support for technologies that generate a certain number of units of energy – for example, defining the amount of revenue they raise through RO Certificates (ROCs).

Table 11: Policies modelled, mechanisms for cost recovery and benefits (to individual households)

Policy	Cost pass-through		Benefit
Included in DIMPSA	**Mechanism**	**Fuel**	
Carbon Price Floor	Per unit £/kWh	Electricity	None[22]
EU Emissions Trading Scheme	Per unit £/kWh	Electricity	None
Renewables Obligation (RO32)	Per unit £/kWh	Electricity	None
Smart Meters	Per unit £/kWh	Electricity & gas	Efficiency savings
Carbon Emissions Reduction Target	Per customer	Electricity & gas	Measures[23]
Feed-in Tariff	Per unit £/kWh	Electricity	Measures
Warm Homes Discount	Per customer	Electricity & gas	Reduction on bill
Energy Company Obligation	Per customer	Electricity & gas	Measures
Green Deal	N/A	N/A[24]	Measures
Products Policy	No cost		Efficiency savings
Boiler Churn (replacement)	No cost		Measures
Electricity Market Reform	Per unit £/kWh	Electricity	None
Renewable Heat Incentive	Taxation		Measures
Not included in DIMPSA			
Carbon Capture and Storage (CCS)	Taxation		None
Nuclear Decommissioning[a]	Taxation		None
Clean Coal Levy	Taxation		None
Alternative policies modelled for this study			
Maximum CO_2 Abatement	Hybrid approach		Measures
Personal Carbon Allowances	N/A		N/A

Note: [a] it is assumed that nuclear decommissioning will continue to be state funded

Table 11 shows all the policies included in DIMPSA and their mechanism for cost recovery and benefits (where applicable). Note that there are no individual household benefits (measures) from carbon capture and storage, nuclear decommissioning or the clean coal levy. As the costs of these are to be recovered through general taxation they are not modelled in DIMPSA, which is primarily a tool for exploring policy impacts on consumer energy bills.

The CPF, EU ETS, RO, Smart Meters, FIT and EMR represent a cost charged per kWh of electricity consumed in the home. The costs of CERT, the Warm Homes Discount and ECO are passed on to consumer electricity and gas bills at a fixed 'per customer' basis (that is, the charge applied is not related to consumption levels).[25] Table 12 shows the assumed policy costs for the modelling of energy costs in 2020. A number of organisations have argued for the ECO to be charged on a per unit basis. This would be more progressive overall as low-income consumers generally consume less and have a higher tendency to use electricity to heat their homes.

Table 12: The cost assumed for UK climate change policy costs in 2020

Policy	Fuels covered	Cost type	Cost	Total cost
Energy Company Obligation	Gas and electricity customers	Per account	£27.58	£1,092,647,493
Feed-in Tariff	Electricity customers	Per unit	£0.0025	£157,503,339
Warm Homes Discount	Gas and electricity customers	Per account	£5.73	£226,800,000
EU Emissions Trading Scheme & Carbon Price Floor	Electricity customers	Per unit	£0.0109	£686,714,559
Renewables Obligation	Electricity customers	Per unit	£0.0148	£932,419,768
Electricity Market Reform	Electricity customers	Per unit	£0.0092	£579,612,288
Smart Meters	Electricity customers	Per unit	£0.0003	£36,954,527
	Gas and electricity customers	Per unit	£0.0001	

In addition to modelling existing government climate policies that impact on consumer bills, the team has modelled an alternative carbon reduction policy scenario. The scenario seeks to deliver a widespread housing stock retrofit programme aimed at achieving maximum possible household emissions reductions. These would be achieved through the installation of the main energy efficiency, heating and renewable energy measures that could be deployed for different homes (referred to as the 'maximum CO_2 abatement' scenario). This modelling scenario is presented in the next chapter of this report. We also explored implications for personal carbon trading when emissions from personal travel are also included. This analysis is presented in a separate paper via Appendix 2: Supplementary project documents.

Headline results: combined policy impacts

Overall impacts on energy bills

The average annual household energy bill in 2020, with government policies applied , appears, at £1,180, to be only slightly higher than baseline (2011) levels and is *lower*, by some £105 (or 8%) on average, than the 'no policy' 2020 energy bill (see Table 13). This suggests, therefore, that existing UK government energy and climate change policies will result in a net reduction on the average household energy bill in 2020.

This finding is consistent with that presented in DECC's own policy impact assessment (DECC, 2010d) and suggests that the impact of policies aimed at reducing household energy demand outweighs the cost of policies passed through to domestic consumers. In the absence of any policy intervention (that is, if we remove the modelled costs and benefits of policies impacting on consumer energy bills), the average household energy bill in 2020 is expected to be some £110 (or around 9%) higher than the modelling baseline year. This increase reflects expected changes in fuel prices over the modelling timeframe (see Box 3).

Table 13: Overall impact of policies on actual annual household energy bills in 2020 (England only)

	Overall	Household: no support	Household: receiving support
Baseline bill (2011)	£1,175	£1,219	£1,043
2020 bill without policies	£1,285	£1,270	£1,302
2020 bill with policies	£1,180	£1,318	£1,012
Impact of policies	−£105	£47	−£290
% change due to policies	−8%	4%	−22%
Change in bill on baseline	£4	£99	−£31
Count of households	21,380,077	11,716,921	9,663,156
% of households	100%	55%	45%

While the overall impact of policies shows an average net reduction on bills in 2020 compared with the 'no policy' option, some households will be benefiting disproportionately by receiving support or measures under certain policies. Others do not receive any of the benefits, but still pay towards the policy cost through their bill (see Box 4).

While the overall impact of policies shows an average net reduction on bills in 2020 compared with the 'no policy' option, some households will be benefiting disproportionately under certain policies.

Under the modelling assumptions applied here, by 2020 some 45% of households are expected to have benefited directly from one policy or more (as shown in the column 'Households: receiving support' in Table 13). For these households, the average energy bill in 2020 is around £300 lower than the 'no policy' energy bill (at £1,012 compared with the 'no policy' scenario of £1,302 – see Table 13).

Conversely, for the 55% of households that do not benefit directly from policies by 2020 (in this modelling scenario), the average annual energy bill in 2020 is expected to be some £50 higher than the counterfactual 'no policy' scenario (£1,318 compared with £1,270 – see Table 13). Thus while the impact of government policy on the 2020 energy bill across all households in England represents a net reduction, for over half of households the 2020 energy bill appears almost £50 higher as a result of policies.

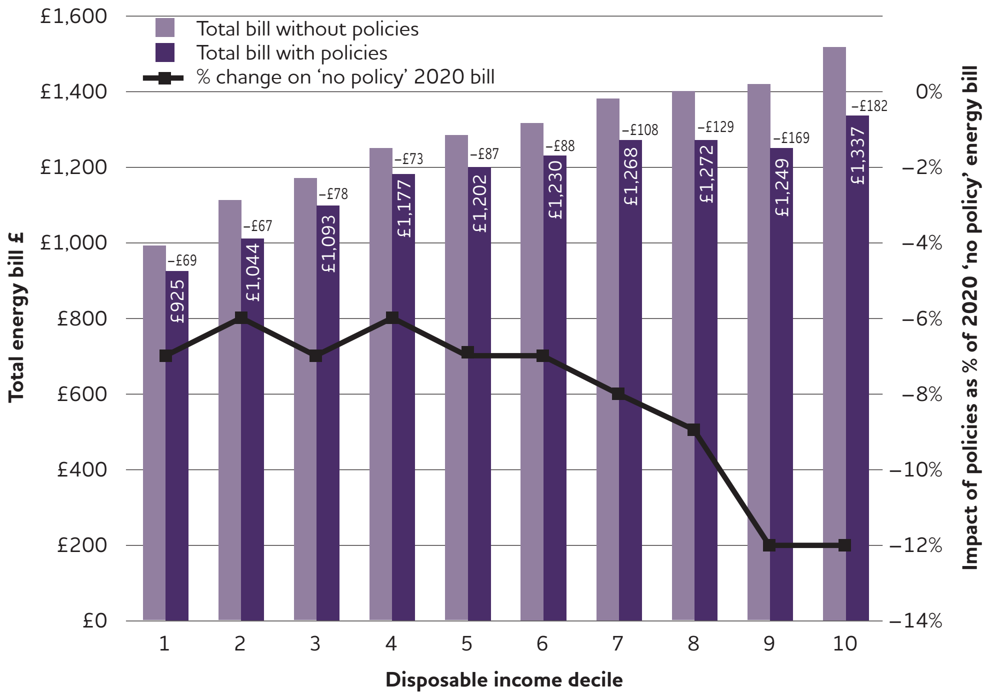
To perform a brief sensitivity analysis of the impacts of products policy, the model was run with the same policy settings but excluding products policy. The results show the mean annual energy bill in 2020 to be £1,340 under this scenario, which represents a £55 (4%) increase on the 'no policy' bill. In reality, the short-term trend for domestic energy demand is one of gradual decline which suggests that, despite population growth, improvements in heating system efficiencies and products policy are reducing usage. The complementary JRF-supported study 'Designing carbon taxation to protect low-income households' provides more discussion on long and short-term trends for energy use (Browne, *et al.*, 2012).

Distributional impacts of policy

All figures presented in this section show the distribution of policy impacts across different socio-demographic groups.

Figure 20 shows that in the absence of existing government policies, the average fuel bill in 2020 for the lowest income decile would be some £69 higher, at £994 (compared with £925 with government policies applied).[26] Thus government policies appear to reduce the average energy bill of the poorest 10% of households in England by 7% in 2020 (solid line, right-hand axis in Figure 20). For the richest 10% of households, the impact of government policies is higher, representing a saving of over £180 (12%) on average in 2020 compared with the 'no policy' scenario.

Figure 20: Impact of policies on actual annual household energy bills in 2020 by disposable income decile (England)



The average household energy bills in 2020 for different socio-demographic groups are illustrated in Figures 21 to 23. Households in the middle age bracket (as defined by the age of the HRP), detached dwellings and properties in rural areas all appear to have the highest energy bills on average in 2020, but experience the greatest average savings due to policies. These results reflect household characteristics and targeting of policies in DIMPSA. In the absence of clear criteria defining which households are targeted with measures (e.g. Priority Group under CERT), assumptions have to be made in programming the model to deploy measures. For example, renewable energy technologies have been targeted at an 'early adopters' group. This group is based on an internal report for DECC by the Energy Saving Trust and Experian that identified household types most likely to take up the Green Deal (internal research, personal communication).

Figure 21: Impact of policies on actual household energy bills in 2020 by age of HRP (England)

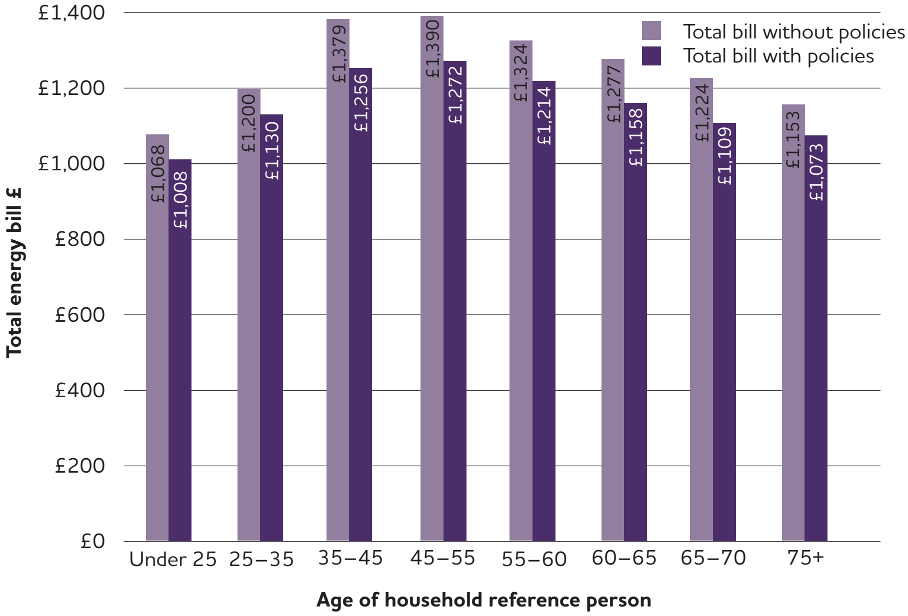
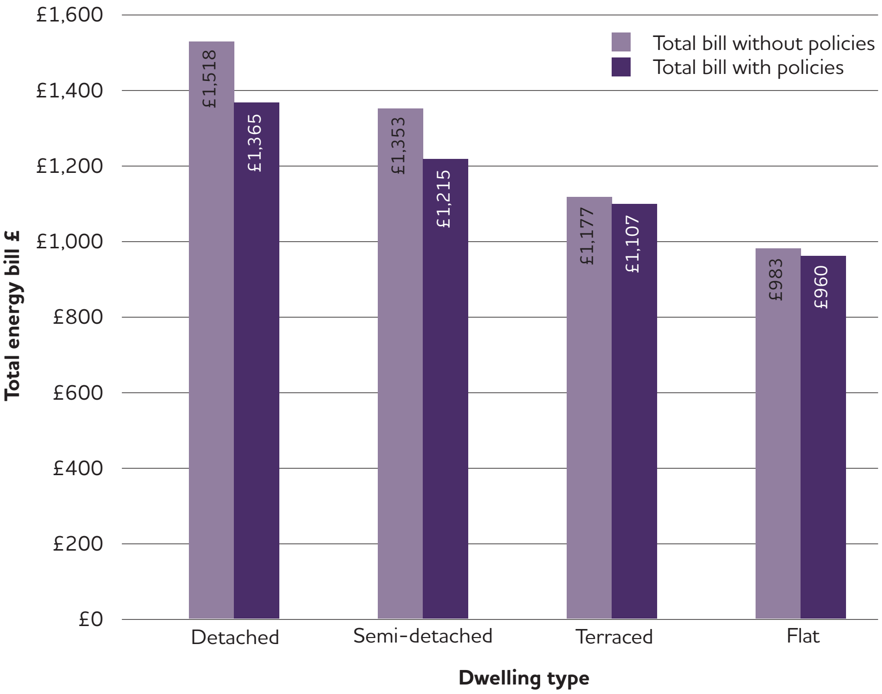
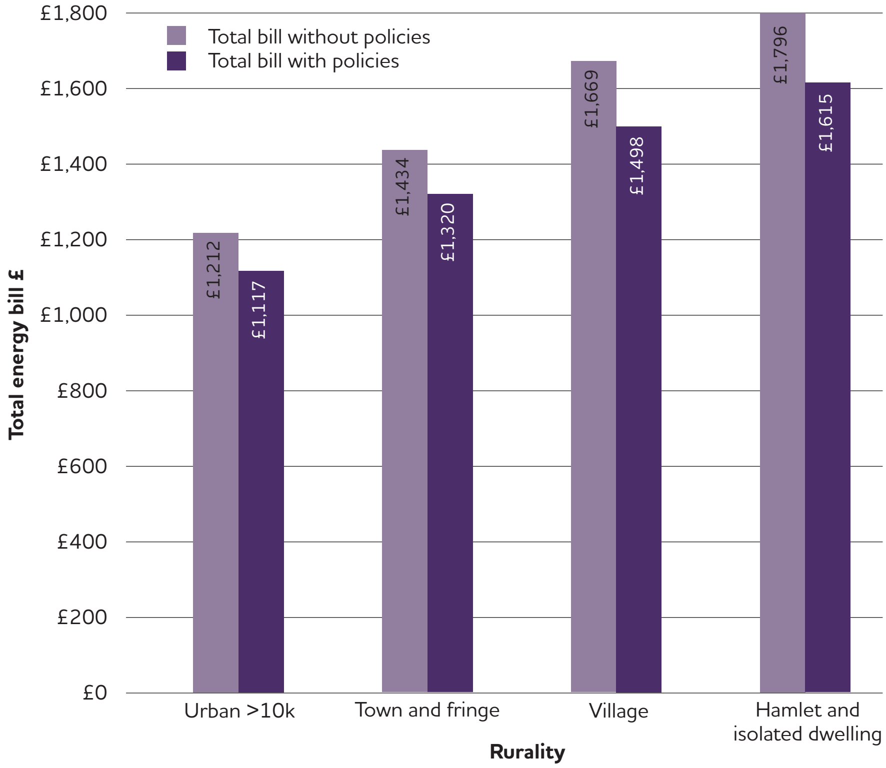


Figure 22: Impact of policies on actual household energy bills in 2020 by dwelling type (England)



With regard to the FIT, to meet the government's predicted 2.8 million domestic photovoltaic (PV) installations by 2020, DIMPSA assumes some modest take-up across all households in the early years to mirror the 'rent-a-roof' scheme approach.[27] However, take-up is significantly higher in the upper income deciles, which transpires in the pattern of policy impacts we are seeing here. Lower income households will still benefit through reduced power demand and the associated energy bill saving.

Figure 23: Impact of policies on actual household energy bills in 2020 by settlement type (England)



Policy impact on households that receive support/measures

While the overall, average policy impact (across all households in England) of policies on energy bills in 2020 is a net decrease (compared with the 'no policy' scenario), this is largely dependent on whether a household receives some form of direct support or benefit from the policies (such as an energy efficiency or renewable energy measure).

Figure 24 shows the average household energy bill in 2020 for income decile, split by those households that do and do not benefit directly from policies. In the lowest income decile, there is a divergence of nearly £200; in the top income decile the difference is even greater at around £550.

Figure 25 shows the *impact* of policies on household energy bills in 2020 (that is, the average cost or saving on energy bills as a result of policy costs/benefits) across the income deciles, again split according to whether a household benefits directly. Figure 26 shows this impact as a percentage of the 'no policy' 2020 energy bill. This further illustrates the divergence in the impact of policies between households that do and do not benefit directly. Around half of the first decile (47%) who benefit directly from policies can expect to see a reduction on their 2020 energy bill of £170 on average, which represents a 17% saving compared with a 'no policy' scenario in 2020. At the same time, the remainder of this income group sees an increase of around £20 on average (a 2% increase on the 'no policy' scenario). At the upper end of the income spectrum, around half of the top decile also benefit directly from policies, resulting in a 2020 energy bill some £450 lower than the 'no policy' scenario – a 30% saving compared with the 'no policy' scenario. Households in this income group not benefiting directly (53%) have an average energy bill in 2020 nearly £70 (4%) higher than the 'no policy' scenario.

Figure 24: Mean total actual energy bill in 2020 by disposable income decile and those that receive/do not receive support (England only)

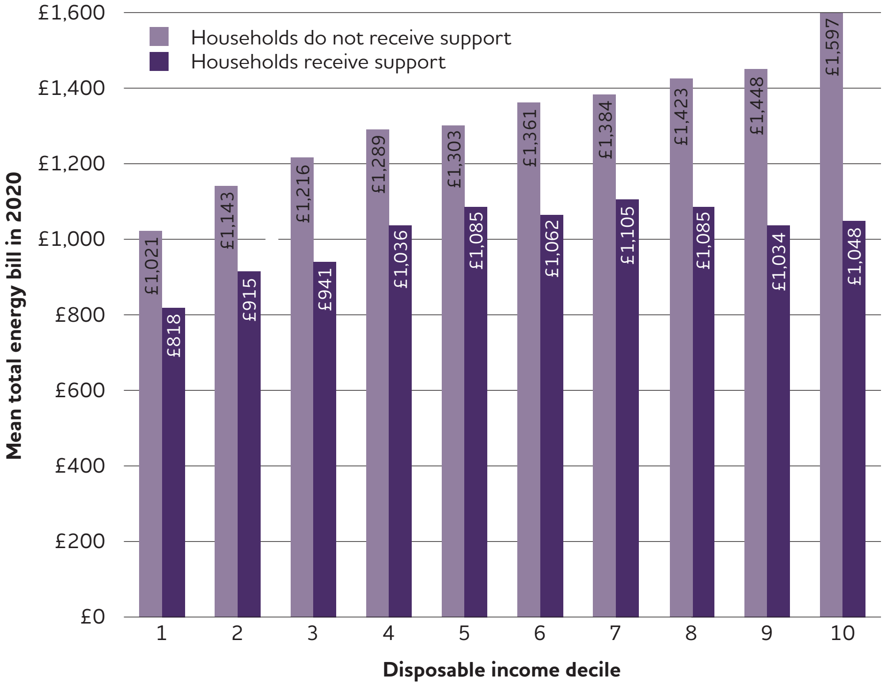
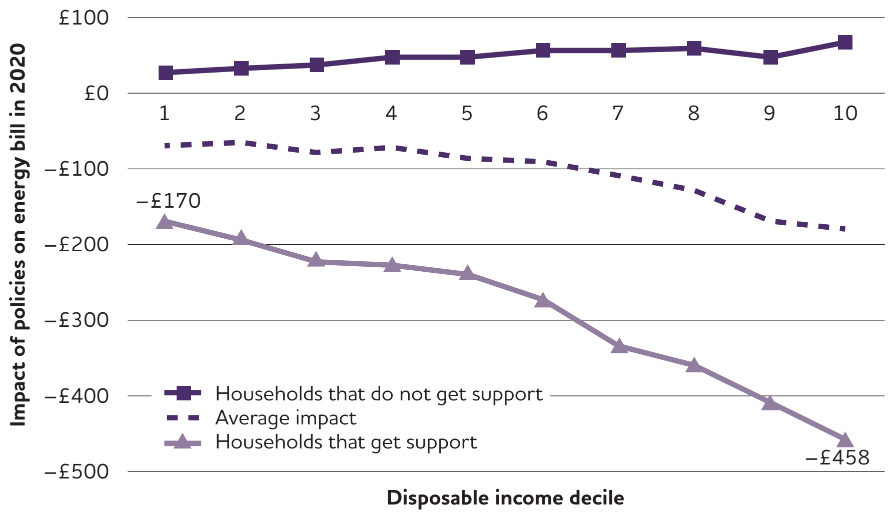


Figure 25: Impact of policies on actual household energy bills in 2020 by disposable income decile and those that receive support (England)



While the proportion of households benefiting directly from policies (receiving support/measures) is relatively uniform across the deciles (with between 42% and 48% of all income groups receiving some form of support), the distributional impact on energy bills appears regressive. On average, higher income households stand to see a greater net saving on energy bills in 2020 through policy impacts (Figure 25 and Figure 26). 47% of households in the bottom and top income deciles benefit directly from policy in 2020. The impact for the poorest 10% is a saving of 17% (£170), while the impact for the richest 10% is a saving of 30% (over £450) on average, compared with a 'no policy' 2020 energy bill scenario. While higher income households benefiting from measures appear better off than their lower income counterparts in absolute terms, the saving this represents as a proportion of income is greater for the poorest proportion of households (see Figure 27). In the same vein, the policy impact (the cost) to households not benefiting directly represents a higher proportion of household income for the poorest 10%, albeit less than 0.5%.

The combined, average impact of existing government energy and climate policies represents an average saving of less than 1% of income, as modelled in this study on household energy bills in 2020 across all income groups.

The combined, average impact of existing government energy and climate policies represents an average saving of less than 1% of income.

Figure 26: Impact of policies in 2020 as a percentage of the 'no policy' 2020 household energy bill by disposable income decile and those that receive support (England)

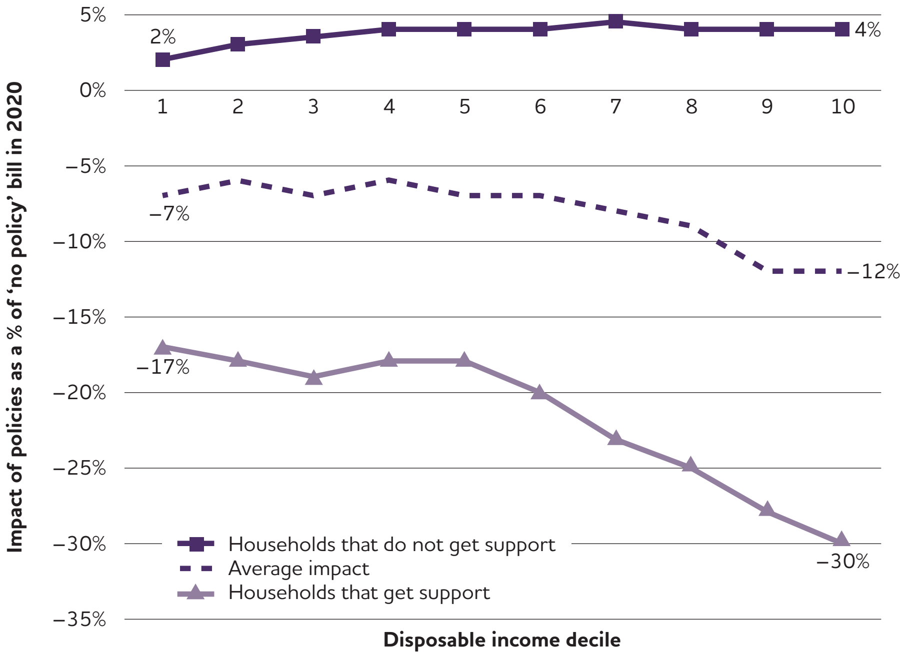


Figure 27: Impact of policies on actual household energy bills in 2020 as a proportion of income by disposable income decile and those that receive support (England)

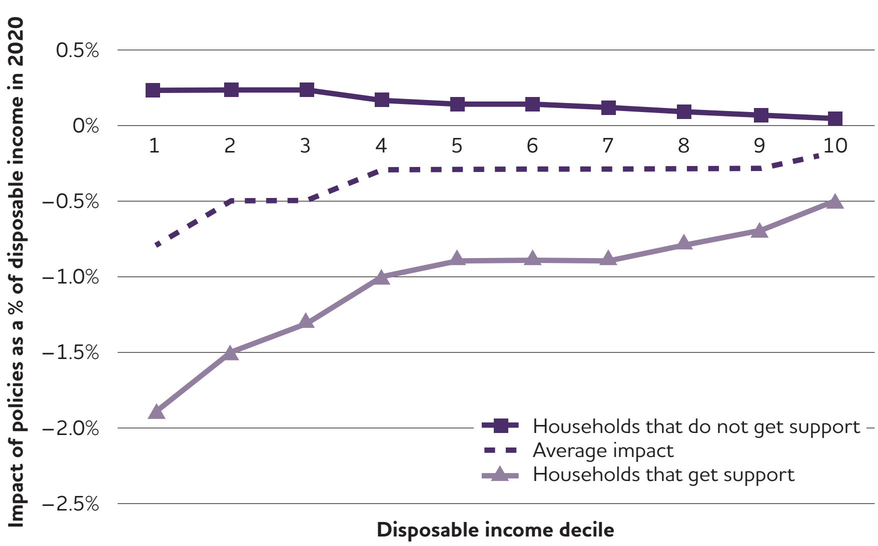
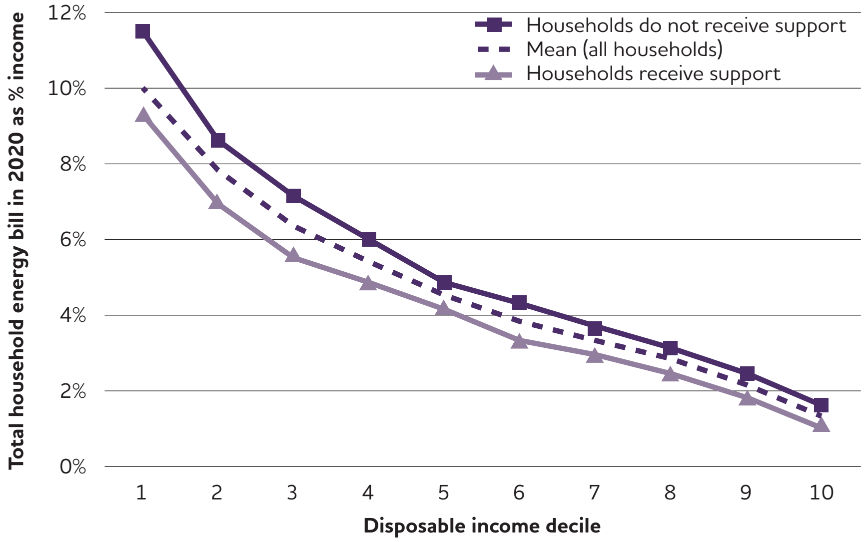


Figure 27 shows the total household energy bill in 2020 as a proportion of household income. This shows that, for the poorest 10%, household energy bills in 2020 represent over 10% of household income on average. The current definition of fuel poverty defines a household as fuel poor if it needs to spend more than 10% of income on maintaining satisfactory levels of warmth in the home. However, there is a fundamental difference between what a household *needs* to spend (a calculation that is based on physical characteristics of the dwelling – see Figure 28) and what is *actually* spent on energy in the home. The former is likely to be much higher. For example, a previous study (CSE and Hirsch, 2012) that explored the fuel expenditure of households in England showed actual energy used for heating to be 68% of the estimated required spend to ensure adequate warmth.

Figure 28: Total actual household energy bill in 2020 as a proportion of income by disposable income decile and those that receive support (England)



As Figure 28 represents *actual* household spend as a proportion of income in 2020, not required spend, the results do not translate into these households being defined as fuel poor. However, the distribution of fuel poverty shows a close relationship with income poverty. For example, 87% of fuel-poor households are in the bottom three income deciles in England.[28] We can therefore infer that low-income households that do not receive support through policies by 2020 – as shown by the top, darker line on Figure 28 – are likely to be at risk of fuel poverty. Chapter 7 of this report explores the implications of policy impacts modelled here for fuel poverty in 2020.

Box 5: Assessing household energy requirements – estimating household required spend on energy

The Standard Assessment Procedure (SAP) is the government's official standard for calculating the energy performance and efficiency of a dwelling. The calculation takes into account the size, shape and physical characteristics of the house, including insulation levels, to estimate the rate of heat loss through walls, roofs, windows, doors and floors. It also uses information about a property's heating system, in particular its efficiency in converting a particular fuel into heat.

The SAP calculation makes a set of standard assumptions on the heating regime, hot water, lighting, appliances and occupancy patterns of every dwelling. A standard heating regime is assumed, whereby the living space (usually defined as the living room) is heated to 21 °C and the rest of the house to 18 °C for nine hours during weekdays and for 16 hours at the weekend. (This is defined by the government as the amount of heating needed to maintain an adequate level of warmth in a home.)

Combining these assumptions with the physical characteristics of a property allows for a calculation of the amount of fuel required to heat a dwelling to this standard. Fuel costs and carbon emission factors can then be applied to these estimates of energy needed in the home in order to ascertain the total cost and associated carbon emissions.

Finally, an SAP rating is calculated, on a scale of one to a hundred, which provides an overall indicator of the energy performance of a dwelling. The rating is a calculation of a building's performance based on energy costs per m^2, and is therefore intrinsically linked to the theoretical running costs of the dwelling. The higher the SAP rating, the better the energy performance and the lower the energy costs.

Individual policy impacts

Overall costs and benefits of individual policies

DIMPSA is designed to model the impact of government policies on consumer bills when applied in combination. This is an important feature of the model that ensures it captures and allows for interacting/counteracting impacts, heat-replacement effects[29] and loan repayments of different policies.

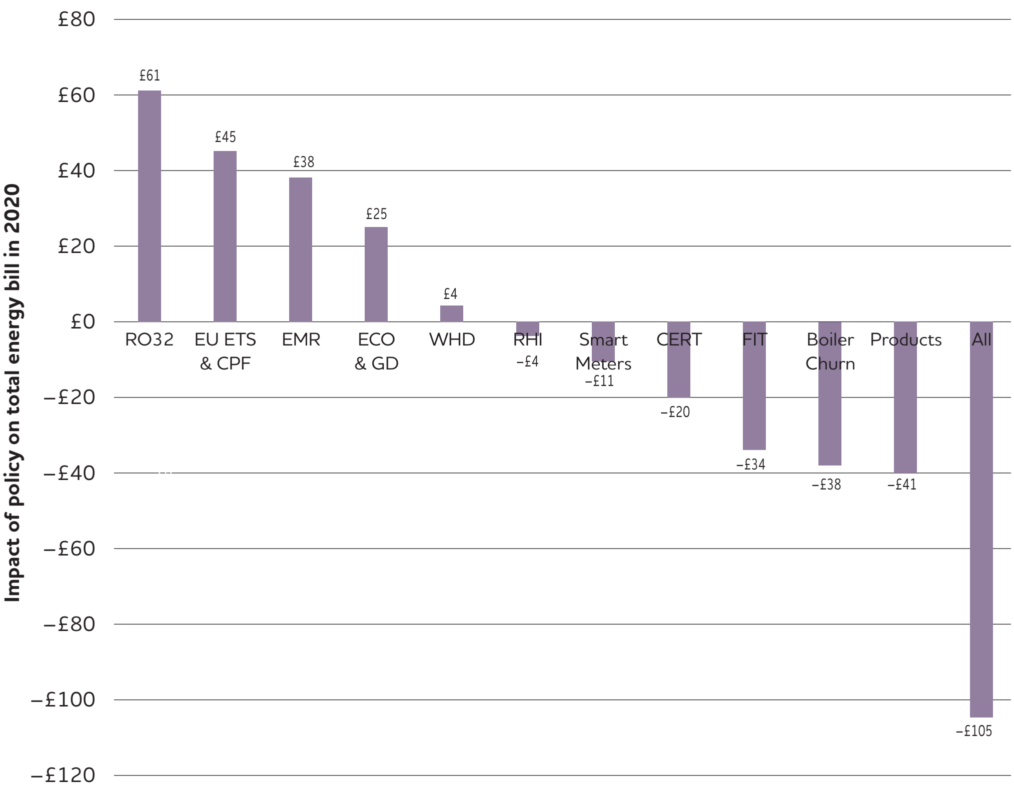
DIMPSA deploys the costs and benefits of policies in sequence. For example, if a household receives a measure under one policy, the model will account for this in modelling the impact of other policies. Households may benefit directly from no policies or from one or more. Isolating the individual impact of a single policy is therefore complex and somewhat misleading because 'the whole is other than the sum of the parts'. However, we have extracted data that will give an indication of the overall progressive/regressive nature of different policies in the mix, as shown in Table 14 and Figure 29. Note that, given the above caveat and the combination of measures households may receive, the sum of the values shown for each individual policy will not equate to the overall impact (–£105) of all policies.

On average, across all consumers, the RO appears to be adding the most to energy bills in 2020, while products policy contributes the greatest savings. This reflects the fact that the former policy only has costs associated with it (within DIMPSA) while the latter only has efficiency savings (that is, no cost on bills). The Green Deal and ECO are expected to add around £25 to the average energy bill in 2020, while the FIT appears to offer a net saving of over £30. However, these policies have both costs and benefits associated with them. The impact on an individual household will therefore vary significantly, depending on whether the household benefits from the policy by taking up one or more measures. There are also distributional effects masked by these average figures: a policy that offers a net reduction on bills overall may impact negatively on some household types, and vice versa. This is explored further below.

Table 14: Impact of individual policies on 2020 total household energy bill (England only)

Policy	2020 bill without any policies ('no policy')	2020 bill with individual policy	Impact of individual policy on 2020 bill
Renewables Obligation	£1,285	£1,346	£61
EU Emissions Trading Scheme & Carbon Price Floor	£1,285	£1,330	£45
Electricity Market Reform	£1,285	£1,323	£38
Green Deal & Energy Company Obligation	£1,285	£1,310	£25
Warm Homes Discount	£1,285	£1,289	£4
Renewable Heat Incentive	£1,285	£1,280	–£4
Smart Meters	£1,285	£1,273	–£11
Carbon Emissions Reduction Target	£1,285	£1,265	–£20
Feed-in Tariff	£1,285	£1,251	–£34
Boiler Churn	£1,285	£1,247	–£38
Products Policy	£1,285	£1,244	–£41
All policies in combination	**£1,285**	**£1,180**	**–£105**

Figure 29: Impact of individual policies on 2020 average household energy bills (England)



Impacts of individual policies on households that receive support

Table 15 and Figure 30 show the impact of individual policies, split by households that do and do not benefit directly from each individual policy.

There are some key points to bear in mind when interpreting these results:

- Some policies represent a cost on household energy bills in 2020 but offer no direct benefit to householders, hence 100% of households fall into the 'do not benefit directly' column. These are RO, EU ETS and CPF, and EMR, and the figures shown therefore replicate those in Table 14).
- Policies that offer direct benefit to householders but are funded through general taxation appear as no cost on household energy bills in 2020. RHI is in this category.
- Some policies will be (nearly) completed by 2020 and therefore represent no (or negligible) cost on energy bills in that year, but may still represent a benefit to householders. These are CERT and smart metering. (The latter also represents a 'universal' policy in that all householders stand to benefit.)

Table 15 therefore shows that households taking up measures under the Green Deal and ECO policies (some 14% of households in this modelling scenario) are expected to see an average reduction in their energy bill of over £130 in 2020, while the remaining 86% of households pay £51 on average towards a share of the cost of these policies. (This is in the context of these policies contributing a cost towards the average bill across the population as a whole.)

Table 15: Impact of individual policies on actual household energy bill in 2020 for households that do and do not receive support/measures under that policy (England)

	Households do not benefit directly from policy		Households benefit directly from policy		Average bill impact
Policy	**Impact of policy**	**% of households**	**Impact of policy**	**% of households**	
Policies with no direct householder benefits					
Renewables Obligation	£61	100%	£0	0%	£61
EU Emissions Trading Scheme & Carbon Price Floor	£45	100%	£0	0%	£45
Electricity Market Reform	£38	100%	£0	0%	£38
Policies that offer householders sustainable energy measures with costs recovered from bills					
Carbon Emissions Reduction Target	£0	77%	–£86	23%	–£20
Green Deal & Energy Company Obligation	£51	86%	–£136	14%	£25
Smart Meters	£0	0%	–£11	100%	–£11
Feed-in Tariff	£10	88%	–£359	12%	–£34
Policies that offer householders a reduction in energy costs					
Warm Home Discount	£11	97%	–£236	3%	£4

continued over

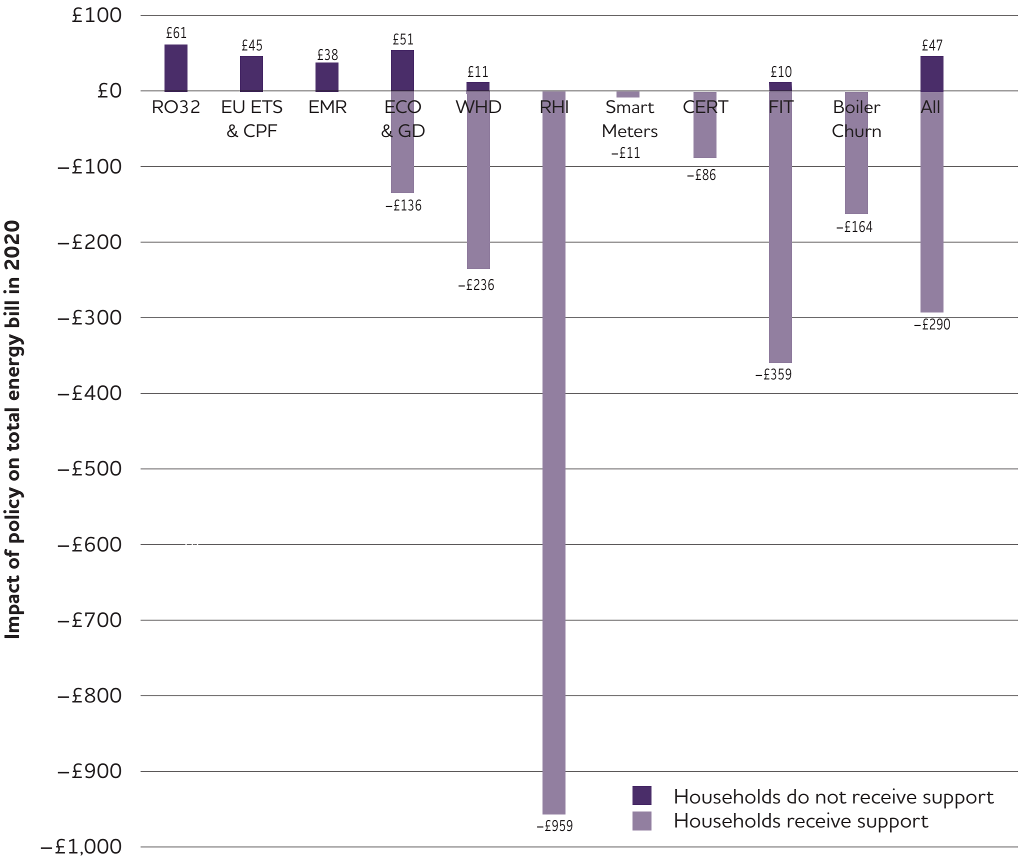
Table 15 *continued*

Policies that offer householders sustainable energy measures without cost recovery from bills					
Boiler Churn	£0	77%	–£164	23%	–£38
Renewable Heat Incentive	£0	99.5%	–£959	0.5%	–£4
All policies[a]	**£47**	**55%**	**–£290**	**45%**	**–£105**

Note: [a] this does not include households benefiting from smart metering as this represents the whole population. Some households may benefit from more than one policy.

The RHI and FIT, on the other hand, present a net saving on average across the population as a whole. However, in practice only those households taking up measures under these policies will experience any savings – and this represents a relatively small proportion (less than 1% for the RHI[30] and 12% for FIT in this modelling scenario – see Table 15). Thus, while those households benefiting from measures are likely to see substantial savings on their 2020 energy bill (a saving of £959 and £359 under the RHI and FIT respectively), the remainder of the population experiences the impact of these policies as a cost on their energy bill (under the FIT) or no impact (under the RHI, the costs of which are to be recovered through general taxation). It is the size of the savings experienced by the minority of households that results in these policies appearing to represent a net reduction on the 2020 energy bill.

Figure 30: Impact of individual policies on total actual household energy bill in 2020 of households that receive/do not receive support (England)



Distributional impacts of individual policies

The impact of individual policies (in actual terms and as a proportion of income) on consumer energy bills in 2020 by income decile is shown below. This illustrates the regressive nature of the different policies and cost-recovery mechanisms applied. For example, the three policies that represent a fixed levy on bills (£/kWh) but offer no direct benefits to householders – namely the RO, EMR, and EU ETS and CPF – result in a higher absolute cost on the bills of higher income consumers (due to £/kWh charging because higher income households typically have higher consumption – see Figure 31). However, this cost represents a higher proportion of income for lower income households (see Figure 32).

CERT applies the typically less favourable 'per customer' approach to cost recovery, so the cost paid by householders does not reflect individual energy consumption levels. This appears progressive due to the modelling timeframe: CERT will no longer be operational as a policy in 2020 and therefore does not have a cost on bills in this year, but households that have benefited from CERT will still be seeing savings on their bills as a result of measures. As CERT targets the most cost-effective measures and includes the Priority (and Super Priority) Group, in order to focus measures on lower income households, the policy appears progressive in 2020. However, this trend is reversed when looking at earlier years when CERT is still 'live' and represents a cost per customer.

The patterns shown in Figures 31 and 32 are in part a function of the assumptions built into the model about which households are likely to benefit from the different policies. Where a policy has both a cost on the energy bill in 2020 and potential benefit – the Green Deal and ECO, Warm Homes Discount and FIT – it is useful to look at the impacts alongside the distribution of take-up of the policy (i.e. measures or support). Figures 33 to 35 therefore show the impact of these three policies on household energy bills in 2020, split by households that do and do not benefit directly, by disposable household income decile. The average impact of the policy across deciles (as shown in Figure 31) is shown again here by the dashed line. The bars (right-hand axis) show the proportion of households in each decile that benefit directly from the policy.

Figure 31: Impact of individual policies on household energy bills in 2020 by disposable income decile (England)

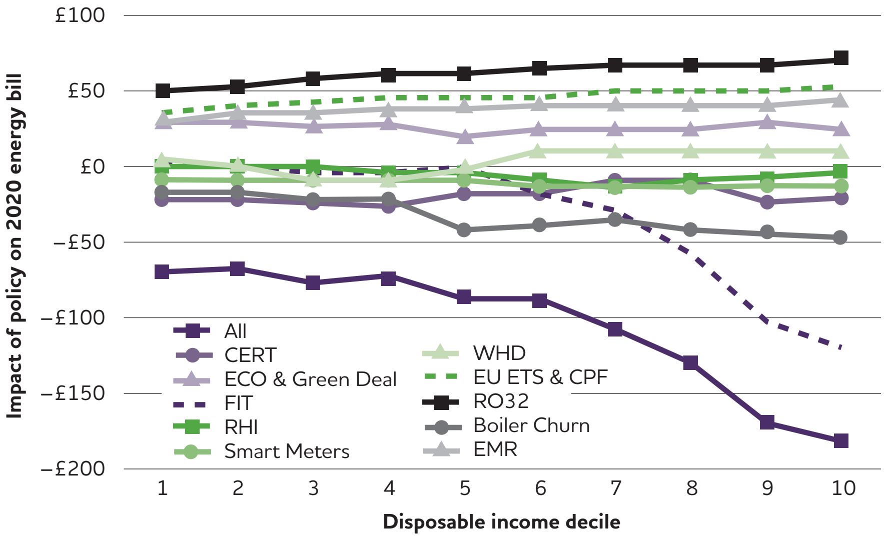
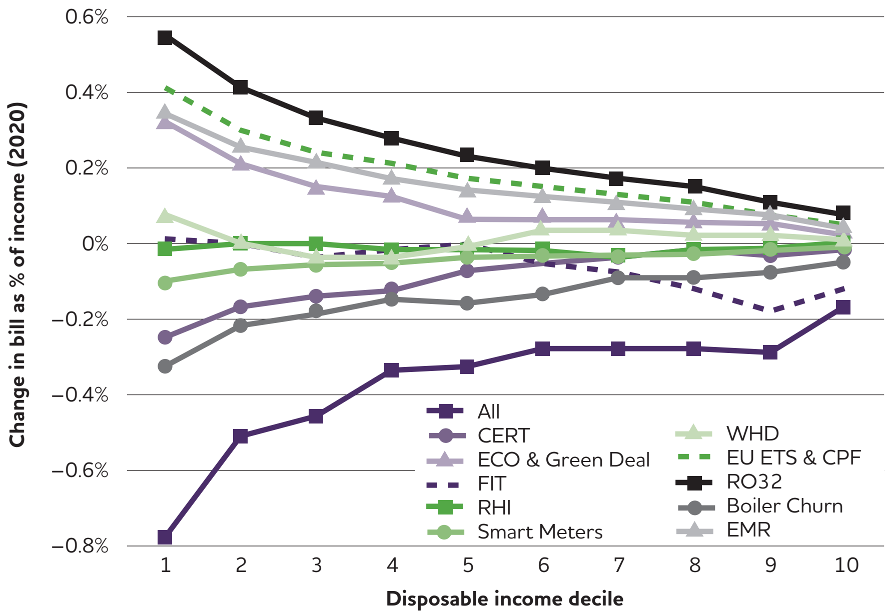


Figure 32: Impact of individual policies on household energy bills as a proportion of income in 2020 by disposable income decile (England)



Note that disaggregating the data in this way results in some small sample sizes. In addition, due to the interaction effects of different policies, the impacts of one policy in isolation will not necessarily reflect the impact of the overall policy mix in 2020. The impact should be considered indicative of the pattern of impacts from individual policies rather than taken as absolute.

Impact of FIT

Figure 33 shows that on average, for higher income households in England, the FIT represents a saving on the 2020 household energy bill, but represents a small cost on bills in 2020 for the lower income deciles (represented by the dashed line). However, there is significant divergence in the impact depending on whether a household benefits directly from the policy. This appears to be skewed towards the upper income deciles, with some 36% of the top decile benefiting from FIT compared with 1% in the bottom income decile (bars, right-hand axis). This is a function of how take-up has been modelled in DIMPSA, which favours higher income households because of the capital costs of installing the technology. The average income of the 12% of households benefiting from FIT in this model is just under £62,400 (see Table 16).

For higher income households in England, the FIT represents a saving on the 2020 household energy bill, but represents a small cost on bills in 2020 for the lower income deciles.

Table 16: Impact of FIT on the proportion of the population that does and does not take up the policy

	Losers	Winners
Count	18,852,878	2,527,199
Percentage	88%	12%
Mean income	£32,728	£62,389
Mean bill 2020	£1,260	£1,187
Mean bill impact	£10	−£359
No policy/counterfactual bill 2020	£1,250	£1,546
Impact as % of counterfactual	1%	−23%

Figure 33: Impact of FIT on household energy bills in 2020 for those that do and do not take up the policy, by disposable income decile (England)

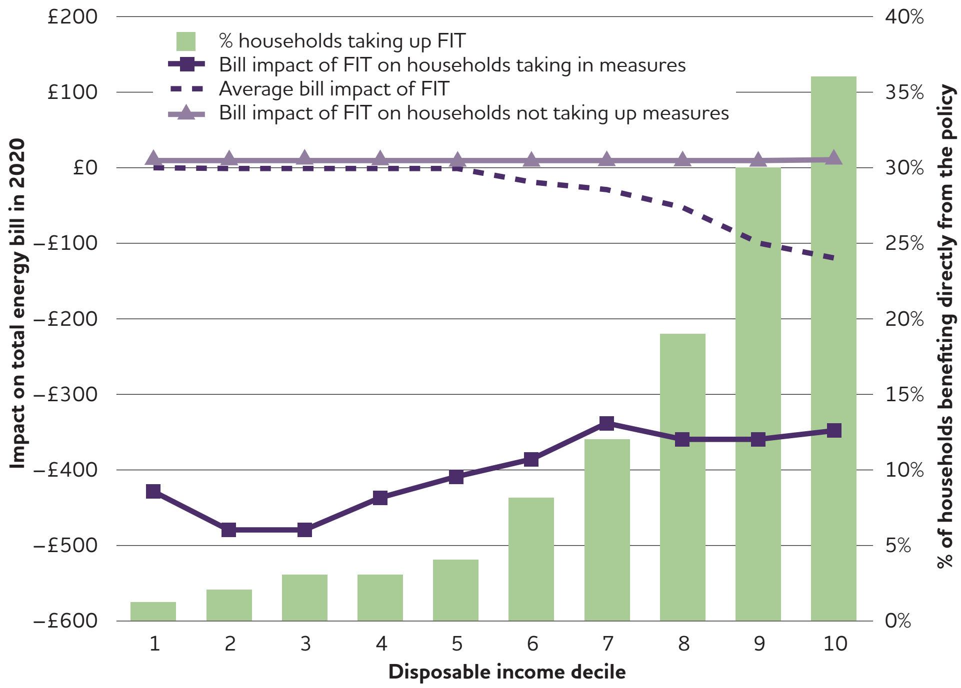
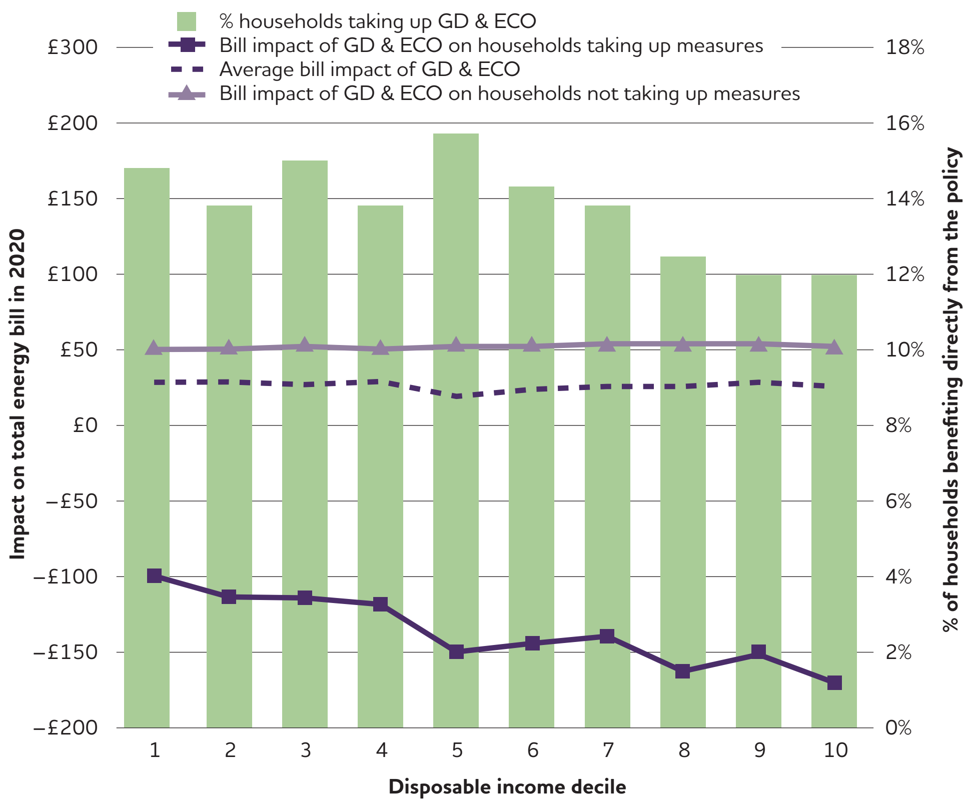


Figure 34: Impact of Green Deal and ECO on household energy bills in 2020 for those that do and do not take up the policy, by disposable income decile (England)

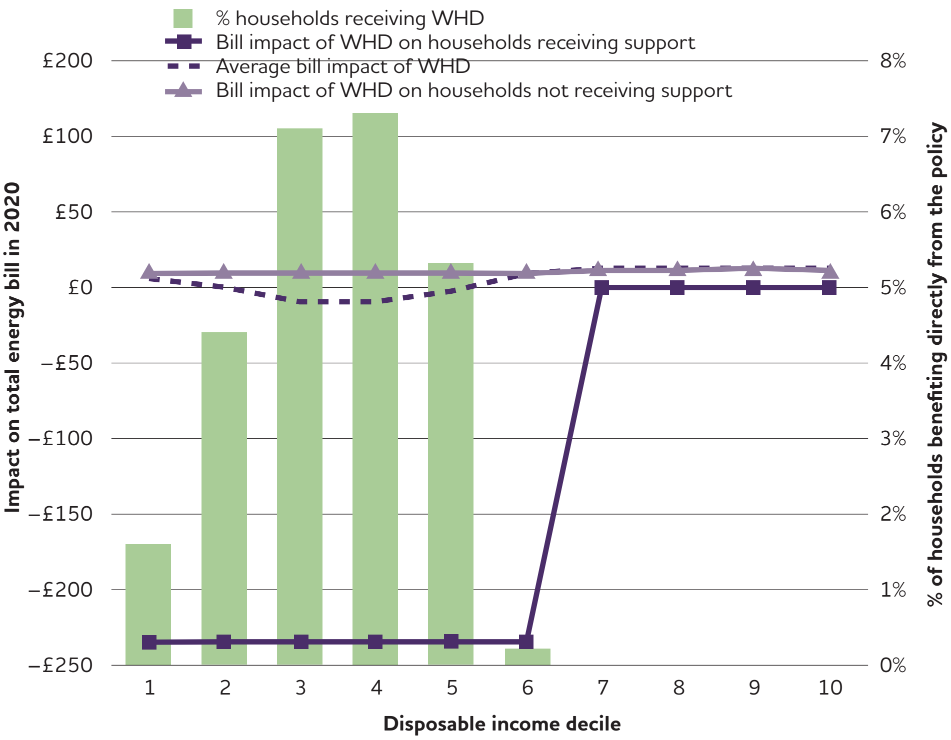


This study has used DECC's 'Option A' scenario for FIT, which targets average rates of return of around 5% for domestic installations. However, it is important to note that the FIT impact assessments do not provide data on the actual number of assumed PV installations per year, their size or the typical profile of householders taking up measures. The modelling therefore represents our best estimate of installation rates. The analysis also assumes that FIT payment is taken from the energy bill (to allow direct comparison with DECC's publications) and that the non-domestic sector also pays towards the cost of domestic FIT via its electricity consumption – that is, the charge per unit to recover the costs is the same for all sectors and customer types.

Impact of Green Deal and ECO
Figure 34 shows that households expected to benefit from the Green Deal and ECO might expect to see this translate into a saving on their 2020 energy bill in the region of £100–200, while households not taking up measures under this policy experience it as a cost on their 2020 bill of around £50. On average, across all income deciles, the Green Deal and ECO is likely to represent a cost on energy bills in 2020 of around £30.

Impact of the Warm Homes Discount
Figure 35 shows that only households in the lowest six income deciles benefit at all from the Warm Homes Discount and this represents a saving on their 2020 energy bill of around £235. This is consistent with the policy criteria and expected value of WHD in 2020. All other households pay for the cost of the policy at an average rate of around £10 on their energy bill in 2020. This policy therefore appears highly progressive overall, as would be expected from one targeted specifically at low-income households.

Figure 35: Impact of WHD on average household energy bills in 2020 for households that do and do not benefit from the policy, by disposable income decile (England)



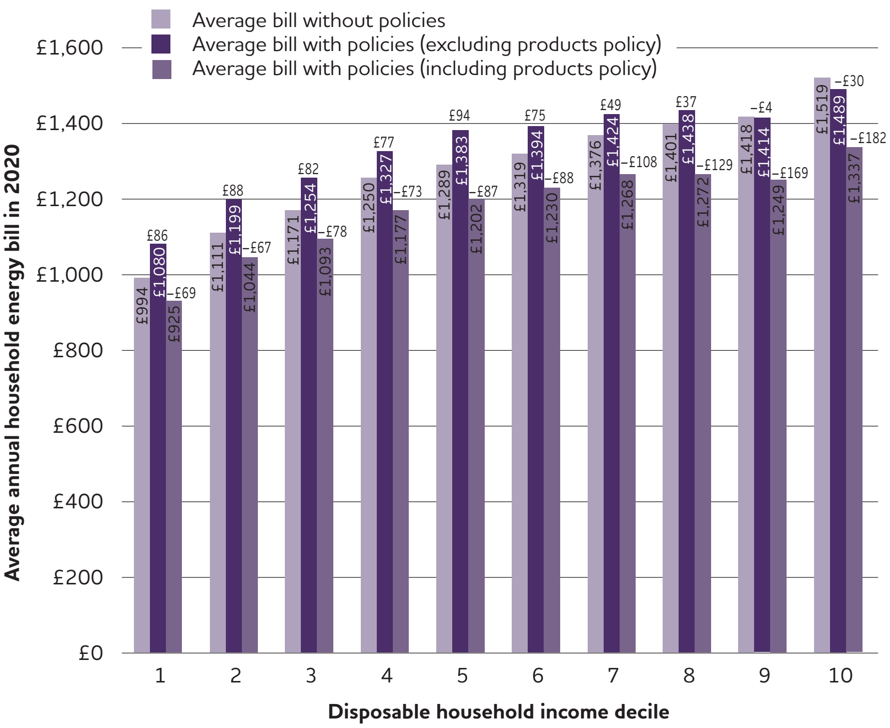
Impacts of products policy
As noted above, the average household energy bill in 2020 appears lower than the 'no policy' scenario, and this can be largely traced back to the impact of products policy. This policy assumes improvements in the efficiency of consumer products will reduce household energy demand. The impacts of products policy applied in the modelling presented here are consistent with government assumptions. However, to explore the extent and implications of these assumptions for the results obtained, the model was run without any products policy savings.

The results, shown in Table 17 and Figure 36, present a very different picture, with average household energy bills in 2020 appearing higher (by £55 on average) than the 'no policy' scenario. The proportional difference between households that benefit directly from policy and those that do not is over £300 (see Table 17).

Table 17: Overall impact of policies without products policy (PP) on actual household energy bills in 2020 (England only)

	Overall	Households: no support	Households: with support
2020 bill without policies	£1,285	£1,270	£1,302
2020 bill with policies (no PP)	£1,340	£1,465	£1,189
Impact of policies (no PP)	£55	£195	−£113
% change due to policies (no PP)	4%	15%	−9%
Count of households	21,380,077	11,716,921	9,663,156
% of households	100%	55%	45%

Figure 36: Household energy bills in 2020 by disposable income decile (England): without any policy; with standard policy assumptions (inc. products policy); and standard policy assumptions without products policy

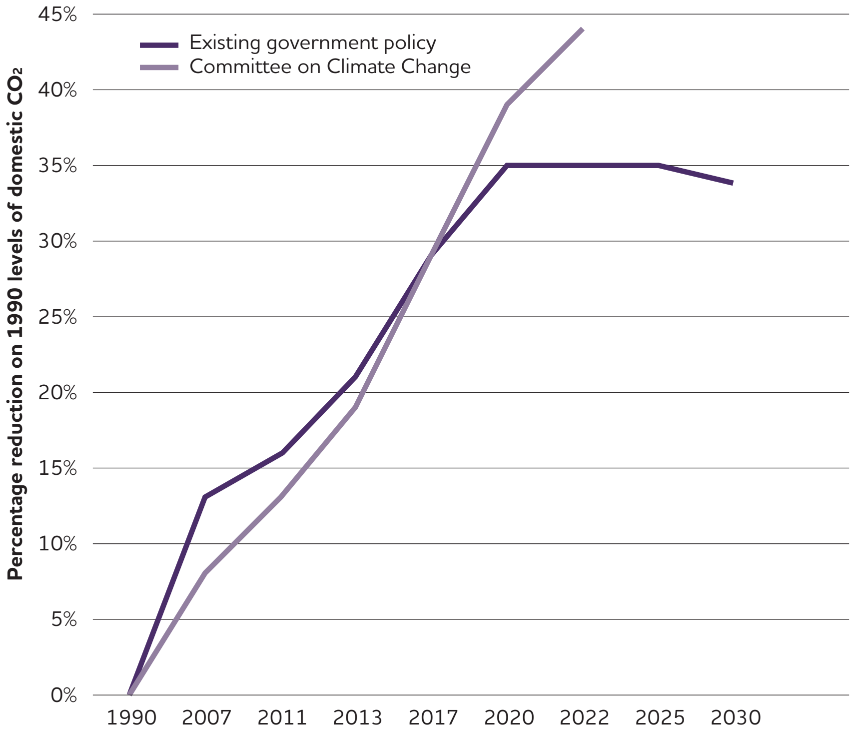


The distributional impact across income deciles appears highly regressive, with the lowest income decile seeing an average increase in its 2020 energy bill of over £80, while the highest income decile still sees a reduction in its 2020 energy bill of £30 (compared with a 'no policy' scenario – see Figure 36). This represents an impact on the 2020 'no policy' energy bill of +9% and -2% respectively.

Impact of government policies on household emissions

This section of the report is primarily concerned with exploring the impact of government climate change policies on domestic energy consumer bills. However, it is also possible, using the outputs of DIMPSA, to explore the impact of these policies on household energy demand and resulting emissions. The results (see Table 18) suggest that by 2020 total household emissions could be reduced to some 83.3 $MtCO_2$, based on current policies in place and what is known about forthcoming policies (Green Deal and ECO) that support the installation of energy efficiency, heating and renewable energy measures across the housing stock. This represents a 25% reduction on the survey baseline (2007) emissions total and a 35% reduction on 1990 emissions levels (see Figure 37).

Figure 37: Emissions trajectory for existing government policy alongside the CCC targets for the first and second carbon budgets



Beyond 2020 there is much uncertainty, hence the levelling out of the line representing government policy impacts in Figure 37. For example, the successor to the Green Deal and the ECO from 2021 is unknown and therefore not modelled here. Alongside these future policy unknowns, the extent to which policies such as the Green Deal, ECO and products policy will deliver savings attributed to them is also uncertain. For example, if we entirely exclude products policy impacts from the model, it results in a much smaller reduction in household emissions to some 90.9 $MtCO_2$ in 2020 (a 17% reduction on the survey baseline emissions total and a 29% reduction on 1990 emissions levels). These results therefore suggest that current policies are expected to meet 2020 emissions reductions targets only if assumptions regarding policy impacts, particularly products policy, are borne out. If not there will be a shortfall of approximately 8 $MtCO_2$.

Table 18: Impact of government policy on household emissions

	Total ($MtCO_2$)	Reduction vs. 1990 ($MtCO_2$)	Reduction vs. 1990 (%)
1990 emissions from household fuel use	128	–	–
Survey baseline (2007)	111	17	13
2020 total with all current policies applied	83	45	35
2020 total excluding products policy	91	37	29
2020 Committee on Climate Change target	78	49	39

Discussion

The analysis of UK government energy and climate policies on household energy bills in 2020, as modelled here, shows the overall, combined impact to be a net reduction on the average annual bill in 2020 of £105. This is 8% below the expected bill in 2020 if these policies were not implemented. While all households stand to benefit on average from the implementation of policies, the impact is greater in absolute and percentage terms in 2020 for the wealthiest households when compared with the poorest. That is, the richest 10% see a £180 (12%) reduction compared with £69 (7%) for the poorest 10% of households (see Appendix 1: Policy modelling assumptions for further details). Furthermore, the *total household energy bill* (the total cost of energy in the home) represents a much higher proportion of household income for poorer households, ranging from 10.5% for the lowest income decile to 1.3% for the wealthiest households.

The difference between households that do or do not benefit from measures under the different policies is relatively significant. While the proportion of households receiving support or measures from one or more policies is relatively uniform across the income deciles, the distributional impact on energy bills appears to be regressive. That is, higher income households that benefit stand to see a greater saving on their energy bills than low-income households in 2020 (compared with a 'no policy' scenario).

The overall average reduction on household energy bills in 2020 that results from the modelling in this study (when compared with a 'no policy' scenario) is predominantly driven by government assumptions about the savings that will be delivered through improvement in products policy. This relates to the regulated requirements for minimum levels of energy efficiency in consumer products. Modelling the impact of policies in combination to include these assumptions means that the cost of policies passed through to consumers' bills is outweighed by the savings assumed from other policies, that is, the assumed universal savings from smart metering and products policy.

The assumed savings from products policy have an important and noticeable impact on the results (Renewable Energy Forum, 2012). Average household energy bills appear higher in 2020 (by £55 on average) when this policy is not included in the modelling, rather than appearing lower (by £105 on average) as is the result with the standard government assumptions applied. When examining trends for domestic electricity demand over the last ten years, there has been a gradual decline in demand; however, the decline does not match that predicted by Defra for products policy.

While the DIMPSA model allows for some distributional effect (such as in distributing products policy savings based on appliance ownership and property size), it is quite likely that lower income households will be slower to replace products and may purchase a higher number of second-hand items so accruing less benefit from improvements in product efficiencies than suggested by the model. Thus the distribution of savings from improvements in product efficiencies may favour lower income households to a lesser extent than modelled here, and the overall impacts would therefore appear more regressive.

Although the rate that the model deploys measures and the assumed performance of these measures is consistent with those of DECC's AES (2011), there is, in practice, no certainty that the policies will be as successful as predicted. The Green Deal and the ECO face a particularly uncertain future in the light of recent delays to their launch and concerns over interest rates for the upfront loans for works. These loans are higher than high street lenders – that is, 7.5% (Richards, 2012) compared with 6.8% (Nationwide, 2012). The unattractive interest rate sits alongside an uncertain economic climate where many householders are reluctant to take on further debt.

Furthermore, the recent DECC Green Deal and ECO consultation included additional 'in-use' factors for measures' performance and installation quality. These factors increase the rate of assumed comfort taking (see 'Glossary of terms of terms') to approximately 50%, which is significantly higher than the 15% applied as standard in DIMPSA. The 'in-use' factors are based on an analysis of measures performance data by Sanders and Phillipson (2006). If these represent a more realistic scenario, then we can infer that the results from the model run for this study may be overestimating the level of savings resulting from the Green Deal and ECO.

The modelling of policies in isolation demonstrates the regressive nature (where lower income households are worse off than higher income households) of certain policies. For example, on average, across all consumers, the RO appears to be adding the most to energy bills in 2020, while products policy contributes the greatest savings. This is not surprising as the former represents only a direct cost on bills to householders, while the latter represents only a saving. The WHD and CERT appear progressive overall, with the costs of policies falling more heavily on higher income households, while lower income households stand to gain.

The Green Deal and ECO are expected to add around £25 to the average energy bill in 2020, while the FIT appears to offer a net saving of over £30 on average across the population as a whole. However, these overall average impacts mask significant variation in the impact on different households. The Green Deal, ECO and FIT all have both costs and benefits associated with them. The impact on an individual household therefore varies substantially, depending on whether the household benefits from the policy by taking up one or more measures. Households taking up measures under the Green Deal (some 14% of households in this modelling scenario) are expected to see an average reduction in their annual energy bill in 2020 of over £130. Households benefiting from FIT (12% in this model) see an average saving of £359 on their 2020 energy bill, while the remaining 88% of the population pay for the policy at an average cost of £10 on their 2020 energy bill.

The WHD shows a progressive pattern of impacts due to the highly effective targeting of this policy, which uses data on benefits provided by the Department for Work and Pensions (DWP). The policy is scheduled to run until the next comprehensive Spending Review in 2015. Government analysis currently assumes that this will continue and our analysis supports this – that is, it should continue until all target households have been given energy efficiency measures that deliver long-term sustainable savings. The target group could arguably be expanded beyond low-income pensioners on the guarantee component of Pension Credit, particularly to include customers with long-term limiting illnesses who may also be considered to be vulnerable.

Conclusion

This study set out to identify who benefits from and who pays for energy and climate policies. The current mix of government policies has the potential to meet our carbon emission targets and also protect the average consumer from the impacts of rising fuel prices. However, the wealthiest householders stand to benefit most from these policies, with lower income households experiencing energy costs that represent a far higher proportion of their income.

The overall picture has been described as both progressive and regressive – that is, all households stand to benefit, but the poor, less so. However, the performance of the set of reviewed policies is key to the delivery of both emissions and bill savings; it is likely that measures or policies will underperform, which will then result in higher bills across all income deciles. Government policy could therefore be likened to a house of cards: if one card is removed then the rest could also fall.

Additional drivers for take-up of energy efficiency measures are therefore needed, such as mandatory standards for rented homes from 2013 rather than 2018; council tax rebates for those that improve their homes; subsidised interest rates for Green Deal loans; and reductions in stamp duty based on pre-sale improvements to property energy efficiency.

6 MODELLING AN ALTERNATIVE HOUSING STOCK RETROFIT POLICY SCENARIO

Analysis of the impact of existing government energy and climate change policies presented in the previous chapter raised issues relating to both fairness and effectiveness. Under existing policies, household energy bills in 2020 are still likely to represent a higher proportion of income for poorer households.

Chapter summary: key points

- Analysis of the impact of existing government energy and climate change policies showed that several of these are highly regressive in nature (Chapter 5). What is more, existing policies are unlikely to deliver the level of reduction in household emissions required by the Committee on Climate Change to meet long-term government targets.
- This study has therefore sought to model an alternative policy scenario that achieves maximum household emissions reductions through the deployment of key energy efficiency, heating and renewable energy measures across England's housing stock from now to 2030 (termed the 'maximum CO_2 abatement policy' or 'max CO_2'). The modelling assesses how the costs of deployment could be recovered, and the associated impact on consumer energy bills and household emissions in 2020 and 2030.

- To achieve a fair distributional impact in terms of energy bills, the scenario relies on income tax as a principle source of funding. In addition it proposes that lower income households receive free measures and higher income households pay a contribution to the cost of their measures through the Green Deal.
- The maximum CO_2 abatement policy scenario sees some 86 million different measures deployed across England's housing stock. This results in a reduction in actual household emissions of some 41% by 2020 on baseline (1990) levels and of 60% by 2030. This is ahead of DECC's requirement to reduce emissions by 35%, but is still far short of the 80% target required by 2050.
- This suggests therefore that a more radical approach to reducing carbon emissions is needed longer term. This might include, for example, even greater emphasis on improving the thermal efficiency of the housing stock; regulated and enforced improvements in product efficiency, particularly lighting; further decarbonisation of the electricity supply; and potentially capping emissions at household level, for example through a personal carbon allowance system.
- It is important to note that the results of this modelling do not take account of embodied emissions (the energy consumption associated with the production of goods and services) or the rebound effect (whereby the financial savings from reduced energy consumption in the home are spent on other emission-generating activities, goods or services). If this were to be included, the estimated emissions reductions reported here would be lower.

Introduction

The most optimistic outcome for emissions reductions from existing government policies results in a 35% saving on 1990 by 2020. However, beyond (and even within) this, there is much uncertainty about the likelihood that policies will deliver the required reductions in emissions. Overall, there is a likelihood of shortfalls as a result of policies or measures underperforming. Such shortfalls would place further pressure on emissions reductions in other sectors, posing an even greater challenge in achieving the shift to a low-carbon economy.

An alternative policy scenario has therefore been modelled to explore the potential for a widespread retrofit of the housing stock in England. In this scenario, measures are installed wherever opportunity is identified and the outcome is deemed cost effective. The costs are not borne solely by individual households but recovered through a variety of different mechanisms, thereby attempting to minimise the cost implications for domestic consumers. The design is illustrative of what could be done over a 19-year period if the political will existed. The 2012 start links with the baseline in the model used here, but could equally be set at a later date.

The analysis presented in this section utilises the EHCS-based dataset created as part of this study. The dataset offers new scope for policy modelling as it provides both the detailed information on housing stock characteristics (needed to identify opportunities for energy efficiency, heating and renewable energy measures) and actual household energy consumption, imputed from the EFS dataset (which can be used to assess the impact on actual household bills). It also provides all the data needed to assess the implications for fuel poverty – that is, the *required* energy and associated energy bills for maintaining satisfactory levels of warmth in the home.

As well as revealing an alternative approach, this scenario also demonstrates the capabilities developed during this project to model policy combinations and assess their distributional impacts across the population.

Method overview

Identifying opportunities for measures

The EHCS represents the entire housing stock in England. The data in the survey contains very detailed and specific information on physical characteristics of dwellings, including loft insulation levels, wall types and insulation, heating systems and fuels, as well as property dimensions. This data can be used to determine the potential for, and applicability of, different measures – insulation, heating and renewables – to improve the energy efficiency of England's housing stock.

CSE has developed a modelling tool – the Housing Assessment Model (HAM) – which aims to do just that. For every property represented in the dataset, the model produces a baseline assessment of household energy requirements and associated CO_2 emissions and fuel costs. It then calculates the best combinations of energy efficiency, heating and renewable energy measures that could be applied to improve the thermal efficiency and sustainability of each dwelling, according to predefined target criteria.

The HAM is used here in modelling a housing stock retrofit policy scenario ('maximum CO_2 abatement' or 'max CO_2') to identify which households in England could benefit from measures that will deliver the maximum possible reduction in household carbon emissions. However, it should be noted that the measures are selected from a finite list input to the model. While this covers the main energy efficiency, heating and renewable energy measures (see Table 19), it does not represent an absolute maximum abatement opportunity as some of the measures deliver minor savings and are not included in the model – that is, they use fossil fuels with marginal improved efficiency and/or are less proven (for example, radiant heating, warm air heating, water source heat pumps, heat recovery systems and triple glazing). The typical costs of measures deployed are shown in Appendix 1: Policy modelling assumptions (Table 36).

The results of this analysis are shown in Table 19. Overall, some 86 million different measures are identified from the list input to the model for installation across England's housing stock to reduce emissions from household fuel consumption as far as possible (within the limits of the measures included in the modelling). This is at a total cost of over £293 billion, and assuming a roll-out from 2012 to 2030 equates to an average cost of £15.4 billion per year (although, as Figure 39 shows, in practice costs vary each year to reflect the overall deployment strategy). The modelling suggests that over three quarters (81%) of the English housing stock could benefit from a gas condensing boiler by 2030; nearly two thirds (63%) from loft insulation; 40% from cavity wall insulation; and 24% from solid wall insulation. Around 40%[31] of properties were deemed suitable for solar water heating and/or PV. While this represents a high proportion of roof tops, previous studies (Boardman, 2012) have assumed higher penetration rates with additional use of east/west systems and garden areas for frame-mounted systems.

Some 86 million different measures are identified from the list input to the model for installation across England's housing stock to reduce emissions from household fuel consumption at a total cost of over £293 billion.

Table 19: Measures included in the Housing Assessment Model and total opportunity identified across the English housing stock (based on modelling using the EHCS 2007 dataset)

Measures	Count ('000)	% of housing stock
Insulation		
Cavity wall insulation	8,512	40%
Solid wall insulation	5,180	24%
Loft insulation	13,560	63%
Floor insulation	2,949	14%
Double glazing	6,820	32%
Heating		
Gas condensing boiler	17,401	81%
Hot water tank insulation	44	0.2%
Oil condensing boiler	181	1%
Heating control upgrade	8,584	40%
Advanced heating controls	9	0.04%
Log stove	2,684	13%
Renewables		
Solar water heating	8,597	40%
1 kW solar PV system	133	1%
2 kW solar PV system	8,387	39%
Air source heat pump	1,397	7%
Ground source heat pump	24	0%
Biomass boiler	1,459	7%
Total measures	**85,919**	
Total cost[a]	**£292.7 bn**	

Note: [a] the typical assumed costs for the measures deployed are shown in Appendix 1: Policy modelling assumptions

Modelling a fairer roll-out of measures

The modelling of this policy scenario has attempted to ensure that the poorest benefit from free measures while the richest pay a fair proportion of the costs of their measures. The remaining costs are recovered from a variety of sources. Box 6 describes the roll-out in more detail.

Box 6: Deploying the maximum CO_2 opportunity

The scenario assumes that all the identified measures are rolled out by 2030.[32] The roll-out has been modelled such that the most cost-effective packages of measures (greatest improvement in thermal efficiency per pound spent – principally, loft insulation, cavity wall insulation and gas condensing boilers) are prioritised for the first six years until 2017. As well as being logical, this approach to modelling also allows for the additional time needed to develop the industry supply chain so that there are products and installers available for the non-traditional measures that will need to be installed at volume in later years (e.g. solid wall insulation).

From 2017 onwards, the deployment of packages is spread evenly over each year to give a relatively constant rate of investment. This avoids a high spike in investment costs towards the end of the roll-out programme.

Recovering programme costs

Based on the scenario modelled, the proportion of each income decile assisted by 2020 ranged from 41% (for the highest income decile) to 51% (for the sixth income decile). The year 2020 is also used again here for reporting to allow for direct comparison with the results of the government scenario modelling. However, as noted above, it is assumed that the maximum CO_2 abatement policy scenario is not completed until 2030. This modelling timeframe was applied to represent a more realistic scenario in terms of annual installation rates and spreading of costs.

In 2020, if households are paying towards the costs of other people's packages of measures but have themselves not yet received assistance, they could be disproportionately burdened by the costs of the scenario's deployment. The use of Green Deal finance (as discussed below) and the level at which the Golden Rule is passed ensure that better off households receiving measures contribute a fair amount towards the package. This approach is complemented by the use of income tax and existing carbon revenues to pay for the majority of the grant funding for measures.

By 2030 the vast majority of householders benefit from reduced energy use due to energy efficiency improvements to their homes. However, higher income households continue to pay the Green Deal charge, which in many cases results in higher fuel costs.

As noted above, the cost of delivering all the measures identified in this alternative housing stock retrofit scenario equates to some £293 billion over the lifetime of the policy (from 2012 to 2030). The cost in each year, as shown in Figure 39, reflects the number and types of measure deployed in that year. If these costs were to be recovered solely through energy bills, this would result in bills almost doubling, at least until the roll-out had been completed. Alternative sources of revenue were therefore explored to provide a complementary set of funding mechanisms, including:

1. **Green Deal Finance:** provide a loan towards the total package cost for households in the fifth income decile and above. The monthly saving is used to calculate the maximum loan available over 25 years at 7% interest, and the loan repayment is then added to their final energy bill. The remaining costs (if any) are fully funded via a grant.
2. **Grant funding:** provide a full grant for the cost of measures for households in the fourth income decile or below. The study has not explored the necessary targeting approach for the scenario; however, a CESP area-based approach could be used for areas of low-income households, or these households could be targeted with the use of primary legislation to encourage further data sharing between HMRC and those delivering energy efficiency measures.
3. **Income tax:**[33] increase the rates of income tax across the basic, middle and higher bands. Table 20 shows the dates at which changes are implemented to the income taxation thresholds and the changes to the rate required.
4. **EU ETS and CPF:** use the revenues levied on energy bills under these policies to invest in energy efficiency directly (as proposed in the Energy Bill Revolution Campaign, 2012), rather than going to public finances as

at present.[34] While it is already planned that these costs will be added to our bills, it is important to note that this represents an additional cost to householders as part of this scenario.

5. **Winter Fuel Payments (WFP):** means test WFP and use the revenue raised to fund energy efficiency measures.
6. **Energy bills:** where there is a small shortfall in required revenue in any year (such as for the total investment cost less Green Deal finance and revenue from other sources), pass the remaining cost on to consumers' energy bills. The shortfall is a result of changes to the income tax rates resulting in step changes in the revenue raised – that is, the exact total cannot always be raised.

Table 20: Changes to income taxation rates

Year	Starting rate	Basic rate	Higher rate	Additional rate
2012 to 2016	10%	20.0%	40.0%	50%
2017	10%	20.0%	40.0%	55%
2018	10%	20.4%	41.5%	55%
2019	10%	21.6%	42.5%	55%
2020	10%	21.4%	42.5%	55%
2021	10%	21.1%	42.5%	55%
2022	10%	21.0%	42.5%	55%
2023 to 2024	10%	20.9%	41.7%	55%
2025 to 2026	10%	20.8%	41.7%	55%
2027 to 2030	10%	20.5%	41.7%	55%

To enable a meaningful comparison of the impacts of this alternative policy scenario with the analysis of the impact of existing government policies presented in the previous section, the alternative scenario also needs to allow for the impacts of large-scale non-domestic policies that impact on consumers' energy bills, namely the EU ETS and CPF, and the RO. These represent a fixed per unit charge on electricity bills (refer to Table 11 for full details on policy cost-recovery mechanisms). Also for consistency with the previous analysis of existing government policy, some savings are assumed to allow for improvements in product efficiency and smart metering (which also includes a cost), as summarised in Table 21.

Table 21: Policy costs and benefits under the alternative housing stock retrofit policy scenario (maximum CO_2 abatement)

	Household CO_2 reductions	Household energy bill savings	Cost on household energy bills	Taxation increase
Retrofit	✓(Households receiving measures only)	✓(Households receiving measures only)	✓(Households receiving measures only)	✓(All households)
Products Policy	✓(All households)	✓(All households)	–	–
Smart Metering	✓(All households)	✓(All households)	✓(All households)	–
EU Emissions Trading Scheme	–	–	✓(All households)	–
Renewables Obligation	–	–	✓(All households)	–
Carbon Price Floor	–	–	✓(All households)	–

Headline results: overall policy costs

A total of some £293 billion (see Table 22) is required to fund a retrofit of England's housing stock in order to achieve the maximum possible reduction in household CO_2 emissions by deploying the main energy efficiency, heating and renewable energy measures. Over the lifetime of the policy, nearly two thirds (60%) of the costs can be raised from alternative sources, with the remainder (some £114 billion) being recovered via a Green Deal charge on energy bills. This cost is spread over each year of the roll-out and depends on the number of measures being installed in each modelling year.

Table 22: Investment required to fund a maximum CO_2 retrofit scenario

Costs (£bn)	Total lifetime cost of policy
Revenue from Green Deal charge	£113.5
Remaining cost on bills[a]	£2.8
Revenue from income tax	£70.6
Revenue from EU ETS & CPF	£79.9
Revenue from means testing WFP[b]	£25.8
Total cost of retrofit policy	**£292.7**

Notes: [a] to balance the remaining cost for the roll-out in any given year, a small charge may need to be levied on the bill
[b] representing the saving from WFPs to all

For example, the total cost of the alternative scenario in the year 2020 is around £20.2 billion (see Table 23). The cost of the additional policies to improve our energy network and increase energy supply from large-scale renewables is some £1.5 billion in 2020 (for example, for smart metering and the RO). These policies are required to meet our climate change targets but do not feature in the maximum abatement roll-out. The total cost of the scenario could therefore be considered to be in the region of £22 billion. While this cost seems high at first sight, it needs to be put in the context of the savings that the investment programme achieves in fuel bills (and thereby carbon emissions) over time. The total net bill savings to householders in 2020 equates to £1.52 billion, which would relieve the burden on other areas of household finances.

Table 23: Costs of the alternative retrofit scenario in 2020

Costs (£bn)	Policy costs in 2020
Revenue from Green Deal Charge	£7.3
Remaining cost on bills	£0.0
Revenue from income tax	£7.4
Revenue from EU ETS & CPF	£3.8
Revenue from WFP	£1.7
Total cost of retrofit policy	**£20.2**
Total cost of additional policies[a]	**£1.5**
Total bill savings to householders (net)	**£1.5**

Note: [a] these include the RO and smart metering.

In 2020, over one third (36%) of the scenario costs are recovered by a Green Deal charge on householders' energy bills, with the remainder being recovered from other (non-consumer bill) sources (Figure 38). Note that in 2020 the balance between the required investment cost and the programme roll-out was such that no further costs were added to bills. Investment patterns required and the overall costs per year during the roll-out are shown in Figure 39. The use of income taxation varies over the lifetime of the programme, with higher rates being applied in the years where the roll-out costs reach a peak – that is, the amount raised from income tax is increased as necessary to protect consumers from unduly high energy bills. How this translates into a cost on energy bills is discussed below.

Figure 38: Proportion of costs raised from alternative sources over the lifetime of the policy and in 2020

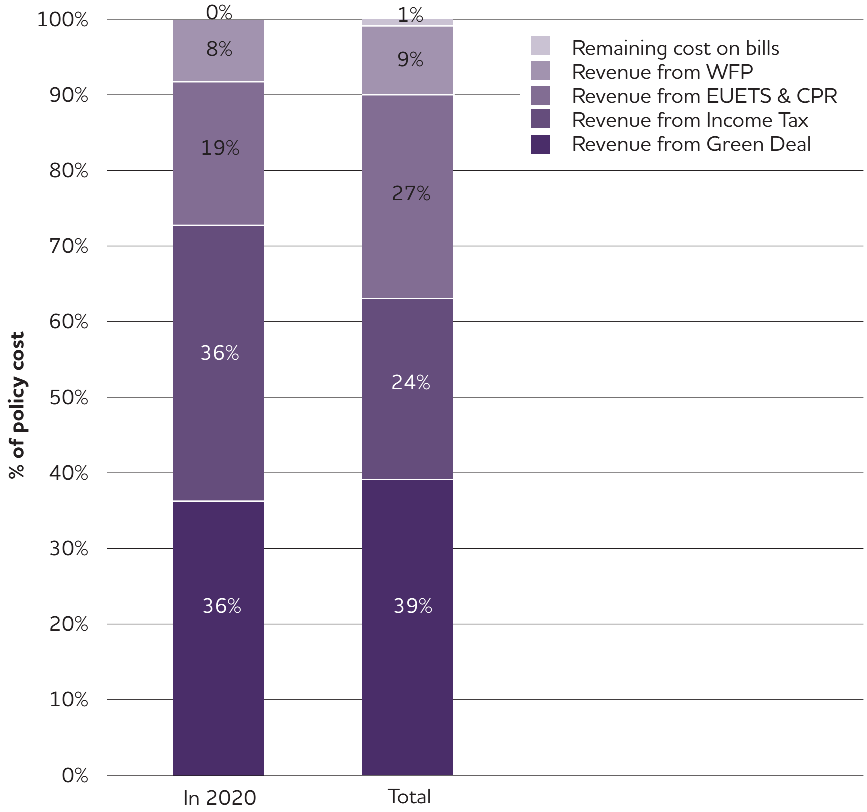
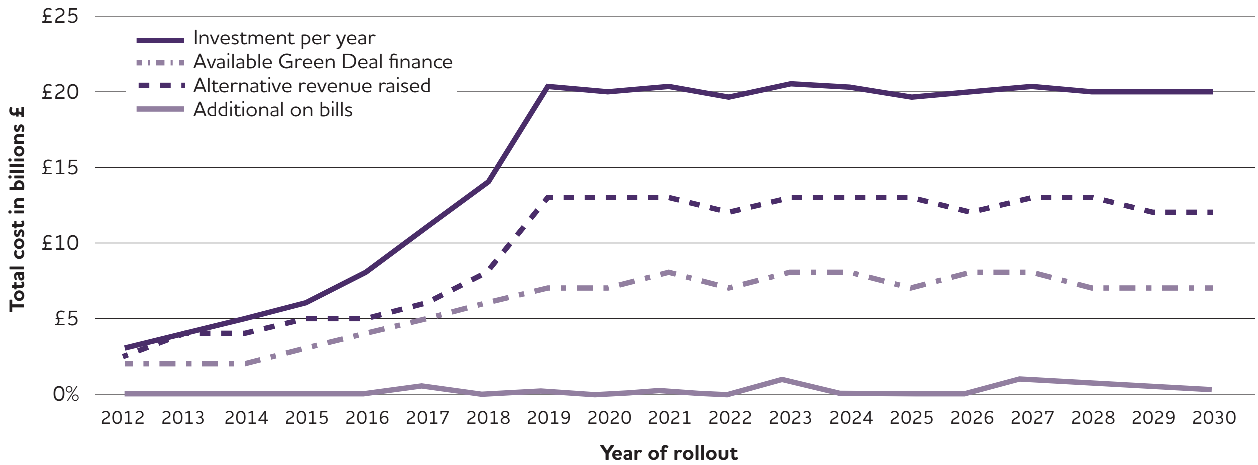


Figure 39: Total cost of the maximum abatement roll-out by year and source



The government has set itself a legally binding target of an 80% reduction in greenhouse gas emissions by 2050 (on 1990 levels). However, the 'baseline' emissions used in this study are derived from survey data from 2007 (the data imputed from the EFS to EHCS dataset) and have not been adjusted to reconstruct the 1990 domestic emissions baseline. In order to assess how the results obtained in our modelling compare with government targets, we have adjusted government targets to show the percentage reduction on a 2007 baseline, using the DECC and CCC trajectory of reductions between 1990 and 2022 (the end of the third carbon budget). This shows that government targets equate to a 35% reduction on 2007 levels by 2020, while CCC latest targets equate to a reduction on 2007 levels of 39% in 2020 (see Table 24).

The maximum CO_2 abatement retrofit policy scenario achieves a 41% reduction in total household carbon dioxide emissions by 2020, rising to 60% by policy completion (assumed to be 2030, see Table 25). In contrast, existing government policies (as modelled and reported in Chapter 5) are expected to achieve a 35% reduction in household emissions by 2020 (Figure 40). This represents a significant step change in the reduction in emissions and the progress towards a low-carbon society in 2050.

The maximum CO_2 abatement retrofit policy scenario achieves a 41% reduction in total household carbon dioxide emissions by 2020, rising to 60% by policy completion.

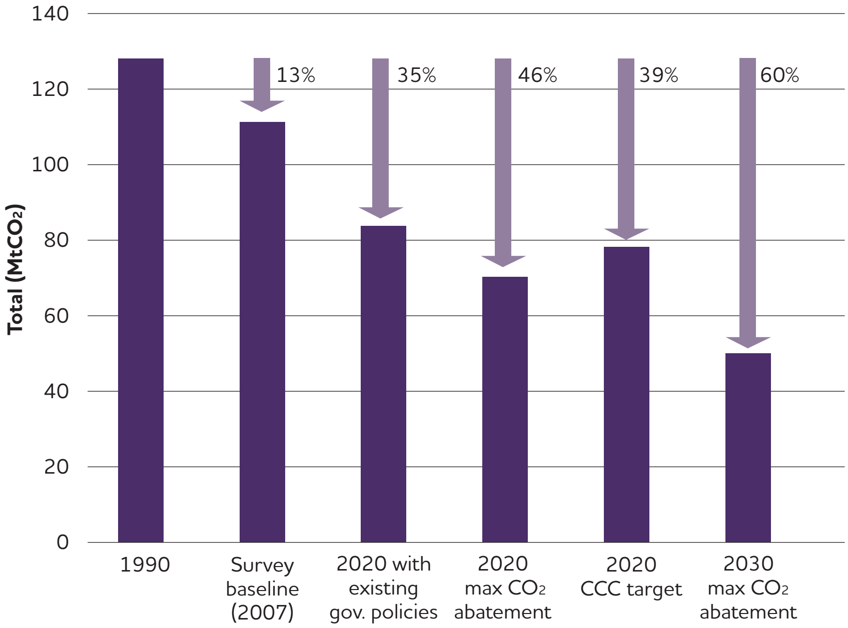
Table 24: DECC and CCC target emissions reductions to the end of third carbon budget

	1990	2007	2011	2013	2017	2020	2022
CCC	0%	8%	13%	19%	29%	39%	44%
DECC	0%	8%	13%	19%	27%	35%	39%

Table 25: Impact of policy scenarios on actual household emissions (England only)

	Max CO_2		Existing government policies	
	Total ($MtCO_2$)	Household mean (tCO_2/yr)	Total ($MtCO_2$)	Household mean (tCO_2/yr)
1990	128	6	128	6
Survey baseline (2007)	111	5.2	111	5.2
2020 household emissions with policies	69	3.2	83.3	3.9
2020 reduction (on 1990)	52.6	2.5	44.7	2.1
2020 % reduction on 1990	41%	41%	35%	35%
2030 household emissions (2030)	51.5	2.4		
2030 reduction (on 1990)	76.5	3.6		
2030 % reduction	60%	60%		

Figure 40: Impact of policy scenarios on actual household emissions (England only) and emissions reductions targets



Impact on consumer bills

In 2020 the costs of the maximum CO_2 abatement policy scenario (once revenue has been sourced from elsewhere, see Table 22) do not require a levy across all consumers. Recall that this scenario is modelled to include the costs on bills of carbon revenues (EU ETS and CPF), RO and the efficiency savings from products policy and smart metering. The overall impact on consumer energy bills in 2020 of these policies applied in combination with the maximum CO_2 abatement scenario is still an average net reduction on the 'no policy' bill – that is, applying these policies results in a lower average bill in 2020 than would be expected if no policies were applied.

The average reduction of £163 that results from the alternative maximum CO_2 abatement housing stock retrofit scenario is more than the savings resulting from modelling existing government policies (as modelled and reported in Chapter 5), which gives an average reduction of £105 on 2020 energy bills (see Table 26). The maximum CO_2 abatement scenario

Table 26: Impact of policy scenarios on actual household energy bills in 2020 (England)

	Alternative (max CO_2) scenario	Existing government policies[35]
Baseline bill (2011)	£1,175	£1,175
2020 bill without policies	£1,285	£1,285
2020 bill with policies	£1,122	£1,180
Impact of policies	–£163	–£105
% change due to policies	–13%	–8%
Change in bill on baseline	–£54	£4
Difference between max CO_2 and government policy scenarios	£58	

therefore appears to represent a reduction on the average energy bill in 2020 of £58 compared with the impact of existing government policies. The scenario also represents a reduction on the baseline bill of £54 in 2011. However, it is important to note that the baseline bill includes a number of policies that have subsequently been subsumed as they do not feature in this roll-out (CERT, CESP and the WHD). These policies themselves are likely to have cost consumers in the region of £50.

Distributional impacts of alternative housing stock retrofit policy

The figures below show the distribution of policy impacts across different socio-demographic groups of the alternative retrofit policy that seeks to maximise carbon emissions reductions. These show the total energy bill without any policy in 2020 ('no policy'), the total energy bill in 2020 with our abatement policy applied, and the difference between the two.

The analysis suggests that a maximum CO_2 abatement policy, if deployed with cost-recovery mechanisms as modelled in this scenario, could reduce the household energy bill of the lowest income decile by around £220 in 2020 (compared with the counterfactual 'no policies' bill), while the highest income group experiences an average net increase on the counterfactual of £70 (see Figure 41). The scenario results in an increase in income taxation of almost £1,500 for the wealthiest households (see Figure 42, right-hand axis and dark purple line). However, as shown by Figure 43, total energy bills are still a far higher proportion of incomes for lower-income householders (left-hand axis), with changes to income taxation representing less than 2% of total income for the wealthiest households (right-hand axis).

Figure 41: Impact of maximum CO_2 abatement policy on actual household energy bills in 2020 by disposable income decile (England)

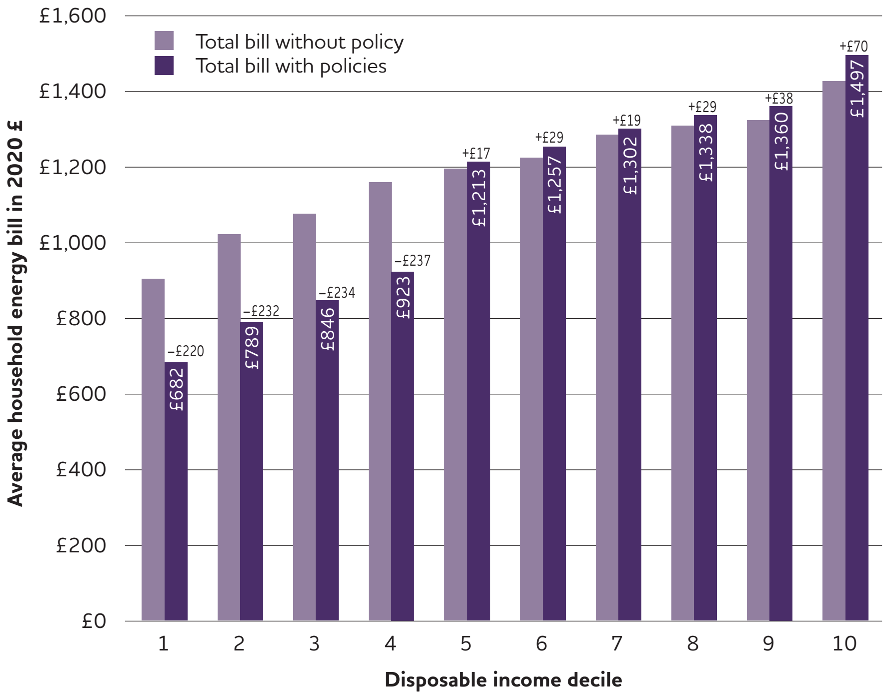


Figure 42: Impact of income taxation modelling on disposable incomes in 2020

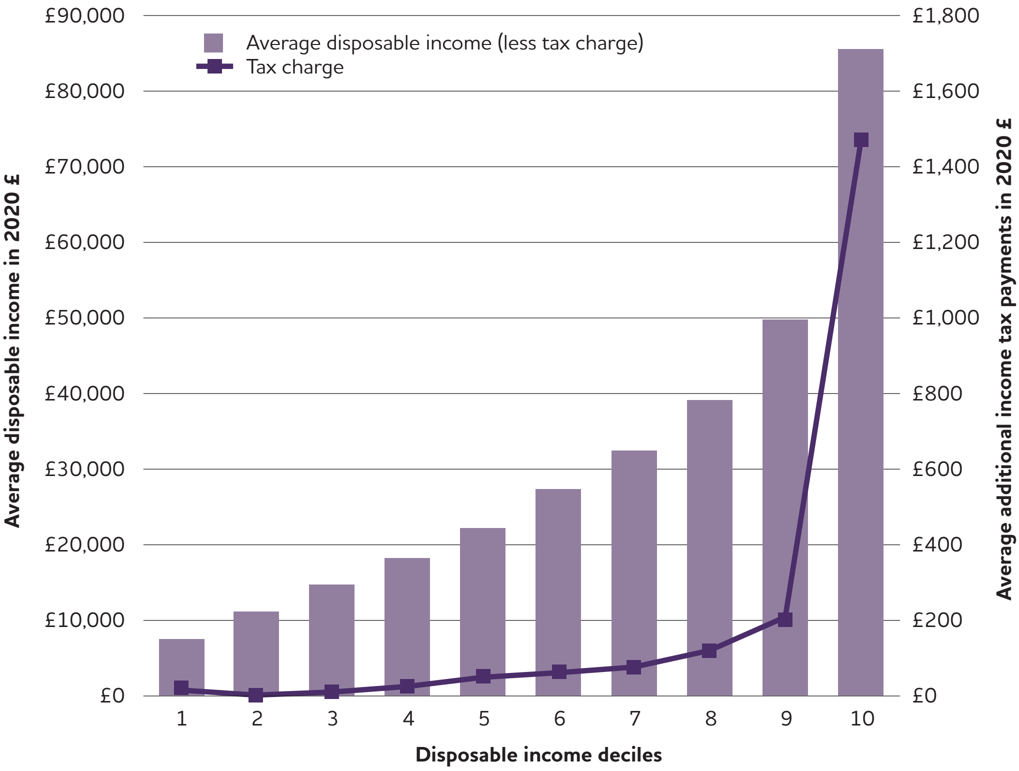
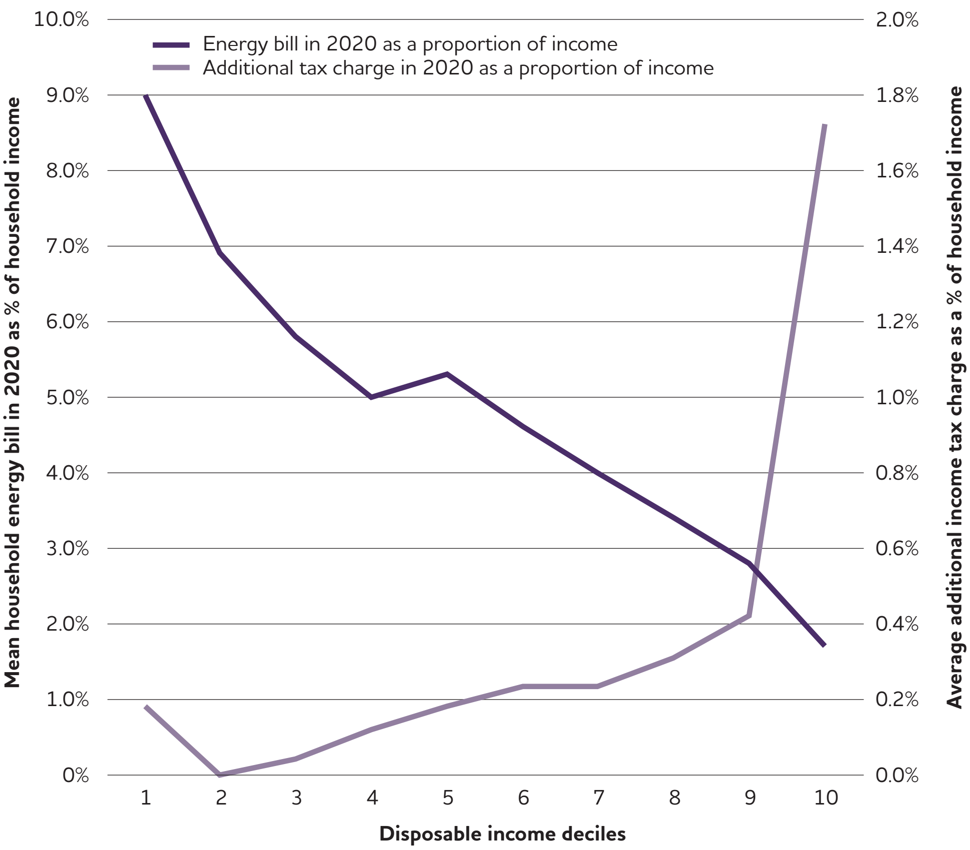


Figure 43: Energy costs and taxation changes as a proportion of disposable income in 2020



The maximum abatement scenario compares favourably with the government's proposed approach for lower income households, whereby the lowest income household's bills fell by £69. Conversely, under the maximum abatement scenario the highest income households see an increase in their bills rather than the reduction of £180 according to existing government policy. Under the maximum abatement opportunity scenario, there is therefore a more progressive trend overall.

By 2030, when roll-out of the policy is complete, household energy bills are lower than the 'no policy' scenario for the bottom four income deciles (see Figure 44). The upper income deciles see an increase in their bills that reflects the Green Deal charge that has been added and will remain in place until the loan has been repaid over 25 years. While the Green Deal is designed to protect householders from an increase in their energy bills (the Golden Rule should ensure the saving is larger than the loan repayment), the package of measures and the associated loan repayment is derived from a model that is based on 'energy need'. Despite the application of performance factors for measures under the Green Deal, the resulting charge is lower than a saving that is based on actual consumption. The modelling was not able to include the additional occupancy settings that would be identified by a face-to-face assessment. However, despite this, the Green Deal model applied by the government may still be overestimating the potential savings for many consumers.

The maximum abatement scenario compares favourably with the government's proposed approach for lower income households [with] a more progressive trend overall.

Figure 44: Impact of maximum CO_2 abatement policy on actual household energy bills in 2030 by disposable income decile (England)

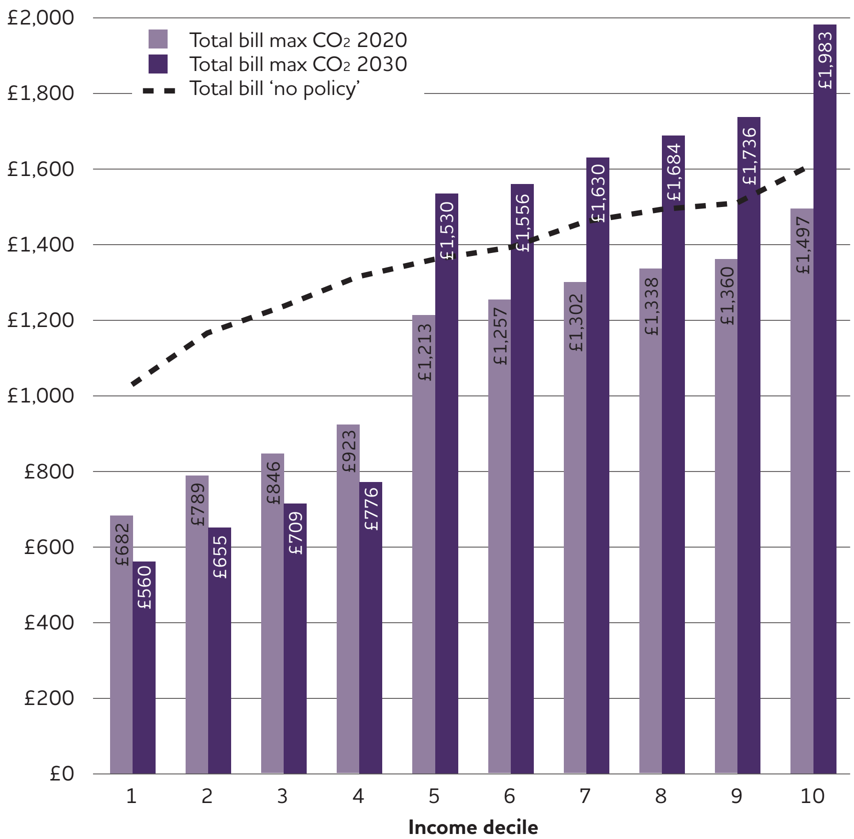


Figure 45: Impact of maximum CO_2 abatement policy on actual household energy bills in 2020 by age of HRP (England)

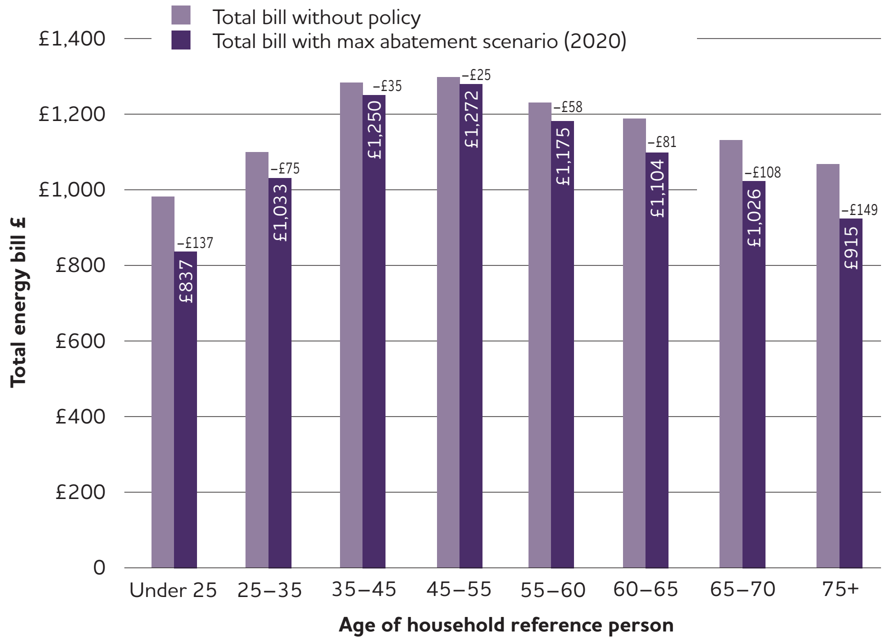
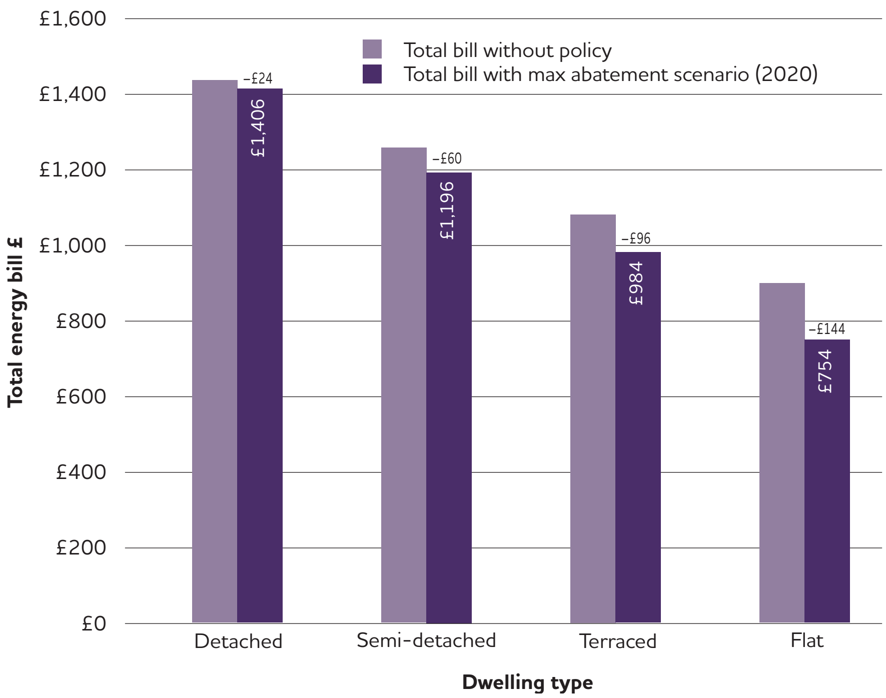
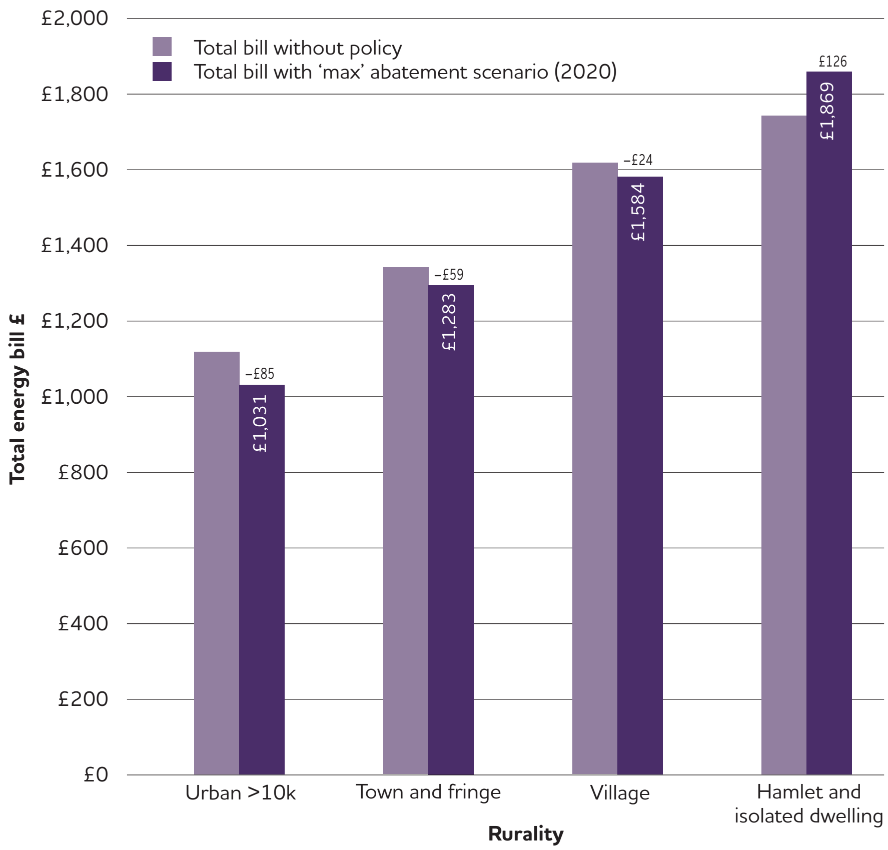


Figure 46: Impact of maximum CO_2 abatement policy on actual household energy bills in 2020 by dwelling type (England)



In addition to the progressive pattern across income deciles, older person households (as defined by the age of the HRP, see Figure 45), terraced houses and flats (see Figure 46) and properties in all but the most rural areas(see Figure 47) all appear to experience a net reduction under the maximum CO_2 abatement policy scenario, compared with the 2020 counterfactual energy bill.

Figure 47: Impact of maximum CO_2 abatement policy on actual household energy bills in 2020 by settlement type (England)



Maximum CO_2 abatement policy impact on households that receive measures

There is significant divergence in the average energy bill in 2020 of households that receive measures under the maximum CO_2 abatement scenario compared with those that do not. (Recall that this scenario has been modelled assuming deployment between now and 2030, and the results for 2020 shown here therefore represent a 'snapshot' of the policy impact at that time, as per the analysis of existing government policies presented in the previous section.) The total energy bill of households in the lowest income decile that receive measures under the maximum CO_2 abatement policy scenario is around half (54%) that of households which have not received measures in 2020 (see Figure 48).

For the fifth income decile and above, households receiving measures under the maximum CO_2 abatement policy scenario see an increase in their 2020 energy bill compared with those that have yet to benefit (see Figure 49). The increase in energy bill ranges from £51 to £281 when compared with the 'no policy' bill for the top four income deciles. However, as shown by Figure 50, this change only represents a very small proportion of income for these households. The increase in energy costs represents the difference between the predicted saving from the Green Deal modelling and the saving derived from actual energy consumption.

Figure 48: Mean actual household energy bill in 2020 by income decile and those that do and do not receive measures (England)

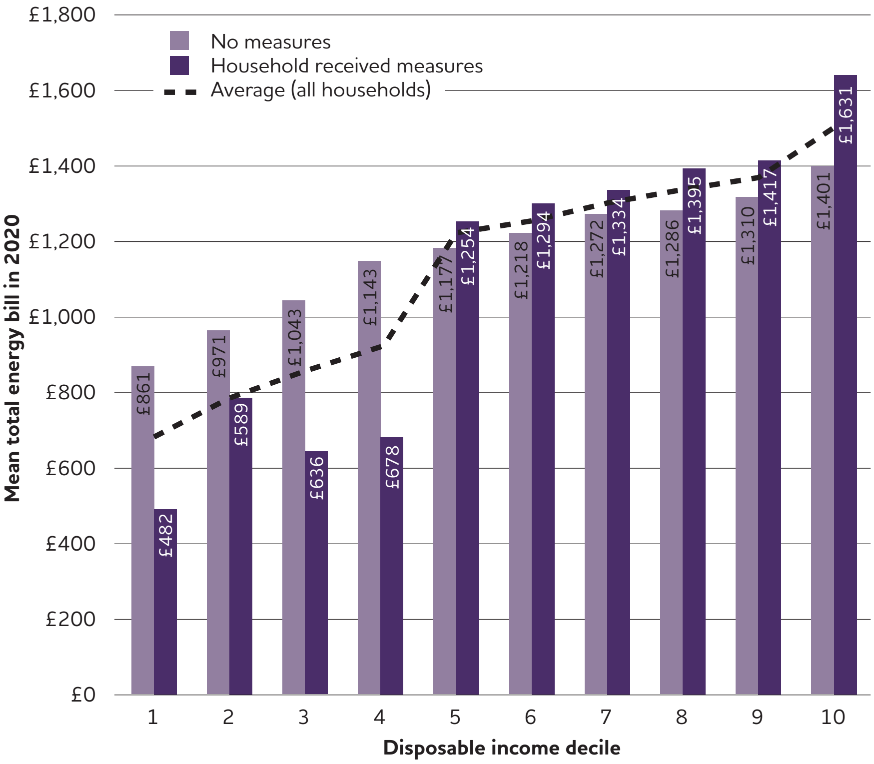


Figure 49: Impact of maximum CO_2 abatement scenario on actual household energy bill in 2020 by income decile (England)

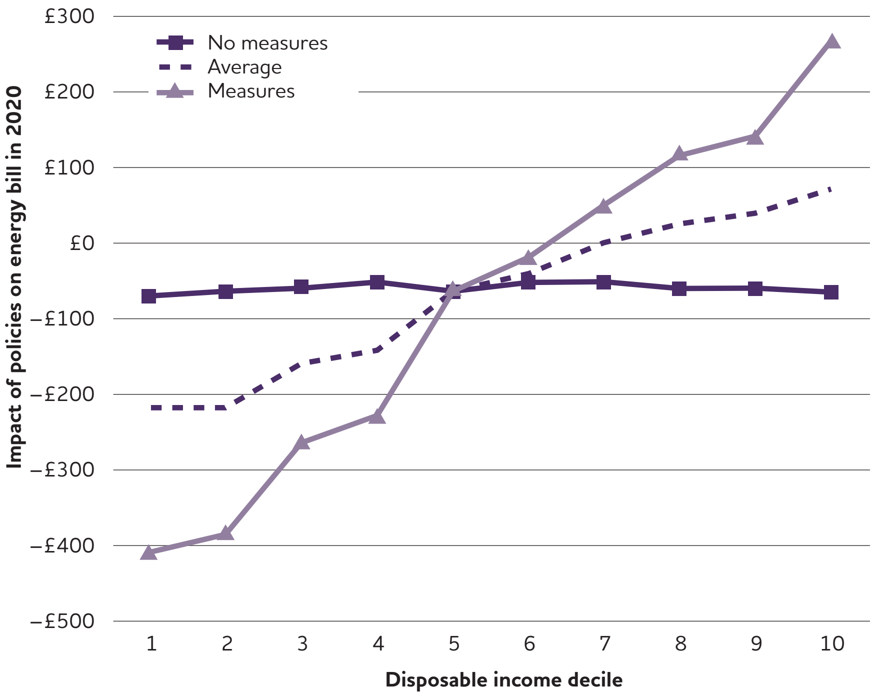
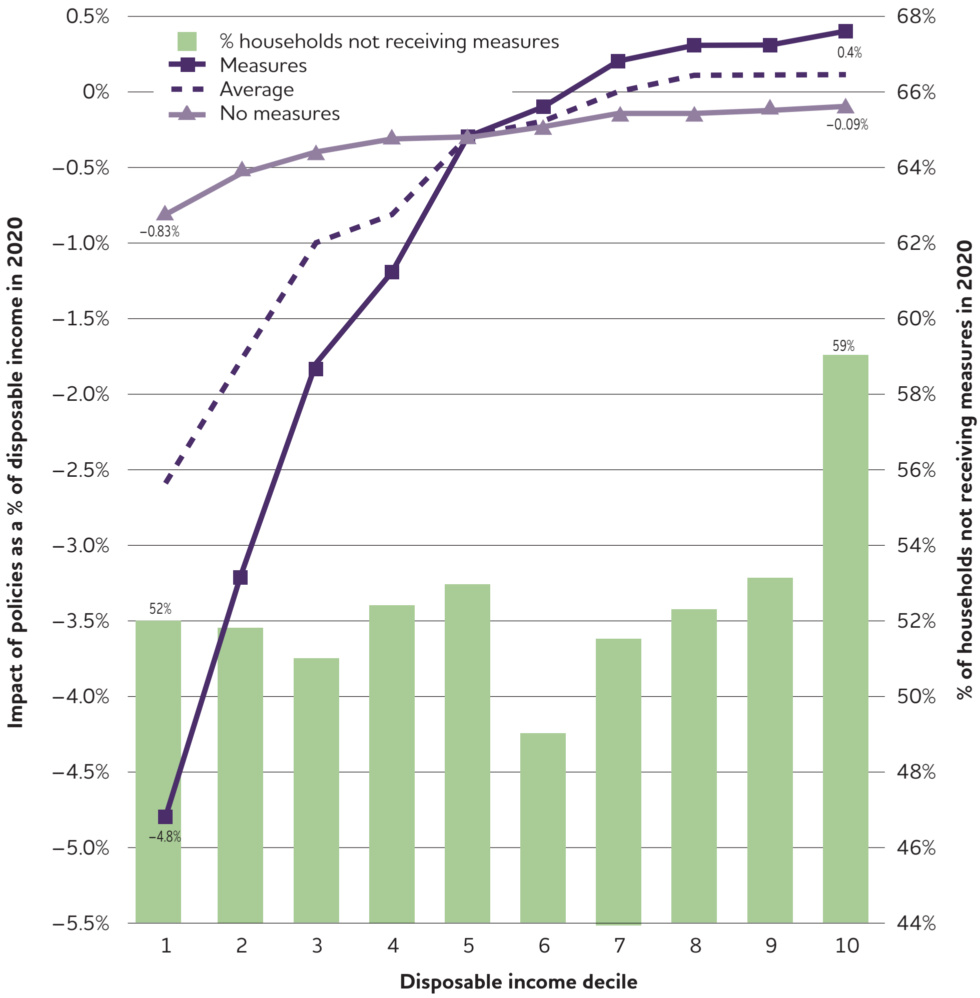


Figure 50: Impact of maximum CO_2 abatement scenario on actual household energy bill as a proportion of household income in 2020 and proportion of households in each decile that do not benefit from measures (England)



The economic case for maximum emissions abatement retrofit

The maximum CO_2 abatement policy scenario modelled here involves the roll-out of some 86 million measures by 2030 to improve the sustainability of the English housing stock. The level of opportunity identified for the different measures included in the model is based on data in the 2007 EHCS that describes the condition of the housing stock at that time. While this dataset is now several years old, and some additional improvements will have been installed across the housing stock since then (see Table 27 and Table 28), the results suggest there is still significant opportunity. In addition to the benefits of reducing household emissions, improving comfort in homes and lowering energy bills, there is a wider macro-economic benefit associated with the roll-out of sustainable energy measures on this scale. A detailed analysis of this wider impact is beyond the scope of this study. Data collated by CSE in 2006 (Preston, *et al.*, 2008) on current installation rates for key household sustainable energy measures suggests a significant step change in annual installation rates would be needed to deliver the number of different measures identified under our maximum CO_2 abatement scenario by 2030 (Table 29).

Table 27: Comparison of loft insulation levels (% of households) reported in the 2007 and 2010 EHCS

	2007	2010
None	3.5	5.2
Less than 100 mm	24.2	22.1
100 up to 150 mm	36.2	28.6
150 mm or more	36.2	44.0
Total	**100.0**	**100.0**

Table 28: Comparison of wall insulation levels (% of households) reported in the 2007 and 2010 EHCS

	2007	2010
Cavity with insulation	33.2	37.7
Cavity uninsulated	37.2	32.2
Other	29.6	30.2
Total	**100.0**	**100.0**

Table 29: Annual installation rates required under the maximum CO_2 retrofit scenario

Measure	Baseline (2006) installations/year	Max CO_2 required/year	Change in yearly rate
Cavity wall insulation	419,900	331,992	0.79
Loft insulation	559,036	680,261	1.22
External wall insulation	10,275	348,096	33.88
Internal wall insulation	3,360	15,856	4.72
Solar water heating	4,740	668,298	140.98
Log stove	1,200	193,604	161.34
Biomass boilers	86	121,096	1,405.06
Ground source heat pumps	86		
Air source heat pumps	50	99,444	1,988.88
Solar PV[a]	115,246	661,234	5.74

Note: [a] figures pre-date the introduction of the FIT which has had a significant impact on installation rates of solar PV in particular

The baseline numbers of installations per year suggest a total number of full-time equivalent (FTE) staff of around 30,000 working as installers or ancillary staff (based on results from CSE, 2008b). Under the maximum abatement scenario based on the changing rates of installation for each measure, this would need to rise to approximately 150,000 FTE staff, thus creating a further 120,000 jobs. The annual expenditure on sustainable energy measures is £22 billion in 2020, with a significant proportion of this representing value to the UK economy. Our previous analysis (CSE, ACE and Moore, 2008) of the Gross Value Added (GVA[36]) associated with sustainable energy measures suggests this figure to be around 40% of the total investment value, that is £9 billion.

The findings support the overall agenda for green growth. The Organisation for Economic Co-operation and Development (OECD, 2011) Green Growth Strategy outlines a rationale that means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. Green Growth must drive investment and innovation in order to sustain growth, giving rise to new economic opportunities.

Discussion

This study set out to establish how to maximise carbon emissions reductions in the English housing stock to support efforts to reach UK climate change targets. If all of the proposed government policies work to the best of their abilities, we can only hope to achieve the minimum required emissions reductions in 2020, that is 35%. The UK can achieve far deeper cuts to emissions and longer term reductions to household energy costs if a maximum scenario for abatement is deployed. The work identified here would cost £293 billion. This equates to an average of £15.4 billion per year for the duration of the roll-out between 2012 and 2030, with a peak in 2023 of £20.6 billion.

The UK can achieve far deeper cuts to emissions and longer term reductions to household energy costs if a maximum scenario for abatement is deployed.

To provide some scale and context for this investment, the government's recent announcement (HM Treasury, 2012) to increase benefits at a lower rate than the cost of living represents a reduction of £3.7 billion spending in 2015–16. On a more positive note, the London 2012 Olympics are estimated to have cost £11.3 billion (Rogers, 2012). While the Olympics are likely to leave a sporting legacy for the nation, the retrofit programme would protect householders from fuel poverty, help deliver energy security, support the nation to meets its targets for carbon emission reductions (41% compared with 35% for government policy) and generate thousands of jobs (as shown in Table 29).

The overall impact on consumer energy bills in 2020 of the maximum CO_2 abatement scenario (including the required energy system policies) is a net reduction on the 'no policy' bill. That is, applying these policies results in a lower average bill in 2020 than would be expected if no policies were applied. The average reduction of £163 that results from the alternative maximum CO_2 abatement housing stock retrofit scenario is more than the savings resulting from modelling existing government policies (as modelled and reported in Chapter 5), which gives an average reduction of £105 on 2020 energy bills (see Table 26).

The lower energy costs are themselves countered by increases in income tax to pay for a large proportion of the installed measures, an average of £202 per household. However, as shown by Figure 43, the increase in income taxation is higher for the wealthiest householders, who pay between £120 and £1,500 per year.

There is significant divergence in the average energy bill in 2020 of households that receive measures under the maximum CO_2 abatement scenario compared with those who do not. In 2020, the total energy bill of households in the lowest income decile who receive measures under the maximum CO_2 abatement policy scenario is just over half (56%) that of households who have not received measures in 2020 (see Figure 48). However, the energy bill for those not receiving measures in 2020 of £861 still represents a slight decrease on the 'no policy' bill of £876.

The extensive use of income taxation, and ensuring that wealthier households pay a Green Deal charge towards the cost of the installed measures, means that the households that are last to receive measures do not face a significant rise in energy costs until they receive their measures. Across all income groups, households not receiving measures under the maximum CO_2 abatement policy scenario see a slight decrease in their 2020 energy bill compared with the 'no policy' (counterfactual) scenario (see Figure 49).

By 2030, when roll-out of the policy is complete, household energy bills are lower than the 'no policy' scenario for the bottom four income deciles. The upper income deciles see an increase in their bills which reflects the Green Deal charge that has been added, and which will remain in place until the loan has been repaid over 25 years. While the Green Deal is designed to protect households from an increase in their energy bills via the Golden Rule, it is important to note that the package of measures and the associated loan repayment is derived from a model that is based on 'energy need'. Despite the application of performance factors for measures under the Green Deal, the resulting charge is lower than a saving that is based on actual consumption. If the model were to include a more detailed occupancy assessment, the difference may be lower; however, there is insufficient data available to account for this in the modelling presented here. The Green Deal model applied by the government may therefore be overestimating the potential savings for many consumers, which could lead to consumer mistrust and a lower take-up of offers.

The design of the roll-out of the alternative policy scenario modelled here was shaped to prioritise the most cost-effective packages of measures first. However, even with this prioritisation built into the model, overall the data presented here on the number of installations required (see Table 19) shows a huge upscaling is needed if carbon emissions reductions in the housing stock are to be maximised. For example, for some measures the yearly rate of installations will need to increase by well over 100% (such as for biomass and solar water heating).

The cost of installing these measures and the necessary supply chain development should be seen as a positive challenge and change. The UK economy is currently in recession and green jobs have been heralded as a way of stimulating growth and tackling environmental targets. However, as highlighted by the IPPR 2010 paper 'Green and decent jobs', the agenda has the potential to deliver more than just new jobs and reductions in greenhouse gas emissions. It could also have a vital role in tackling inequality by improving the employment prospects of people who often lose out in the labour market.

7 POLICY MODELLING IMPLICATIONS FOR FUEL POVERTY

Under the current definition, a household is said to be in fuel poverty if it needs to spend more than 10% of its income to maintain a satisfactory heating regime. Fuel poverty can be seen as a combination of four factors, namely income, energy prices, the energy efficiency of people's homes, and (under) occupation.

Chapter summary: key points

- In 2010, official government figures estimated that there were some 3.5 million households in fuel poverty in England.
- Based on modelled data presented earlier in this report to estimate the 2020 'no policy' household energy bill, without any of the existing government interventions or policies as modelled in this study, the number of fuel-poor households in England is expected to rise to some 4.9 million.
- The impact of government policies, which reduces the average household energy bill in 2020, suggests this figure could be reduced to some 3 million fuel-poor households in 2020.
- Adopting a housing stock retrofit scenario that seeks to achieve maximum household emissions reductions ('max CO_2') by 2030, through the installation of key energy efficiency, heating and renewable energy measures, impacts on household bills to leave some 2.8 million fuel-poor households in 2020 (only part-way through the roll-out of measures), reduced to 2.4 million by 2030 (the modelled year for completion of the housing stock retrofit).
- In 2011 the government commissioned Professor John Hills to undertake a review of the definition of fuel poverty. Applying the proposed new method of calculating fuel poverty (still under consideration at the time of writing) to our estimates of

consumer energy bills in 2020 and 2030 under each policy scenario modelled here gives estimates of:
  - 2.5 million fuel-poor households in 2020 under a 'no policy' scenario;
  - 2.4 million fuel-poor households in 2020 with existing government policies applied;
  - 3.3 million fuel-poor households in 2020 under a maximum CO_2 reduction retrofit scenario;
  - 2.3 million fuel-poor households in 2030 under a maximum CO_2 reduction retrofit scenario.
- Under this proposed new definition, the implementation of existing government policies appears to have very little effect on the number of fuel-poor households in 2020. This is a phenomenon of the proposed Hills Review methodology, which uses a changing median cost threshold, resulting in a headline figure for fuel poverty that is relatively static.
- However, the proposal also includes a new measure called the 'fuel poverty gap'. This is the total amount of money that would be required to remove people from fuel poverty. So while the impact of existing government policies does not appear to reduce the total number of fuel-poor households in 2020, it does impact on the gap, reducing it by some £250 million (from £1.67 billion under a 'no policy' scenario to £1.42 billion with policies applied). This represents an average fuel poverty gap of £597 (the amount by which the assessed energy needs of fuel-poor households exceed the threshold for reasonable costs).
- The maximum CO_2 reduction retrofit scenario impacts on the estimated number of fuel-poor households under the new proposed definition, increasing it to some 3.3 million in 2020 (reducing again to 2.3 million in 2030 with policy completion). However, under this scenario we see the fuel poverty gap increase in 2020 to £2.12 billion before falling to £1.26 billion. The average fuel poverty gap in 2020 under the maximum abatement scenario is £636.
- Fuel poverty rates vary across England. In part, this is likely to be a result of the differing rural and urban composition of the different regions.
- The results suggest that the policy scenarios modelled here are less effective in very rural areas; these parts of the country continue to have higher rates of fuel poverty.
- Using the standard definition, fuel poverty predominantly affects households with people over 60. The two policy scenarios modelled (existing government policies and maximum CO_2 abatement) go some way to reducing fuel poverty in these households, but have the biggest beneficial impact on lone-parent households.
- Despite the drop in fuel poverty numbers by 2020 and 2030 under each of the policy scenarios, fuel poverty remains prevalent in lower income households, with rates in the bottom two income deciles of 55% and 20% respectively. For these households, fuel poverty is generally a consequence of their low-income status, rather than resulting from poorly insulated dwellings – that is, fuel costs are high relative to incomes for these households because their income is extremely low, rather than because the energy inefficiency of their homes is excessively high. The remaining high incidence of fuel poverty (even under a scenario of major retrofit of the housing stock) therefore suggests that further income measures would need to be considered to protect low-income households in the future.

Introduction

Under the current definition, a household is in fuel poverty if it needs to spend more than 10% of its income on energy bills to keep adequately warm. Following a review process, Professor John Hills (Hills, 2012) proposed a new 'low income, high cost' (LIHC) method whereby 'a person is to be regarded as living "in fuel poverty" if he is a member of a household living on a lower income in a home which cannot be kept warm at reasonable cost.' The new proposed definition includes an estimate of the total number of people in fuel poverty and of the 'fuel poverty gap' – the total amount of money that would be required to remove people from fuel poverty (see Box 7).

Box 7: The proposed new definition of fuel poverty and the 'fuel poverty gap'

In 2011, the government commissioned Professor John Hills to undertake an independent review of the definition of fuel poverty. The Hills Review (published in March 2012) concluded with a proposed new definition of fuel poverty and a methodology for calculating it.

The proposal for a new 'low income, high cost' (LIHC) definition of fuel poverty adopts wording from the Warm Homes and Energy Act 2000 stating that 'a person is to be regarded as living "in fuel poverty" if he is a member of a household living on a lower income in a home which cannot be kept warm at reasonable cost.'

The LIHC indicator of fuel poverty applies two thresholds in calculating a household's fuel-poverty status:

- the **low-income threshold** which defines those households that are in income poverty, after accounting for their required fuel costs;[37]
- the **energy cost threshold** which is set at the median of total energy costs for all households (equivalised for household composition).

If a household has an income less than the income threshold and fuel costs greater than the median equivalised fuel costs, it is deemed to be in fuel poverty, hence the 'low income, high cost' reference.

The LIHC definition includes an additional method of measuring fuel poverty – the '**fuel poverty gap**'. This provides a measure of the severity of fuel poverty. It assesses the extent to which a household falls below the energy cost threshold or, if near the income threshold, has costs below the latter.

The proposal for the new definition underwent further consultation in September to November 2012 (the outcome of which is pending), but it has important implications for both the resulting estimates of the *number* of households defined as fuel poor, and the *types* of household appearing as fuel poor.

This section of the report explores the implications for fuel poverty of the two policy scenarios presented previously, namely: the impact of existing government policies (see Chapter 5) and the alternative household emissions reduction retrofit policy (maximum CO_2 abatement scenario, see

Chapter 6). The analysis applies both the current definition and the new proposed definition of fuel poverty to assess the impact of these policy scenarios on fuel poverty numbers in 2020 (and in 2030 for the alternative retrofit scenario, as this is the year adopted for completion of this policy) compared with a 'no policy' (counterfactual) scenario.

The impact of existing government policies on fuel poverty has been assessed in 2020, both with and without products policy included. The rationale for this is twofold. Firstly, as we saw in Chapter 5, applying the suite of existing and forthcoming government energy and climate change policies results in consumer energy bills appearing lower in 2020, compared with a 'no policy' scenario. This result can largely be traced back to the impact of assumptions about improvements in product efficiency (products policy) reducing household energy demand. If these improvements are not realised on the scale assumed, consumer energy bills in 2020 appear much higher. This would translate into a higher estimate of households in fuel poverty.

Secondly, in modelling products policy, some fairly broad-brush assumptions have to be made about the impact across households. If, in fact, lower income households purchase fewer new products, they stand to benefit disproportionately less from this policy. This again has implications for estimates of the number of fuel-poor households, which are typically on lower incomes. Running the analysis with and without products policy assumptions therefore provides an element of sensitivity analysis to the results.

The maximum CO_2 abatement scenario has been analysed in both 2020 and 2030, the latter being the modelled year for completion of roll-out of this scenario.

Results are presented alongside the 'no policy' (counterfactual) scenario. This represents an estimate of fuel poverty in 2020 if none of the existing government policies were implemented. However, it does allow for fuel price and income changes over the modelling timeframe. The count and distribution of households in fuel poverty under this scenario is therefore very similar to the 2010 picture.

Headline fuel poverty results

Table 30 shows the total number of fuel-poor households under each of the policy scenarios and calculated according to the two definitions. The 'no policy' (counterfactual) scenario results in there being some 4.9 million households in fuel poverty in 2020, under the current definition. This is nearly 1.5 million higher than the figures for fuel poverty in 2010 (DECC, 2012a). The trend for rising fuel prices is therefore not offset by the assumed longer term increases in household incomes.

As a result of all government policies, this number could fall to 3 million fuel-poor households in 2020. However, excluding products policy from the policy mix would increase the number by 1.3 million to 4.3 million. This suggests that products policy – or, at the least, current assumptions about its impact – could have significant implications for fuel poverty in the future.

Products policy – or, at the least, current assumptions about its impact – could have significant implications for fuel poverty in the future.

Under the maximum CO_2 abatement policy scenario, the number of fuel-poor households in 2020 appears lower at 2.8 million. By 2030, the modelled date for completion of roll-out of this scenario, fuel poverty could be reduced to 2.4 million households. This scenario was designed to deliver maximum possible emission reductions through the installation of key energy efficiency and renewable energy measures in the English housing stock.[38]

Table 30: Total number of households in fuel poverty as a result of different scenarios (England)

Existing definition	Fuel-poor households (m)	Fuel-poor households (%)
2010 national figures	3.536	16.54%
2020 counterfactual	4.945	23.13%
2020 government policy (no products policy)	4.300	20.11%
2020 government policy (with products policy)	2.973	13.91%
2020 alternative max CO_2 abatement	2.768	12.95%
2030 alternative max CO_2 abatement	2.371	11.09%
Hills Review definition		
2010 national figures	2.667	12.47%
2020 counterfactual	2.530	11.83%
2020 government policy (no products policy	2.556	11.96%
2020 government policy (with products policy)	2.370	11.08%
2020 alternative max CO_2 abatement	3.342	15.63%
2030 alternative max CO_2 abatement	2.323	10.86%

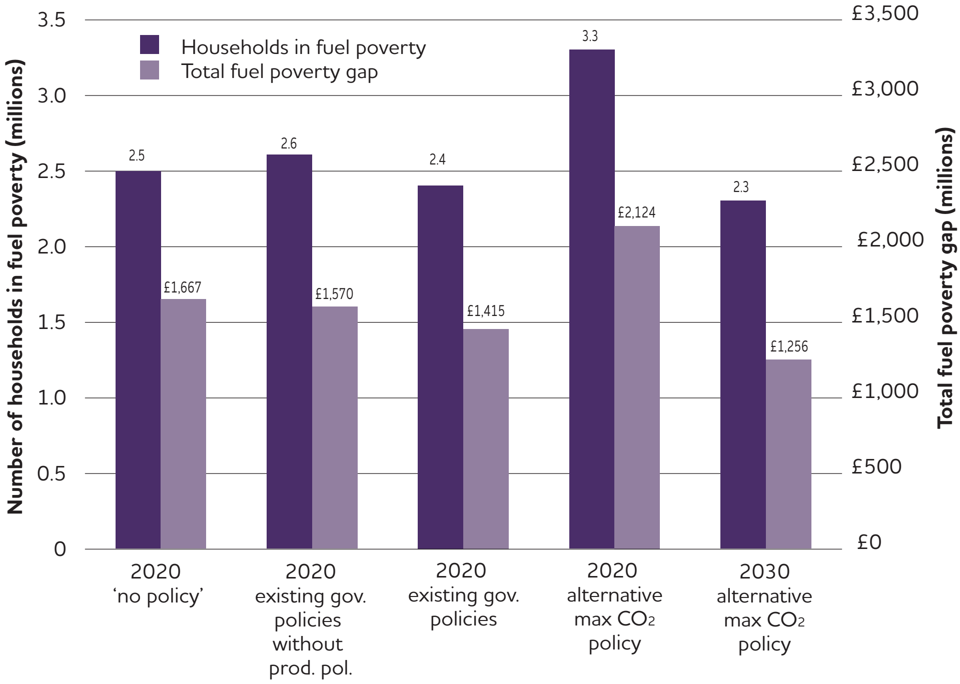
Modelling fuel poverty according to the proposed new method (Hills, 2012) is more complex. It involves a relative measure of fuel costs, based on the median equivalised fuel bill for the whole population. This will differ under each of the scenarios modelled here, which makes comparison of the resulting fuel poverty levels difficult. The results suggest that there is a small reduction in the total number of households in fuel poverty in 2020 under the existing government policy scenario compared with a 'no policy' scenario: under the government policy scenario the rate of fuel poverty would be 11.08%, while the counterfactual rate would be 11.83%. The maximum CO_2 abatement policy scenario could reduce the proportion of fuel-poor households a little further to some 10.86% by 2030.

However, under this definition, the total headcount does not reveal the whole fuel poverty picture. The 'fuel poverty gap' (see Hills, 2012) – a new measure of fuel poverty proposed under the new definition – provides an additional useful indicator of the depth of the problem. Figure 51 shows the number of fuel-poor households experiencing fuel poverty under the different policy scenarios modelled (as per the counts shown in Table 30), alongside the total (sum of the) fuel poverty gap.

Under the 'no policy' scenario, the total number of fuel-poor households in 2020 under the proposed new definition is some 2.5 million, with a total fuel poverty gap of £1.67 billion. As noted above, there appears little difference between the total number of fuel-poor households in 2020 under this 'no policy' scenario and under the existing government policy scenario (the total number of fuel-poor households is 2.4 million), but the total fuel poverty gap appears lower at approximately £1.42 billion. The average fuel poverty gap for fuel-poor households under the counterfactual scenario is £659, falling to £597 for the government policy scenario.

The results suggest that adopting a maximum carbon abatement approach could lead to an increase in fuel-poor households compared with the counterfactual and government policy scenarios in 2020. The total fuel poverty gap rises to £2.12 billion, although the increased number of fuel-poor households means that the average fuel poverty gap reduces to £636. However, by the end of this policy scenario timeframe (2030) these figures reduce to £1.26 billion and £541, with some 2.3 million households in fuel poverty.

Figure 51: Number of households in fuel poverty and total fuel poverty gap as measured by Hills method (England)



The likely increase in fuel poverty and the gap under the maximum carbon abatement scenario in 2020 are due to the divergence in energy costs for those receiving support and those who have yet to receive support. In particular, low-income households can experience significantly lower bills once they receive support. While this balance is redressed on completion of roll-out of the policy, the results suggest that in the interim period, the depth of the fuel poverty problem could increase for a select group of households.

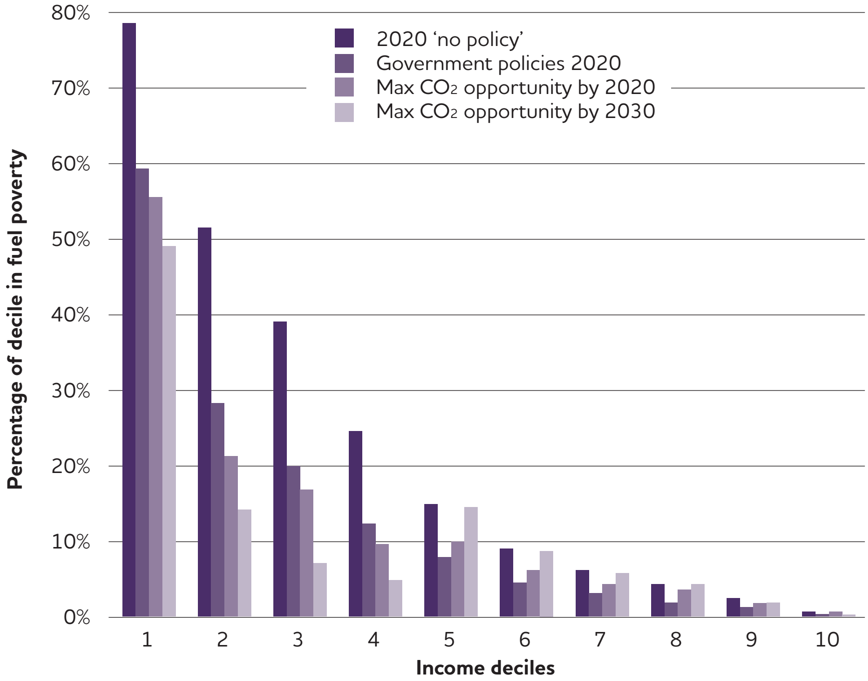
Distribution of fuel poverty by geography and socio-demographics

In order to further assess the impact of the different policy scenarios on fuel poverty in England, the results have been broken down by income deciles, household composition, rural-urban classification and government office region. The analysis shown includes three scenarios: 'no policy', existing government policies (including products policy) and alternative maximum carbon abatement policy in 2030. Although the latter is reporting on a different year from the former two, it nevertheless reveals the full potential of adopting the scenario, whereas using results for 2020 would provide an incomplete and partial comparison. All analysis below uses the current definition of fuel poverty, unless otherwise stated.

Income

Figure 52 shows the percentage of households in each income decile in fuel poverty under each policy scenario. Under the current definition, fuel poverty appears strongly correlated with income, as demonstrated by the concentration of fuel-poor households in the lower income deciles.

Figure 52: Percentage of households in fuel poverty by income decile (England)



Both current government policy and our alternative maximum abatement policy scenario have a similar impact on the bottom two deciles, reducing rates of fuel poverty in the lowest decile from 80% to around 55%, and from 45% in the second decile to around 21%. However, the alternative maximum CO_2 abatement scenario seems almost to eliminate fuel poverty from the top six deciles which comprise a total of 29,000 fuel-poor households. After the implementation of existing government policies, 160,000 households in these top six deciles would still be in fuel poverty in 2020. This finding reflects the design of the maximum CO_2 abatement policy scenario whereby low-income households receive the measures free, and higher income households make a contribution to the costs via a Green Deal charge.

Household composition

Table 31 shows the rates of fuel poverty in different types of household under each policy scenario modelled, compared with the current rates (2010, using the existing definition). For example, under the existing definition 35% of single-person households over 60 are fuel poor. Under the existing government policy scenario, the proportion of fuel-poor households in each category appears to be marginally lower in 2020 compared with the counterfactual 'no policy' scenario. By 2030, the maximum CO_2 abatement scenario reduces fuel poverty numbers in single-person households by approximately 50% compared with the counterfactual. The biggest beneficial impact of this scenario is for lone-parent households where fuel poverty is reduced by 29% from 280,000 households (under the 'no policy' scenario) to 198,000 households in 2030. However, the distribution of fuel poverty across different households remains similar under each scenario.

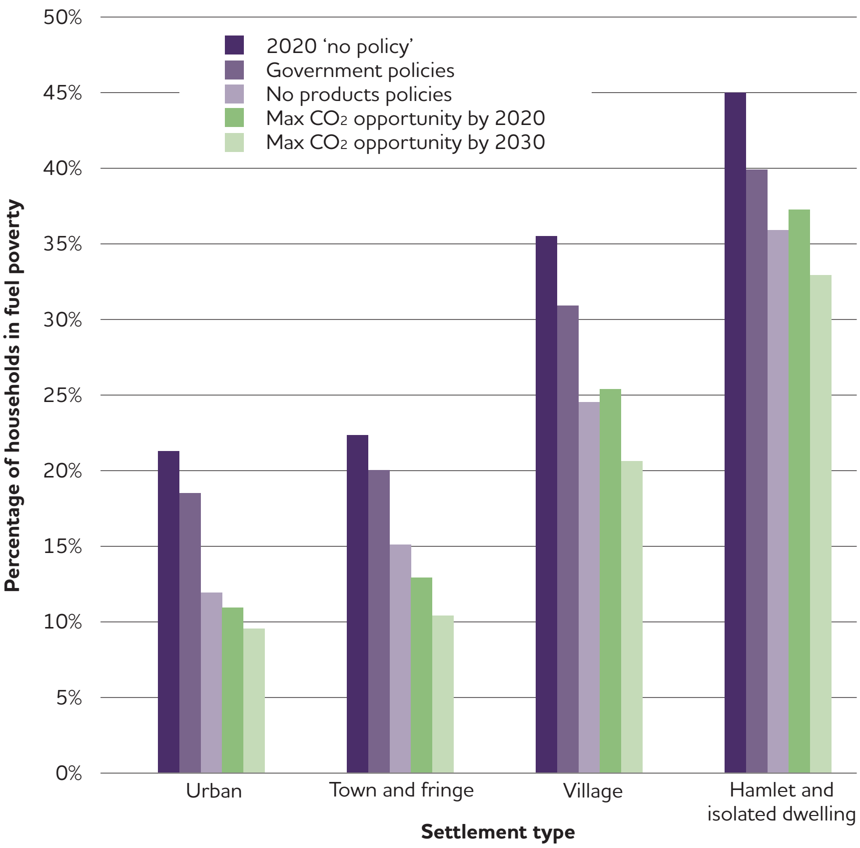
Table 31: Proportion of households in fuel poverty by household composition for England

	2010 (Original definition)[39]	Counterfactual (2020)	Government policies, no products policy	Government policies (2020)	Max CO_2 abatement (2020)	Max CO_2 abatement (2030)
Couple, no children, under 60	6%	9%	8%	5%	5%	5%
Couple, no children, aged 60 or over	18%	25%	21%	15%	13%	12%
Couple with child(ren)	6%	9%	7%	5%	5%	6%
Lone parent	18%	28%	22%	15%	12%	7%
Other multi-person households	15%	19%	16%	12%	11%	8%
One person under 60	25%	36%	33%	22%	21%	18%
One person aged 60 or over	35%	52%	47%	32%	30%	23%

Settlement type and region

Figure 53 shows that under the 'no policy' counterfactual and government policy scenarios, fuel poverty rates are higher in more rural areas. However, while this pattern persists under the alterative maximum CO_2 abatement policy scenario, the impact in rural areas is much more pronounced. The proportion of fuel-poor households is reduced dramatically to some 24% in 2030 (compared with 38% under the 'no policy' scenario and 28% under the current government policy scenario).

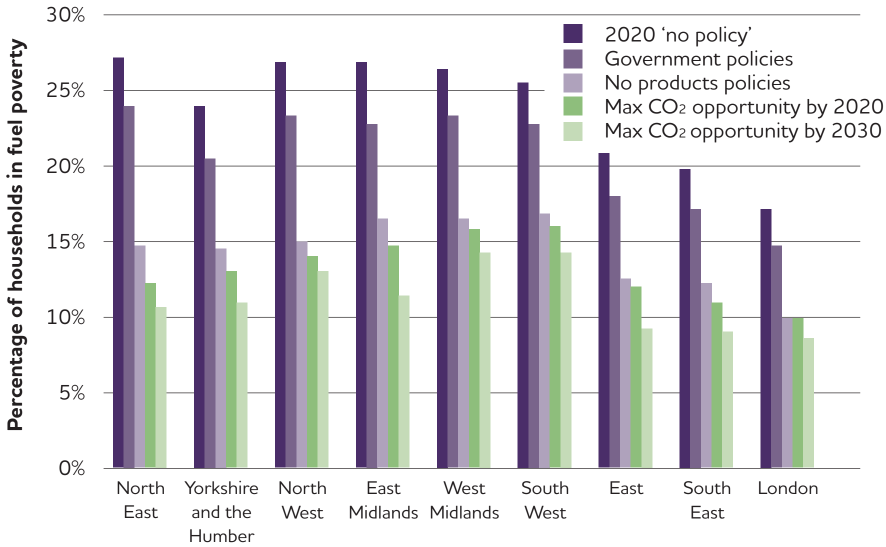
Figure 53: Percentage of households in fuel poverty for different urban and rural classifications from different scenarios (England only)



This reflects the design of this policy scenario, being targeted at achieving maximum emissions reductions. Rural dwellings tend to have higher energy demand due to construction types (proportionally more solid-walled properties) and the likelihood of being off-gas, and therefore offer the greatest potential for emissions savings.

Figure 54 shows the total numbers of fuel-poor households for the three scenarios by government office region. In a 'no policy' scenario, the three regions with the highest rates of fuel poverty are the North East, North West and East Midlands. On the whole, the impact of the government policy scenario and the maximum CO_2 abatement scenario follow the trend of the national figures, with the maximum CO_2 abatement scenario having a larger impact on reducing fuel poverty on its completion.

Figure 54: Percentage of households in fuel poverty by government office region as a result of different scenarios (England only)



Overall the two policy scenarios reduce fuel poverty from the counterfactual level of 23.1% in 2020 to 13.9% and 12.9% respectively. However, across the different English regions these rates vary significantly. For the government policy scenario, London has the lowest rate of fuel poverty at 9.7%, while the South West has the highest rate at 16.9%. For the alternative maximum CO_2 abatement policy scenario, London has the lowest rate at 8.7% and the highest rate of 14.2% is in the West Midlands.

Discussion

This study set out to explore the impact of the proposed carbon reduction policies on the fuel poor. The existing fuel poverty definition results in some 4.9 million households being fuel poor under the 'no policy' (counterfactual) scenario in 2020. This is significantly higher than the most recent figures for fuel poverty in 2010.

The number of fuel-poor households could fall to 3 million in 2020 if government policy is deployed successfully, and our economy begins to grow (as predicted by government) rather than falling further into recession (based on the current definition of fuel poverty in 2012). Chapter 5 provides some commentary on the modelling assumptions and the areas of potential underperformance. However, excluding products policy from the policy mix would increase the number of fuel-poor households by 1.3 million to 4.3 million. Under the maximum CO_2 abatement policy scenario, the number of fuel-poor households in 2020 appears lower at 3 million. By 2030 – the modelled date for completion of roll-out of this scenario – fuel poverty could be reduced to 2.2 million households.

Under the existing definition of fuel poverty, the maximum abatement scenario delivers the lowest long-term reduction in headline figures. However, the impact of policies on fuel poverty is highly dependent on the definition used. The existing definition is particularly sensitive to fuel prices and has been criticised by the Hills Review (2012) for the delivery of headline figures that do not reflect the real energy experience of householders or the aims of the Warm Homes and Energy Conservation Act.

Under the Act, 'a person is to be regarded as living in fuel poverty if he is a member of a household living on a lower income in a home which cannot be kept warm at reasonable cost.' The Hills Review states that 'it is unreasonable for low-income households to have to pay more to keep warm than typical households on much higher incomes.' The Hills Review therefore defines 'unreasonable' as having to spend more than the median.

Modelling fuel poverty according to the proposed new Hills Review method is more complex. By defining 'reasonable' as 'less than the median', the energy costs threshold becomes relative in nature: half of households would always fall beneath it and be facing 'reasonable' fuel costs and half of households would always be facing 'unreasonable' fuel costs. The shifting nature of the median means that it is difficult to reduce the fuel poverty headcount through efficiency improvements. As energy costs reduce, so will the median.

The results of this analysis provide evidence of this. When applying the proposed Hill's Review definition, we see only a small reduction in fuel poverty figures in 2020 under the existing government policy scenario compared to the 'no policy' 2020 scenario, with the number of fuel-poor households dropping from 2.5 to 2.4 million. Furthermore, the use of the median value in defining the fuel costs threshold is likely to result in low-income households living in small dwellings no longer being classed as fuel poor. The fact that these households are small in size (floor area) does not diminish the fact that the fuel costs experienced may be high and the householder may be cold.

The 'fuel poverty gap' is the new measure proposed by the Hills Review that provides an additional useful indicator of the depth of the problem and the impacts of each scenario. For example, the results suggest that adopting a maximum carbon abatement approach could lead to a total and average fuel poverty gap of £1.26 billion and £541 respectively in 2030, which is significantly lower than the government policy figures of £1.42 billion and £597 respectively.

However, prior to the completion of the maximum abatement opportunity roll-out, the fuel poverty gap would rise. The total number of households, the total fuel poverty gap and the average fuel poverty gap are all higher for this scenario in 2020 than for the government policy scenario. The fairness of climate change mitigation policies for fuel-poor households is very much dependent on the order in which they receive sustainable energy measures. This is true for either current government policy or the maximum abatement scenario. However, ensuring that low-income households that receive measures last do not pay for the benefits experienced by others first would protect them from unfair increases to their bills.

8 CONCLUSIONS

This study set out to assess the fairness and effectiveness of climate change policies aimed at tackling household energy emissions.

It specifically aimed to answer the following key questions:

- Who emits most?
- Who benefits from and who pays for energy and climate policies?
- How can we maximise carbon emissions reductions in the English housing stock?
- How do policies impact on the fuel poor?

In terms of understanding fairness, it is important to take the pre-existing distribution of household emissions into account. This study contributes to the growing body of evidence that shows that the wealthiest households emit the most. Put simply, higher income households are responsible for a disproportionate share of total domestic sector emissions, and this becomes starker if emissions from driving and international flights are included in the analysis. The inclusion of transport emissions suggests that the richest 10% of households are actually emitting more than three times the carbon emissions of the poorest 10%. Emissions from private road travel and international aviation account for a high proportion of this differential: international aviation emissions of the highest income decile are more than ten times those of the lowest income decile, while emissions from private vehicle travel are around seven to eight times higher.

Higher income households are responsible for a disproportionate share of total domestic sector emissions, and this becomes starker if emissions from driving and international flights are included.

The differential from poorest to richest is smaller for energy consumed in the home: the richest emit twice that of the poorest 10% of households. This has important implications for the distributional consequences of current climate change policies. Where policies affect domestic energy prices, the impact is likely to be regressive: while the poor emit – and thus consume – less, the cost of doing so represents a far higher proportion of their income. In contrast, taxes on private transport, while politically more sensitive, might be expected to be less regressive as those with higher incomes emit substantially more from travel than those on lower incomes.

If we consider who benefits from and who pays for current climate change and energy policies, the impacts again appear skewed. The average annual household energy bill in 2020, with government policies applied, appears (at £1,180) to be lower, by some £105 (or 8%) on average, than the 'no policy' 2020 energy bill. However, higher income households tend to benefit more than lower income households. The richest 10% of households see an average reduction of 12% (£182) while the poorest 10% see an average reduction of 7% (£69) compared with the 2020 'no policy' energy bill. This therefore suggests that the overall impact of government policies is both positive and regressive, in that low-income households stand to benefit, but to a lesser extent than higher income households.

However, this impact depends largely on whether a household is expected to benefit directly from policies, for example receiving financial support for installing energy efficiency measures or renewables in the home. Households not benefiting directly – some 55% of households in our modelling analysis – may expect to see an increase in household energy bills in 2020 of around £50 on average as a result of current policy.

The current set of government policies is designed to deliver the necessary 35% reduction in carbon emissions on 1990 levels by 2020. However, there is little leeway for the underperformance of policies or measures. The savings that are associated with the EU products policy provide a significant overall contribution to the reduction in bills and emissions. As shown in the analysis, the failure of products policy would result in the emissions targets being missed by a significant margin (6%). Furthermore, average bills could be expected to rise by 4% (£55) as a result of policy costs, with a 9% (£86) increase for the lowest income households, and a 2% (£30) decrease for the highest income households.

The short-term trends for domestic energy demand over the last ten years suggest a gradual decline, which is most likely associated with improvements in product efficiency, the recession and the deployment of energy efficiency measures across the housing stock. If the government ensures the aggressive implementation of products policy through enforcement, then the most likely reason for failure to meet future emission reduction targets would instead be the underperformance of policies such as the ECO and Green Deal. Government policy could therefore be likened to a house of cards: removing one card could be catastrophic for the overall result.

The introduction of additional regulatory measures could underpin the success of policies like the Green Deal and the ECO. For example, bringing in mandatory standards for rented homes from 2013 rather than 2018; offering council tax rebates for those that improve the thermal efficiency of their home; providing subsidised interest rates for Green Deal loans; and reducing stamp duty based on pre-sale improvements to property energy efficiency could all support positive progress.

CLG recently scrapped plans for the so-called 'Conservatory Tax'. The proposal would have introduced new requirements under Part L of Building Regulations to force homeowners to carry out additional energy efficiency improvements, known as 'consequential improvements', when other specified works (for example, an extension) were planned. This proposal was twice considered and rejected by the previous Labour Government, one reason being the additional upfront costs it would introduce for the homeowner. However, the introduction of the Green Deal opened a new avenue, providing scope for the costs of the consequential improvements to be met through Green Deal finance (so those measures that meet the Golden Rule[40] would be undertaken). Following consultation early in 2012, the proposal was nonetheless still aborted.

The failure of two successive governments to implement a requirement for 'consequential improvements' suggests a lack of appetite for mandating removal of secondary heating. This reluctance has been echoed over the years by Eaga (now Carillion Energy Services) which argued against an SAP target of 65+ for Warm Front because achieving this score would require secondary heating to be removed when a new gas condensing boiler is installed. The issues of the customer liking the existing secondary heating, and of the cost of redecorating following its removal, are not negligible. However, if government were serious about stimulating the necessary deep cuts to emissions then policies and schemes would need to be designed to achieve maximum reductions.

From the analysis undertaken in this study, we can conclude that the current raft of government energy and climate change policies is likely to reduce emissions, but this reduction is not certain and is not necessarily within the scale required. To achieve maximum reductions of carbon emissions from the consumption of energy in the home we therefore need a more radical approach in the longer term. The research identified an alternative scenario for maximum abatement that could deliver a 41% emissions reduction on 1990 CO_2 by 2020 and a 60% reduction by 2030. This is significantly higher than the projected reduction from current government policies of 35% by 2020.

The current raft of government energy and climate change policies is likely to reduce emissions, but this reduction is not certain and is not necessarily within the scale required.

Making the improvements to English housing required to achieve this total reduction would cost around £293 billion. The costs for a fully funded programme to deliver this scale of retrofit could be recovered through a mixture of taxation, carbon pricing mechanisms (such as the EU ETS) and savings through means testing the Winter Fuel Payment. This approach has several advantages: progressive distributional impacts, meeting carbon targets, reducing fuel poverty significantly upon completion, and the potential to create a significant number of jobs.

The alternative housing stock retrofit scenario, as modelled here, deploys measures initially based on the installation of the most cost-effective packages first and then the rest in equal volumes until 2030. To protect low-income households from being unduly burdened by the cost of installing measures in the homes of others, they receive measures at no cost and the only additional charge to energy bills is a Green Deal payment towards the cost of packages for the fifth income decile and above.

Despite the application of performance factors for measures under the Green Deal, the resulting charge is often lower than a saving that is based on actual consumption. The research also challenges the likelihood of the modelled savings from the Green Deal translating to actual reductions in energy bills. This raises issues for the policy itself, which could result in consumer mistrust and lead to a lower take-up of offers.

This study includes exploratory analysis of the potential impact of different policy scenarios on fuel poverty. The future of fuel poverty – the number of households defined as fuel poor – is intrinsically linked to how this is defined. The Scottish Fuel Poverty Forum (2012) recently rejected the Hills Review definition of fuel poverty as it 'was specific to England and so does not fully reflect Scottish conditions'. It could be argued that the proposed Hills Review definition does not fully reflect English conditions either. For example, it is unduly weighted such that low-income but larger properties are more likely to be classed as fuel poor while low-income householders in smaller dwellings may be overlooked. Furthermore, the final headcount of the numbers in fuel poverty under the proposed Hills Review definition for each of the policy scenarios modelled here varies little, which could be seen by government as a rationale for inaction rather than a call to arms.

If the UK government decided to support a large-scale retrofit programme with the aim of delivering deep emissions cuts and economic growth, then ultimately the actual emissions reductions associated with the deployment of these measures would still be uncertain. The uncertainty is a result of the consumption of energy in the home not being constrained in any way. How the householder behaves in response to the improved energy efficiency of the dwelling is fundamental to the level of emissions reductions achieved. For example, the financial savings from reduced energy consumption in the home could be spent on other products and services that result in increased carbon emissions, a phenomenon referred to as the 'rebound effect'. This effect extends to both direct and indirect (embodied) emissions, analyses of which are beyond the scope of this study (see discussion in the next chapter on further work).

The current landscape for energy and transport policy is one of a regressive distribution of measures and costs. The cost of policies and environmental taxes, such as fuel duty, represents a higher proportion of income for the poorest. In addition, policies such as FIT are likely to benefit the wealthiest at the expense of the poorest. The challenge is therefore to encourage the progressive deployment of a housing retrofit scenario in an environment where emissions are reduced and low-income households are not unduly burdened. While this may require significant investment, it is important to acknowledge the avoided household expenditure on fuel and the additional economic activity as an additional rationale for a retrofit scenario that stimulates far deeper cuts in emissions.

9 GAPS AND FURTHER WORK

The datasets and modelling tools developed as part of this project open up a number of new avenues for research.

The policy modelling in this study has focused on the impact on emissions from the consumption of energy in the home and household energy bills. However, data on household travel patterns is also available in the dataset. Additional modelling could be undertaken to utilise this and explore the potential impacts of transport policy (for example, air passenger duty) and potential alternatives.

The modelling of opportunities for households to reduce their emissions through the installation of measures (energy efficiency, heating and renewable energy) has applied a finite list of measures and criteria to select combinations that will deliver the greatest reduction in emissions. These modelling criteria could be developed to explore, for example, a scenario for deploying measures to achieve maximum reductions in fuel poverty. As discussed at the end of Chapter 6, low-income homes that do not receive early measures could also be compensated until they receive support. The Warm Homes Discount could be re-targeted at these households until they benefit from the programme.

Under either the existing government policy or the maximum abatement opportunity scenario, there need to be additional drivers for take-up of energy efficiency measures. These might include mandatory standards for rented homes from 2013 rather than 2018; council tax rebates for those that improve their homes; subsidised interest rates for Green Deal loans; and reductions in stamp duty based on pre-sale improvements to property energy efficiency. Further work is needed to examine the political drivers required to support the primary legislation to underpin these changes.

Although energy efficiency savings may make a considerable reduction in UK emissions from the *production* perspective, when looked at from the *consumption* perspective, the rebound effect becomes more important. The rebound effect has implications for the resulting emissions savings (at the domestic and global level) from the deployment of a housing stock retrofit scenario as explored in this study. For example, there are some key different elements of the rebound effect, an important one being the ‘income effect'. This describes the situation where financial savings resulting from reduced energy consumption in one area (such as lower household energy bills following the installation of insulation measures) are spent on other emission-generating activities, services or products, such as new appliances or a flight overseas (see Chitnis, *et al*., 2012; Druckman, *et al*., 2011). Analysis of the rebound effect and the inclusion of embodied emissions are beyond the scope of this report.

The dataset could be extended to include both direct and indirect emissions. The potential for different capping mechanisms could then be explored in the UK and global context, such as through 'personal carbon allowances' or 'cap and share'. The inclusion of indirect emissions is particularly important from a global perspective, as many goods and services are manufactured abroad. All these are areas that require further study to understand how policies can be developed fairly and effectively to respond to the challenges of climate change and fuel poverty.

NOTES

Executive summary

1 Put simply, Gross Value Added (GVA) is the value of goods and services produced by an area, sector or producer minus the cost of the raw materials and other inputs used to produce them. For sub-national GVA, the Office for National Statistics (ONS) uses an income-based measure. GVA is mainly composed of the income made by employees (earnings) and the business (profits/surplus) as a result of production.

Chapter 2

2 Based on a CCC recommendation that the government establish a fourth budget for 2023–27, which set a limit of 1,950 $MtCO_2e$ (a cut of 50% on 1990).

3 Here taken to cover the socio-economic classification of the household reference person, household income and tenure.

4 Equivalent schemes operate in the devolved administrations, namely: NEST in Wales, the Energy Assistance Package in Scotland and the Warm Homes Scheme in Northern Ireland.

5 The availability of data limits this analysis to English households only.

6 Defined by DECC (2010c) as 'Vulnerable households are those which contain children, the elderly or someone who is disabled or who has a long term illness.'

7 The most commonly used threshold of income poverty is household income that is 60% or less of the average (median) British household income in that year. An *after fuel costs poverty* approach takes the fuel poverty line as 60% of median income after deducting both fuel and housing costs.

Chapter 3

8 By 'direct sources' we refer to the emissions of carbon dioxide associated with the consumption of household fuels and transport energy services – this excludes emissions embodied in the production and distribution of other goods and services (e.g. as modelled by Gough, *et al.*, 2011).

9 This includes buses, coaches, surface rail, light rail, underground, taxis and ferries.

10 Defra (2010). For electricity, the five-year rolling average was applied. All factors were applied on a net calorific value basis where relevant.

11 The analysis in this study uses estimates of actual household emissions, all derived from survey data. We have not sought to reconcile the resulting carbon emissions totals derived from the surveys with published figures at the national level. This is because the two use very different approaches and are designed for very different purposes.

12 Under-reporting of incomes is a key issue in both the EFS and EHCS survey data, as indicated by the maximum values shown.

13 DECC figures are reported 'by source' or 'by end user'. This difference in reporting mainly affects emissions related to electricity generation from power stations. By source, these emissions are allocated to the energy supply sector since the power stations are responsible for producing the electricity. Reporting by end-user reallocates all these emissions to the final users of the electricity, such as to homes and businesses. Hence figures quoted above are by 'end user' for residential emissions, but 'by source' for transport. http://www.decc.gov.uk/assets/decc/Statistics/climate_change/407-uk-emissions-stats-faq.pdf

Chapter 4

14 Business travel is not included but commuting – that is, travel to place of work – is.

15 This includes household emissions from energy consumed in the home; car travel for leisure and commuting purposes; public transport travel for leisure and commuting purposes; domestic aviation and international aviation.

16 For example, emissions from private road travel are some 2.4 times higher on average in households with three or more cars, compared with households with one car, while emissions from the use of household fuels are only 1.4 times higher on average in households with three or more cars compared with households with one car.

17 Investigation of the relationship between a single predictor and the dependent variable – as distinct from multivariate analysis which takes into account multiple predictors in a single analysis.

18 The urban/rural classification system used here is based on the ONS Rural and Urban Classification of Output Areas (ONS, 2003) for England and Wales. A different classification system exists in Scotland. As it is not possible to merge the two, analysis is limited to the England and Wales subset of the EFS dataset (22,017,000 weighted count).

19 ONS (2003) classifications categorise settlements with a population of 10,000 or more as 'urban'. The remaining 'rural' areas are grouped into three other broad morphological types based on the predominant characteristics, being 'town and fringe', 'village' or dispersed (the latter being described as 'hamlets and isolated dwellings'). The latter two categories have been grouped together here for analysis purposes (small sample sizes).

20 EFS 2004–07 imputed dataset.

21 The terms regressive and progressive are used to describe the distributional impact across income groups. Where lower income households are proportionally worse off than their higher income counterparts, the effect is considered regressive. Where the reverse is true, the effect is described as progressive.

Chapter 5

22 These policies do not have any associated costs savings for individual households, hence the reference to 'none' here.

23 The term 'measures' refers to energy efficiency improvements, heating and renewable energy technologies, and gains will only be made by participating/targeted households. Several of these improvement measures applied in combination to the same property are referred to as 'packages of measures'.

24 The cost of installing a measure under the Green Deal represents a payment through a charge in instalments on the energy bill (tied to the property not the householder) linked to the level of finance received to cover the upfront costs of the measures. Only properties accessing Green Deal finance will pay this cost. There is therefore no 'policy' cost.

25 At the time of modelling (October 2012), the ECO was to be split between suppliers based on numbers of customers. Therefore as a result, it would be assumed that the cost would be split by customer. In the final version of the Bill in parliament it was agreed to split the levy

by volume of sales. Therefore, it could now be assumed that the ECO levy will be passed on a per unit basis. However, this is still unclear.

26 For the purpose of this analysis, incomes are adjusted to 2020 to be consistent with DECC's analysis. See Table 1.4 in Office for Budgetary Responsibility (2011).

27 Where rent-a-roof schemes are implemented on local authority or housing association properties and the LA/HA receives the FIT rather than the tenant, the householder still stands to benefit from power generated and therefore may see some bill savings.

28 English Housing Survey, 2010 dataset.

29 This relates specifically to products policy and the 'heat replacement effect', as explained in the 'Glossary of terms'. Improvements in the energy efficiency of products reduce the amount of heat emitted. As a result, more heating fuel is needed to maintain the same level of warmth in the home.

30 The impact of the RHI appears very high, but this is based on only a small sample and reflects the nature of the properties selected for renewable heat technologies. A number of criteria are enforced in the model that limit the applicability of renewable heat measures (for example, heat pumps are not installed where the main heating fuel is gas).

Chapter 6

31 The roof orientation is unknown; therefore, a randomised selection of almost half of the housing stock is deemed suitable for solar.

32 It would not be possible to deliver this many measures by 2020 as the supply chain is not sufficiently developed and the costs of doing so would be prohibitive.

33 It is important to note that, while sophisticated, the income tax model used here is not as extensive as other models of the tax benefit system that account for a multitude of interactions between income sources. However, the results provide a realistic estimation of the levels of revenue available.

34 www.energybillrevolution.org

35 These figures replicate those shown in Table 13.

36 Put simply, GVA is the value of goods and services produced by an area, sector or producer minus the cost of the raw materials and other inputs used to produce them. For sub-national GVA, ONS uses an income-based measure. GVA is mainly composed of the income made by employees (earnings) and the business (profits/surplus) as a result of production.

Chapter 7

37 The most commonly used threshold of income poverty is household income, that is 60% or less of the average (median) British household income in that year. An *after fuel costs* poverty approach takes the fuel poverty line as 60% of median income after deducting both fuel and housing costs.

38 Deployed in parallel with existing government policies for smart metering, products and some decarbonisation of the grid. This is the 'maximum possible' reduction based on the deployment of a limited number of different measures only. Not all possible household improvement measures are included.

39 DECC, 2012a.

Chapter 8

40 The Golden Rule states that the expected financial savings from installing the measures must be equal to or greater than the costs attached to the energy bill to pay for those measures.

Appendix 1

41 The therm is a unit of heat energy used to describe volumes of natural gas.

42 The costs shown here are full installation costs. While many householders will be capable of installing insulation measures themselves, others, for example, elderly householders, will require a professional installer and thus incur an installation fee. The figure shown in Table 35 is therefore an average derived for modelling purposes to take account of this additional fee.

REFERENCES

Annual Energy Statement (2011) '2011 annual energy statement', delivered by Chris Huhne on 23 November 2011. Available at: http://www.decc.gov.uk/en/content/cms/news/aes_2011/aes_2011.aspx [Accessed 5 October 2012]

Boardman, B. (2012) *Achieving Zero: Delivering future-friendly buildings.* Oxford: Environmental Change Institute

Browne, J., Dresner, S., Ekins, P., Hamilton, I., Preston, I. and White, V. (2013) 'Designing carbon taxation to protect low-income households', a research report for the Joseph Rowntree Foundation

CCC (2009) 'Meeting carbon budgets – The need for a step change', progress report to Parliament. London: Committee on Climate Change

CCC (2010) 'Meeting carbon budgets – Ensuring a low-carbon recovery', 2nd progress report to Parliament. London: Committee on Climate Change

CCC (2012) 'Energy prices and bills – Impacts of meeting carbon budgets'. London: Committee on Climate Change

Chitnis, M., Sorrell, S., Druckman, A., Firth, S. K. and Jackson, T. (2012) 'Estimating direct and indirect rebound effects for UK households', Sustainable Lifestyles Research Group: Working Paper 01–12, University of Surrey, February 2012

CSE: White, V. and Thumim, J. (2008a) 'Distributional impacts of personal carbon trading', a report to Defra, Centre for Sustainable Energy

CSE: Preston, I., Moore, R. and Guertler, P. (2008b) 'How much? The cost of alleviating fuel poverty', a report to eaga Charitable Trust

CSE, ACE and Moore, R. (2008) 'How low? Achieving optimal carbon savings from the UK's existing housing stock', a report to WWF-UK

CSE and ACE (2012) 'The impact of energy policy on consumer bills', a report to Consumer Focus. Available at: http://www.cse.org.uk/downloads/file/impact_of_energy_policy_on_consumer_bills.pdf [Accessed 12 February 2013]

CSE and Hirsch, D. (2012) 'Understanding fuel expenditure: Fuel poverty and spending on fuel', a report to Consumer Focus

DECC (2001) 'The UK fuel poverty strategy'. Available at: http://www.decc.gov.uk/en/content/cms/funding/fuel_poverty/strategy/strategy.aspx [Accessed 5 October 2012]

DECC (2010a) 'Estimated impacts of our policies on energy prices and bills: July 2010'. Available at: http://www.decc.gov.uk/en/content/cms/meeting_energy/aes/impacts/impacts.aspx [Accessed 5 October 2012]

DECC (2010b) 'Digest of United Kingdom energy statistics 2010'. Available at: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx [Accessed 5 October 2012]

DECC (2010c) 'Fuel poverty methodology handbook'. Available at: https://www.decc.gov.uk/publications/basket.aspx?FilePath=Statistics%2ffuelpoverty%2f614-fuel-poverty-methodology-handbook.pdf&filetype=4#basket [Accessed 5 October 2012]

DECC (2010d) 'Estimated impacts of energy and climate change policies on energy prices and bills'. Available at: http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20 supply/236-impacts-energy-climate-change-policies.pdf [Accessed 5 October 2012]

DECC (2011a) 'Estimated impacts of our policies on energy prices and bills: November 2011'. Available at: http://www.decc.gov.uk/en/content/cms/meeting_energy/aes/impacts/impacts.aspx [Accessed 5 October 2012]

DECC (2011b) 'The Carbon Plan: Delivering our low carbon future', presented to Parliament pursuant to Section 12 and 14 of the Climate Change Act 2008

DECC (2011c) 'Total sub-national final energy consumption 2005, 2006, 2007, 2008 and 2009', 11D/936

DECC (2011d) 'UK emissions statistics'. Available at: http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/uk_emissions/uk_emissions.aspx [Accessed 5 October 2012]

DECC (2011e) 'DECC fossil fuel price projections'. Available at: http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/ff_prices/ff_prices.aspx [Accessed 5 October 2012]

DECC (2011f) 'Updated energy and emissions projections – Annex F: Fossil fuel, wholesale and retail prices'. Available at: http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx [Accessed 5 October 2012]

DECC (2011g) 'Green Deal and the Energy Company Obligation – Impact assessment', secondary legislation domestic consultation (DECC0072), 23 November 2011

DECC (2011h) 'Digest of UK energy statistics (DUKES)'. Available at: http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/source/electricity/electricity.aspx [Accessed 5 October 2012]

DECC (2011i) 'Renewable Heat Incentive – Impact assessment', secondary legislation domestic final proposal (DECC0057), 1 December 2011

DECC (2012a) 'Annual report on fuel poverty statistics'. Available at: http://www.decc.gov.uk/assets/decc/11/stats/fuel-poverty/5270-annual-report-fuel-poverty-stats-2012.pdf [Accessed 5 October 2012]

DECC (2012b) 'Comprehensive Review Phase 1 – Consultation on Feed-in Tariffs for solar PV: Impact assessment', secondary legislation domestic final (DECC0073), 8 February 2012

Defra (2010) '2010 guidelines to Defra/DECC's GHG conversion factors for company reporting: Methodology paper for emission factors'. Available at: http://archive.defra.gov.uk/environment/business/reporting/pdf/101006-guidelines-ghg-conversion-factors-method-paper.pdf [Accessed 5 October 2012]

Dresner, S. and Ekins, P. (2004) 'The distributional impacts of economic instruments to limit greenhouse gas emissions from transport', *PSI Research Discussion Series 19*. London: Policy Studies Institute

Druckman, A., Chitnis, M., Sorrell, S. and Jackson, T. (2011) 'Missing carbon reductions? Exploring rebound and backfire effects in UK households', *Energy Policy*, 39, pp. 3572–81

Druckman, A. and Jackson, T. (2008) 'Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model', *Energy Policy*, 36(8), pp. 3167–82

Energy Bill Revolution campaign (2012) [online] http://www.energybillrevolution.org/ [Accessed 5 October 2012]

Gough, I., Abdallah, S., Johnson, V., Ryan-Collins, J. and Smith, C. (2011) 'The distribution of total greenhouse gas emissions by households in the UK, and some implications for social policy', *CASE Paper* 152, July 2011

Gross, R., Heptonstall, P., Anable, J., Greenacre, P. and E4Tech (2009) 'What policies are effective at reducing carbon emissions from surface passenger transport? A review of interventions to encourage behavioural and technological change', Technology and Policy Assessment Function of the UK Energy Research Centre (UKERC)

Hills, J. (2012) 'Getting the measure of fuel poverty: Final report of the fuel poverty review', *CASE report 72*, March 2012

HM Treasury (2012) 'Autumn statement', Cm 8480

IPPR (2010) 'Green and decent jobs: The case for local action', a scoping study paper

Jackson, J., Choudrie, S., Thistlethwaite, G., Passant, N., Murrells, T., Watterson, J., Mobbs, D., Cardenas, L., Thomson, A. and Leech, A. (2009) 'UK greenhouse gas inventory: 1990 to 2007', *Annual Report for Submission under the Framework Convention on Climate Change*. Harwell: AEA Technology

JRF (2009). 'The social justice implications of climate change in the UK'. Call for proposals from the Joseph Rowntree Foundation, June 2009

Koehler, J. (2009) 'Dynamics of socio-technical change in the transport sector: An application of transition theory to environmental policy', Dynamics of Institutions and Markets (DIME) workshop, Utrecht, Netherlands, 10 May 2009

National Travel Survey (2012) 'Updated NTS, 2002–2010', Available at: http://www.esds.ac.uk/government/nts/ [Accessed 5 October 2012]

Nationwide (2012) [online] http://www.nationwide.co.uk/loans/default.htm [Accessed 5 October 2012]

OECD (2011) 'Towards Green Growth'. Available at: http://www.oecd.org/greengrowth/towardsgreengrowth.htm [Accessed 17 January 2013]

Office for Budget Responsibility (2011) 'Economic and fiscal outlook – November 2011'. Available at: http://budgetresponsibility.independent.gov.uk/economic-and-fiscal-outlook-november-2011/ [Accessed 5 October 2012]

Ofgem (2010) 'RIIO – A new way to regulate energy networks', *Media Factsheet 93*, 4 October 2010

ONS (2003) 'Rural/urban definition (England and Wales)'. Available at: http://www.ons.gov.uk/ons/guide-method/geography/products/area-classifications/rural-urban-definition-and-la/rural-urban-definition--england-and-wales-/index.html [Accessed 5 October 2012]

Pöyry (2011) 'Potential impact of revised Renewables Obligation technology bands', a report to DECC

Preston, I., Richards, M. and Guertler, P. (2008). 'How much? The cost of alleviating fuel poverty', a report to eaga Partnership Charitable Trust. Available at: http://www.cse.org.uk/pdf/pub1110.pdf [Accessed 12 February 2013]

Radov, D., Klevnäs, P., Hanif, A., Abu-Emid, M., Barker, N. and Stambaugh, J. (2009) for NERA Economic Consulting and AEA, 'The UK supply curve for renewable heat', a study for DECC

Renewable Energy Forum Ltd (2012) 'Shortfall, rebound, backfire: Can we rely on energy efficiency to offset climate policy costs?' Available at: http://www.ref.org.uk/attachments/article/257/ref.shortfall.21.05.12.pdf [Accessed 5 October 2012]

Richards, P. (2012), 'The Green Deal', *Parliamentary Note SN/SC/5763*

Rogers, S. (2012) 'London Olympics 2012: Where does the money come from – and where's it being spent?', *The Guardian* [online], 26 July 2012 10.20 BST). Available at: http://www.guardian.co.uk/sport/datablog/2012/jul/26/london-2012-olympics-money [Accessed 5 October 2012]

Sanders, C. and Philipson, M. (2006) 'Review of differences between measured and theoretical energy savings for insulation measures', Centre for Research on Indoor Climate and Health, Glasgow Caledonian University and the Energy Saving Trust

Scottish Fuel Poverty Forum (2012) 'Scottish Fuel Poverty Forum: Review of the Scottish Government's fuel poverty strategy – Interim Report May 2012'. Available at: http://www.scotland.gov.uk/Topics/Built-Environment/Housing/warmhomes/fuelpoverty/ScottishFuelPovertyForum/SFPFinterimreportmay012 [Accessed 5 October 2012]

SMMT (2012) 'July 2012 – EV and AFV registrations'. Available at: http://www.smmt.co.uk/2012/08/july-2012-%E2%80%93-ev-and-afv-registrations/ [Accessed 5 October 2012]

Stern, N. (2006) 'The Stern Review: The economics of climate change'. London: HM Treasury and Cabinet Office

Wayman, J. (2003) 'Multiple imputation for missing data: What is it and how can I use it?' Paper presented at the 2003 Annual Meeting of the American Educational Research Association, Chicago, IL

Woodcock, J., Banister, D., Edwards P., Prentice A. M., Roberts, I. (2007) 'Energy and transport', *The Lancet*, 370(9592), pp. 1078–88

WWF-UK (2011) 'Electric avenues: Driving home the case for electric vehicles in the UK'. Available at: http://assets.wwf.org.uk/downloads/electric_avenues_fullreport.pdf [Accessed 5 October 2012

APPENDIX 1: POLICY MODELLING ASSUMPTIONS

The fuel price and policy cost assumptions used in the analysis of the distributional impacts of UK climate policy are primarily taken from a recent study that CSE and the Association for the Conservation of Energy (CSE and ACE, 2012) completed for Consumer Focus. The study, 'The impact of energy policy on consumer bills', provided a detailed analysis of the changes and bills and costs associated with two policy scenarios and three fuel price scenarios.

For the purpose of this work we have taken the most central scenario for policy performance, policy costs, and changes to network costs and wholesale prices. The scenario taken should therefore most closely match the government's most recent thinking on future energy costs and measures deployment as published in its annual energy statement (AES, 2011) on distributional impacts.

The tables at the end of the Appendix contain the key assumptions used.

Wholesale/network assumptions

Fossil fuel prices

The study uses DECC's (2011f) central fossil fuel price scenario with updated projections that predict a gas price of 70p/therm[41] by 2020. The wholesale cost of energy currently accounts for 43% of the unit price of electricity and 57% of gas unit prices. Under the central fuel price scenarios, this falls to around 34% for electricity and 55% for gas in 2020. The global trends for the wholesale costs of energy are therefore a key uncertainty in the estimation of future fuel prices. While this study has presented the impacts of three different fuel price scenarios, the most likely outcome is unknown.

Network costs

The cost of transmitting and distributing electricity and gas is subject to price control by Ofgem, due to the monopolies managing the networks in each area. The existing price control framework, based on an 'RPI-X' calculation that rewards efficiency, is currently being changed in favour of a model that it is hoped will best reward companies for efficiently delivering the £32 billion of required grid upgrades that Ofgem (2010) has identified through to 2020.

Price controls under the new model, known as RIIO (revenue = incentives + innovation + outputs), have yet to be set. A new price control model designed to stimulate network investment presents a highly uncertain outlook for impacts upon consumer bills. The study follows DECC's methodology of using historic data on network costs provided by Ofgem and projecting these forward to 2020.

Other supplier costs and margin

In addition to the wholesale costs of fuel and the costs associated with electricity and gas networks, there are other costs that fall upon energy bills. These include the costs of metering, balancing the grid, and losses and constraints. In addition, suppliers can make a margin on the price of energy – one of several ways in which they can make a return to their shareholders and investors. DECC assumes these costs represent a fixed percentage mark-up on wholesale costs.

Policy assumptions

In addition to the costs associated with fuel and its transportation, assumptions need to be made about the costs and impact of energy and climate change policies.

EU Emissions Trading System and the Carbon Price Floor

The price of carbon under the EU ETS is inherently uncertain, subject to myriad factors that include: the rate of economic growth; the success of complementary policies that reduce carbon emissions from entities subject to the EU ETS; changes to the number of allowances in circulation; and signals over future targets from policy-makers. Households currently pay around £20 a year on average to cover the cost of the EU ETS. The above factors, twinned with the impact of Phase 3 of the EU ETS in 2013, where all emissions allowances to the electricity generators will be auctioned, make the impact on the 2020 energy bills highly uncertain.

In addition, the government is introducing a CPF that will guarantee a minimum price for carbon by amending the Climate Change Levy (CCL). The CCL will become an upstream charge for electricity generation, set at a level such that, when combined with the EU ETS carbon price, the total cost paid per unit of carbon emitted equals the CPF. The CPF will begin at around £16/tCO_2 in 2013 and follow a straight line trajectory to £30/tCO_2 in 2020, increasing at around £2/tCO_2 per year from 2013 to 2020 (all in 2009 prices).

To a degree, the combination of the EU ETS and CPF reduces the volatility and uncertainty over the impact upon bills: where the EU ETS carbon price is low, the CPF has a larger impact. However, there are differences in the scope of the policies (with the EU ETS covering a wider range of entities). In addition, if the EU ETS price exceeds the CPF, the volatility would remain. In its AES, DECC predicts a cost of the EU ETS in 2020 of 1.0p/kWh, with a CPF of 0.1p/kWh. The study has used the DECC AES projections as a basis for future EU ETS and CPF costs.

Renewables Obligation and Electricity Market Reform

A highly uncertain aspect of future energy bills is the potential impact of the proposed EMR. EMR will see support for plant offering generating capacity, create a FIT Contracts for Difference (FIT CfD) for low-carbon generators, and put limits on the emissions from generators with an Emissions

Performance Standard. Generators will be able to choose between support from the RO or support from the FIT CfD mechanism under the EMR until April 2017.

DECC's assumptions are based on an RO and EMR combination in line with a trajectory to deliver an emission intensity of 100gCO_2/kWh for the power sector by 2030. They assume that the RO supports new renewable generation until 2016 when support switches to the FIT CfD.

For the RO, the assumptions used are based on the Consumer Focus funded analysis of the Pöyry (2011) report to DECC on the proposed RO bandings to estimate the costs to consumers. We used the obligation level in ROCs shown in Figures 8, 9 and 11 in Pöyry's report, historical data for the buy-out price from Ofgem, and Figure 15 showing total policy costs, to estimate the cost pass-through.

For the EMR, the study uses DECC's central scenario; however, these costs need to be adjusted to reflect the most recent wholesale and network prices as this changes the EMR's impact. For example, low fuel prices give a high cost for the EMR (due to the higher cost of FIT CfDs) and vice versa. In this way, the EMR policies act to moderate price volatility to an extent.

Energy Company Obligation and the Green Deal

Domestic energy efficiency improvements are currently being delivered by two obligations on energy suppliers, CERT and CESP (the latter covers generators as well). Both of these policies run until the end of 2012, when they will be replaced by a new supplier obligation, the ECO. The ECO plans have yet to be finalised, but the position that government consulted on would see an obligation of around £1.3 billion per year (in total) from 2013–20.

Alongside the ECO will be a new energy efficiency financing mechanism called the Green Deal. This will allow households to install packages of energy efficiency measures at no upfront cost, instead making repayments through their energy bills spread over 25 years. The repayments would need to be lower than the savings that the household makes (the Golden Rule), meaning that the household bills would still be lower than before the installation. In addition, the repayments are tied to the home, not the household, so the occupant is not liable for the outstanding balance if they move before it is fully repaid.

Expected delivery under the ECO and particularly the Green Deal is highly uncertain. DECC's (2011g) draft impact assessment for the ECO and Green Deal consultation gave an estimated cost (mentioned above) of £1.3 billion a year for the ECO. There was little further detail on expected delivery, aside from a chart that illustrated an expectation for the two policies to insulate 1.52 million solid walls, 1.35 million cavities, and 220,000 lofts above business as usual between 2013 and 2022.

This is a very low number of lofts and cavities to be insulated through to 2022. It should be noted that these figures were released before an additional £205 million was announced by HM Treasury to be used to incentivise Green Deal take-up. However, no updated figures have been released by DECC to date.

The study uses total measures to be installed from a bottom-up analysis of the ECO and Green Deal policies. DECC's draft impact assessment gives a total cost of around £1.3 billion/year that covers the costs of measure subsidy, scheme administration and economic rents (the latter at £0.5 billion/year). DECC assumes that the majority of solid wall insulation goes into the homes of those in a position to take up the Green Deal (generally assumed to be those of higher incomes who are less debt-adverse or able to contribute their own funds). Boilers will also be delivered through the Green Deal and ECO with an assumed yearly take-up of approximately 100,000 boilers through the ECO's Affordable Warmth obligation.

Feed-in Tariffs

On 31 October 2011 the government published a consultation on Phase 1 of the FIT Comprehensive Review. The take-up of domestic solar PV had significantly exceeded expectations owing to significant cost reductions and innovative business models such as the rent-a-roof approach. The government therefore announced a reduction in the level of solar subsidy through the FIT from 43.3p to 21p/kWh. The addendum report 'Environmental levies, past, present and future' provides more detail on the potential implications of the tariff reduction on energy bills.

We were therefore required to estimate the bill impacts and total installations associated with the revised rate. The following sources were used to help identify the possible take-up:

- Cumulative installations to date taken from DECC (2011h, see Table ET 5.6).
- DECC's response to Energy and Climate Change, and Environmental Audit Committee's (Parliament, 2011) look at the impact of the FIT on consumers' bills. This provides an explanation of the methodology needed to calculate the assumed cost and per unit pass-through to consumers from the figures presented in £/MWh for each year.
- DECC recently published an updated impact assessment (DECC, 2012b) to accompany the 'Comprehensive Review Phase 1 – Consultation on Feed-in Tariffs for solar PV'. We used the estimated cost to consumers, the revised tariff rates and the estimated total number of measures to 2020 to predict annual installation rates.

The study uses DECC's most recently published 'Option A' which targets average rates of return of around 5–8%, with around 5% for domestic installations. This produces a tariff of 13.6p for 4 kW solar PV installations, which gives a return on investment (ROI) ranging from 0.5% to 10%.

Renewable Heat Incentive

The proposals for the RHI were originally published alongside the February to April 2010 consultation. The historical analysis on the RHI can now be found on the National Archives website, which features the NERA/AEA study on the 'UK supply curve for renewable heat' (Radov, *et al.*, 2009). However, the projections for installed capacity and the potential numbers of installations associated with the NERA analysis for the domestic RHI are dependent on different tariffs.

The current RHI impact assessment contains an outline of the proposed domestic tariff levels, but there is no detailed information on the possible installed capacity they might stimulate (DECC, 2011i). The Consumer Focus study therefore reviewed the current numbers of installations installed under the existing Renewable Heat Premium Payment (RHPP) on the Energy Saving Trust's website. The level of take-up has been relatively low, and for the purposes of this analysis we assumed an annual sector growth rate of 40%. In other words, we have assumed that the RHPP (subsidy-based) will continue to support domestic renewable heat with the deployment of tariff-based incentives focusing on the non-domestic sector.

Boiler churn

DECC's AES excludes boiler replacement as the minimum boiler efficiency standards are covered by building regulations (CLG policy; outside of DECC's remit) rather than an exclusively energy or climate change-focused policy. The Consumer Focus study therefore reviewed the findings of the CCC study 'Household energy bills' (CCC, 2012).

The CCC's analysis of energy bills allowed for the 'natural replacement' of boilers due to their age, inefficiency or failure – often referred to as 'churn'. According to the CCC, from 2013 there will be 6.5 million old boilers to replace by 2020. The boiler churn scenarios deployed in this study assume that all old boilers have been replaced by 2020.

The extent to which gas and oil boiler replacement will become an integral part of the Green Deal is unclear; however, they represent a measure that is easy to install (where the boiler replaces an older model) and often purchased out of necessity. Boilers will in any case be delivered via the ECO's Affordable Warmth obligation. Where boilers are not delivered via Green Deal or the ECO, they are bought outright.

Products policy

The products policy assumptions are prepared by Defra as part of its analysis of the Market Transformation Programme (MTP). The products policy savings cover Tranche 1 and 2 of EU policy with a variety of measures ranging from appliances to improvements in boiler efficiency. The savings associated with boiler replacement have been excluded as boiler churn is modelled separately.

Electricity demand is projected to fall by 19.88 TWh to 2020 with gas demand set to increase by 8.66 TWh (NB: this is England only). The increase in projected gas use is due to the heat-replacement effect whereby more efficient appliances give off less heat.

Assumptions not covered

In this analysis we have attempted to address a wide range of assumptions. However, there are several aspects that we have not reflected in our analysis, including:

- demand response to increased fuel prices across the scenarios. We might expect our high energy price scenarios to see a greater behavioural response;
- in addition to energy demand responding to price, price can respond to energy demand.

Table 32: Total number of measures deployed in modelling the impact of government policies

Policy	Measure	Number of measures
Carbon Emissions Reduction Target	Cavity wall insulation	2,927,759
	Loft insulation	2,723,049
	Solid wall insulation	66,937
Energy Company Obligation	Cavity wall insulation	496,951
	Gas condensing boilers	817,066
	Loft insulation	77,760
	Oil condensing boilers	83,047
	Solid wall insulation	1,147,642
Feed-in Tariff	Micro CHP (combined heat and power)	23,064
	Photovoltaic	2,504,135
Green Deal	Cavity wall insulation	866,357
	Gas condensing boilers	20,821
	Loft insulation	315,548
Renewable Heat Incentive	Air source heat pump	43,653
	Biomass boilers	20,832
	Ground source heat pump	23,300
	Solar water heating	24,470
Boiler Churn	Gas condensing boilers	5,028,087
	Oil condensing boilers	444,669

Table 33: Policy costs passed through to consumers in modelling the impacts of government policies in 2011

Policy	Fuels covered	Cost type	Cost	Total cost
CERT & Community Energy Saving Programme	Gas and electricity customers	Per account	£18.53	£735,192,461
FIT	Electricity customers	Per unit	£0.0006	£54,439,300
Warm Homes Discount	Gas and electricity customers	Per account	£4.87	£193,200,000
EU Emissions Trading Scheme	Electricity customers	Per unit	£0.0051	£4,319,130,701
Renewables Obligation	Electricity customers	Per unit	£0.0049	£410,740,862

Table 34: Policy costs passed through to consumers in modelling the impacts of government policies in 2020

Policy	Fuels covered	Cost type	Cost	Total cost
ECO	Gas and electricity customers	Per account	£27.58	£1,092,647,493
FIT	Electricity customers	Per unit	£0.0025	£157,503,339
Smart Meters	Electricity customers	Per unit	£0.0003	£36,954,527
	Gas customers	Per unit	£0.0001	
WHD	Gas and electricity customers	Per account	£5.73	£226,800,000
EU ETS & Carbon Price Floor	Electricity customers	Per unit	£0.0109	£686,714,559
RO	Electricity customers	Per unit	£0.0148	£932,419,768
Electricity Market Reform	Electricity customers	Per unit	£0.0092	£579,612,288

Table 35: The components of final fuel costs expressed as p per kWh in 2011 and 2020

	Gas		Electricity	
	2011	**2020**	**2011**	**2020**
Wholesale	2.09	2.32	6.21	5.99
Transmission	0.09	0.15	0.51	1.19
Distribution	0.65	0.77	2.18	3.45
Metering	0.03	0.00	0.13	0.01
Other supplier costs and profit	0.85	0.94	3.38	3.70
ECO support cost		0.18		0.77
Smart Meters		0.01		0.03
CERT Extension	0.13		0.43	
CESP	0.01		0.03	
Better Billing	0.00	0.00	0.00	0.00
WHD support cost	0.03	0.05	0.12	0.16
EU ETS	0.00	0.00	0.51	1.09
CPF	0.00	0.00		0.24
RO support cost	0.00	0.00	0.49	1.48
EMR support cost	0.00	0.00		0.92
FIT support cost	0.00	0.00	0.06	0.25
VAT	0.19	0.22	0.70	0.96
Total price	4.07	4.63	14.76	20.24

Table 36: Typical costs used in the HAM

Measure description	Average cost (£)[42]	System size
Cavity wall insulation	£430	n/a
Internal solid wall insulation	£7,400	n/a
Loft insulation, full	£290	n/a
Loft insulation, top-up	£240	n/a
External solid wall insulation	£13,100	n/a
Hot water cylinder insulation (80 mm jacket)	£70	n/a
Heating controls upgrade (to include programmer, room thermostat and TRVs)	£340	n/a
Air source heat pump	£7,500	9.5 kW
Biomass boiler	£7,600	15 kW
Gas condensing boiler	£2,600	15 kW
Ground source heat pump	£9,100	5 kW
Oil condensing boiler	£4,700	15 kW
Solar water heating	£4,600	2 kW
Micro wind turbine	£2,500	1.5 kW
1 kW solar PV system	£4,500	1 kW
2 kW solar PV system	£8,800	2 kW

APPENDIX 2: SUPPLEMENTARY PROJECT DOCUMENTS

A number of reports related to this study are available as separate documents, as follows:

Document reference and title	Available at
Technical Report 1: Developing the datasets (Survey harmonisation; deriving emissions estimates from survey data; working with imputed data)	CSE website
Project Paper 1: The distribution of household CO_2 emissions in Great Britain	JRF website
Project Paper 2: Exploring accessibility to public transport and local services, and its role in determining travel CO_2 emissions in Great Britain	CSE website
Project Paper 3: Personal carbon allowances – the implications of transport emissions and household abatement opportunities	CSE website

GLOSSARY OF TERMS

APS	Air Passenger Survey
Boiler churn (replacement)	In modelling the impact of policies and measures on household energy consumption and bills over time, we also make some allowance for the natural cycle of households replacing old boilers first.
CAA	Civil Aviation Authority: the UK's aviation regulator
Carbon budget	A cap on the total quantity of greenhouse gas emissions in the UK over a specified time. Under a system of carbon budgets, every tonne of greenhouse gas emitted between now and 2050 will count. Where emissions rise in one sector, corresponding reductions will therefore have to be achieved in another to ensure the overall cap is maintained. Four carbon budgets have now been set for the UK, which cover the five-year periods 2008–12, 2013–17, 2018–22 and 2023–27.
CCC	Committee on Climate Change: an independent body established under the Climate Change Act 2008, which advises the UK government on setting and meeting carbon budgets, and on preparing for the impacts of climate change.
CCS	Carbon capture and storage: technology attempting to prevent the release of large quantities of CO_2 into the atmosphere from fossil fuel use in power generation and other industries. CCS captures CO_2, transporting it and ultimately pumping it into underground geologic formations to store it securely away from the atmosphere.
Comfort taking	The notion that improvements to the thermal efficiency of the home – through the installation of energy efficiency or heating measures – are taken as improved levels of comfort (i.e. warmth) rather than as a reduction in energy consumption and energy bills. For example, a household may be using its heating system to an extent, but not feel the benefits because of heat loss through a poorly insulated building fabric. If this household installs cavity wall insulation, it may continue to use the same level of heating energy but now feels comfortably warm. This phenomenon is especially true for lower income households that heat the home to their financial capacity: unaffordable energy costs limit their ability to maintain a comfortable living environment. The installation of energy efficiency measures may therefore mean the level of heating that they can afford is now sufficient to avoid living in a cold home.
CSE	Centre for Sustainable Energy: an independent charity whose mission is to help people and organisations from the public, private and voluntary sectors meet the twin challenges of rising energy costs and climate change.
CLG	(Department for) Communities and Local Government
DECC	Department of Energy and Climate Change
DIMPSA	Distributional Impacts Model for Policy Scenario Analysis: a modelling tool developed by CSE and used under licence by DECC to analyse the distributional impacts of government energy and climate policies on domestic consumer energy bills.
Direct emissions	In the context of this report, direct emissions include those resulting from the consumption of energy in the home (for heating, hot water, lighting, and cooking and other appliances); travel by private vehicle for leisure or commuting purposes (i.e. travel to work is included, but travel during or for the purposes of business is not); travel by public transport (buses, rail, underground, etc.) for leisure and commuting purposes; domestic flights for leisure and commuting; international aviation for leisure purposes. This study focuses on emissions from direct sources only.
EFS	Expenditure and Food Survey (see LCF for more details)

EHCS	English House Condition Survey: a continuous national survey of housing in England, commissioned by CLG. It covers all tenures and involves a physical inspection of property by professional surveyors. The information from the survey provides an accurate and representative picture of the type and condition of housing in England, the people living there, and their views on housing and their neighbourhoods.
EHS	English Housing Survey: in April 2008, the EHCS and SEH were integrated, resulting in this new survey.
EV	Electric vehicle
HAM	Housing Assessment Model: a computer modelling tool developed by CSE, which is used to analyse housing stock data. For every property represented in the dataset, the model produces a baseline assessment of household energy requirements and associated CO_2 emissions, fuel costs and the 2011 SAP rating. It then calculates the best combinations of energy efficiency and renewable energy measures that could be applied to improve the thermal efficiency and sustainability of the housing stock, according to user-defined criteria.
(Survey) Harmonisation	A methodological term that describes the initial step in developing the two distinct datasets used for analysis in this report. The datasets are created by combining data from a number of different surveys (namely the EFS, NTS, APS and EHCS). These surveys were each designed in isolation, which has undermined comparability with regard to concepts, definitions, design and fieldwork. Processing practices ('inputs') and the way results are released ('outputs') are also different. The harmonisation of datasets was therefore essential in ensuring that key concepts are defined and measured in the same way, and to ensure that the data itself is comparable with regard to its distribution and weighting.
Heat-replacement effect	In the context of products policy, this relates to the impact of improvements in appliance efficiency that results in reductions (savings) in electricity consumption. However, at the same time, improved efficiency levels mean less waste heat is generated from electrical products. To maintain the same levels of warmth in the home, it is assumed that additional heating is required.
HRP	Household reference person: this is typically used in national survey data to refer to the 'head of household' – defined as the individual with the highest income (or the older of two or more occupants with the same income levels).
(Multiple) Imputation	This methodological term describes a key stage in the creation of the two distinct datasets used for analysis in this study. Given that no single nationally representative dataset exists to provide all the data needed to understand the distribution of emissions and the impact of energy policies on households, data has been combined from several different survey sources. The process of multiple imputation is a way of predicting values that are missing in a dataset, using values that exist for other variables in the dataset. The predicted values are substituted for the missing values, resulting in a full dataset (the 'imputed dataset'). This process is performed multiple times, producing multiple imputed datasets (hence the term 'multiple imputation'). Multiple imputation replaces missing data values in such a way that both the natural variability in the missing data and the uncertainty caused by estimating missing data values are accounted for. Thus, in performing multiple imputation, important characteristics of the dataset as a whole (e.g. means, variances, regression parameters) can be preserved (Wayman, 2003).
Indirect (or embodied) emissions	Indirect or embodied emissions refer to the energy required for the production of goods and services, and therefore the carbon within. For example, there are carbon emissions associated with the production of insulation materials to improve the energy efficiency of homes. The analysis presented in this study does not allow for these embodied emissions.
LCF	Living Costs and Food survey: in January 2008, the LCF replaced the EFS. The LCF collects information on spending patterns and the cost of living that reflect household budgets across the country. The survey is conducted throughout the year across the whole of the UK.
NTS	National Travel Survey
Progressive	This term describes the distributional impact across income groups whereby lower income households appear proportionally better off than higher income counterparts.

Rebound effect	The phenomenon whereby carbon reductions estimated from improvements in energy efficiency in the home (e.g. through the installation of insulation or improved product standards) are not realised in practice because of increases in emissions elsewhere. The rebound effect is often divided into 'direct' and 'indirect' behavioural responses. For example, a direct rebound effect may result when a householder increases their use of a product or service that has become cheaper owing to improvements in efficiency (e.g. installing low-energy lighting, but increasing the level of lighting in the home – lower energy demand per light fitting, but an overall increase in lighting). An indirect rebound effect may result from financial savings from improvement in energy efficiency in the home being spent elsewhere (e.g. taking more holidays abroad). These goods and services also require energy and produce emissions, thus the overall net reduction in emissions is not realised in practice (see Chitnis, *et al.*, 2012 and Druckman, *et al.*, 2011)
Regressive	This term describes the distributional impact across income groups whereby lower income households appear proportionally worse off than higher income counterparts.
SAP	Standard Assessment Procedure: the government's official standard used to calculate the energy performance and efficiency of a dwelling. It assesses the energy *required* for heat and power in the home, based on an assumed need for warmth. The calculation takes into account the size, shape and physical characteristics of the house, including heating systems and insulation levels. The resulting SAP rating is therefore an estimate of a household's required energy costs per m^2. It is intrinsically linked to the theoretical running costs, not the actual consumption of energy in the home. The higher the SAP rating, the better the energy performance and lower the energy costs.
Secondary heating	Supplementary heating in the home, over and above the main (e.g. central) heating system. This is often in the form of an individual room heater.
SEH	Survey of English Housing

POLICY GLOSSARY AND OVERVIEW

(Further detail of policies and their costs is contained in Appendix 1: Policy modelling assumptions)

Abbrev.	Timeframe	Who delivers	Who benefits	Policy overview
CERT	Ended 2012	Energy suppliers, Scheme managers	Householders	**Carbon Emissions Reduction Target** The government's existing obligation that requires domestic energy suppliers to make savings in the amount of CO_2 emitted by householders by promoting the uptake of low-carbon energy solutions. The third and final phase of CERT ran to the end of 2012, when it was replaced by the Green Deal and ECO.
CESP	Ended 2012	Energy suppliers, Generators, Scheme managers	Householders	**Community Energy Saving Programme** Launched in September 2009, CESP targets households across GB, in areas of low income, to improve energy efficiency standards and reduce fuel bills. CESP is funded by an obligation on energy suppliers and electricity generators. The CESP obligation period ran from 1 October 2009 to 31 December 2012.
CPF	2013 onwards	Businesses, Generators	Energy system	**Carbon Price Floor** The carbon price set by the EU ETS has not been certain or high enough to encourage sufficient investment in low-carbon electricity generation in the UK. The CPF is a pricing mechanism that has been created to set a minimum price for carbon emissions in the traded EU ETS market for carbon from the electricity generation sector, starting at £16 per tonne of CO_2 in 2013 and rising linearly to £30 per tonne in 2020.
ECO	2013–20	Energy suppliers, Scheme managers	Householders	**Energy Company Obligation** A new ECO works alongside the Green Deal (from October 2012), ensuring support worth around £1.3 bn a year to deliver energy efficiency and heating measures across GB to help tackle fuel poverty and climate change. The key focus of the new ECO will be on those householders who cannot achieve significant energy savings without an additional or different measure of support, including vulnerable and low-income households (targeted through the Affordable Warmth element of the ECO) and those living in harder to treat properties, such as solid-walled properties (targeted through the Carbon Saving Obligation element of the ECO).
EMR (FIT CfD)	2014 onwards	Electricity generators	Energy system	**Electricity Market Reform** EMR will put in place the institutional and market arrangements to deliver the scale of change in the power sector needed to meet the UK's carbon budgets, including the recently adopted fourth carbon budget.

EU ETS	Phase III runs until 2020	Businesses, Generators	Energy system	**European Union Emissions Trading System** An EU-wide cap and trade scheme (started in 2005) that sets an overall cap on the total emissions allowed from all the installations covered by the system. This is converted into allowances (one allowance equals one tonne of CO_2), which are then distributed by EU member states to installations covered by the system. At the end of each year, installations are required to surrender allowances to account for their actual emissions. They may use all or part of their allocation. Installations can emit more than their allocation by buying allowances from the market. Similarly, an installation that emits less than its allocation can sell its surplus allowances. In theory, the environmental outcome is certain as the amount of allowances allocated is fixed and therefore any wider shortfall will result in a higher price which will drive action. The EU ETS covers electricity generation and the main energy-intensive industries – power stations, oil refineries, iron and steel, cement and lime, paper, food and drink, glass, ceramics, engineering and the manufacture of vehicles. Combined, these account for around 48% of UK CO_2 emissions. From 2013, there is full auctioning for the power sector in GB.
FIT	2020 (contracts will extend beyond this)	Installation contractors	Householders	**Feed-in Tariff** The government's policy to provide financial incentive for the installation of small-scale (less than 5 MW) low-carbon electricity generation. Introduced on 1 April 2010, the FITs aim to encourage investment by offering a guaranteed payment from an electricity supplier for the electricity generated and used, as well as a guaranteed payment for unused surplus electricity exported back to the grid.
Green Deal (GD)	2013–20	Unclear, most probably Energy suppliers, Scheme managers, Local authorities, RSLs	Householders	**Green Deal** The government's new flagship initiative to underpin the installation of energy efficiency improvements in the domestic sector, which began in October 2012. It sets out a framework to enable private firms to offer consumers energy efficiency improvements to their homes, community spaces and businesses at no upfront cost, and recoup payments through a charge in instalments on the energy bill (tied to the property not the householder). The expected financial savings must be equal to or greater than the costs attached to the energy bill, known as 'the Golden Rule'. Where the Golden Rule is not met (if costs of the work outweighs the savings), or people need extra financial help, energy companies will be able to offer additional support to top up the loan under the ECO.
PP	Ongoing	Manufacturers of products	Householders	**Products policy** This relates to the regulatory framework that sets minimum efficiency standards for household goods and appliances. The products policy assumptions are prepared by Defra as part of its analysis of the Market Transformation Programme (MTP). The products policy savings cover a variety of measures ranging from appliances to improvements in boiler efficiency.

RHI	2013 onwards	Central government	Householders	**Renewable Heat Incentive** The government's policy to provide a financial incentive for the installation of renewable heating technologies. It is being introduced in phases, with the first phase (launched in November 2011) offering long-term tariff support to the non-domestic sector, particularly targeting the big heat users in the industrial, business and public sector. This phase also offered support for households through the RHPP scheme.
RHPP	Ended 2012	Central government	Householders	**Renewable Heat Premium Payment** A one-off grant designed to help householders meet the costs of installing renewable heat technologies, until the RHI is introduced for domestic customers. This scheme was introduced in July 2011 and closed to applicants at the end of March 2012. It was originally intended that it would be followed by the introduction of long-term tariff support, with the RHI being extended to the domestic sector in October 2012 (to coincide with the Green Deal). However, this was delayed to summer 2013. In place of this, a second phase of the RHPP, worth £25m, was introduced from the beginning of May 2012 (running to 31 March 2013).
RO	Targets set until 2020 (contracts will extend beyond this)	Electricity suppliers	Energy system	**Renewables Obligation** The UK government's current main financial mechanism for incentivising the deployment of large-scale renewable electricity generation. Introduced in 2002, the RO places a mandatory requirement on licensed UK electricity suppliers to source a specified and annually increasing proportion of electricity they supply to customers from eligible renewable sources, or pay a penalty. The scheme is administered by Ofgem which issues Renewables Obligation Certificates (ROCs) to electricity generators in relation to the amount of eligible renewable electricity they generate. Generators sell their ROCs to suppliers (or traders); suppliers are then required to present ROCs to Ofgem to demonstrate their compliance with the obligation. Where they do not present sufficient ROCs, suppliers have to pay a penalty known as the buy-out price. The money collected by Ofgem in the buy-out fund is recycled on a pro-rata basis to suppliers who presented ROCs. In April 2010, the end date of the RO was extended from 2027 to 2037 for new projects to provide long-term certainty for investors, and to ensure continued deployment of renewables to meet the UK's 2020 target and beyond.
WFP	Until 2015 (then subject to Spending Review)	Central government	Householders	**Winter Fuel Payment** An annual tax-free payment made by the government to eligible people (over 60s) to help towards winter heating costs. It is a lump sum and in most cases is paid automatically. The value ranges from £100–300 (2012/13 figures) depending on personal circumstances.

WHD	Until 2015 (then subject to Spending Review)	Energy suppliers	Householders	**Warm Home Discount** A four-year scheme that runs from April 2011 to March 2015 to help low-income and vulnerable households with energy costs. The scheme is worth up to £1.1 bn per annum and is expected to assist around 2 million low-income and vulnerable households annually. The funding comes from the participating energy suppliers in the form of a discount on the energy bill for eligible households of £130 (2012/13). There are four elements to the scheme: the Core Group (a discount on the electricity bill for older customers on low incomes); the Broader Group (eligibility criteria are at the discretion of the energy supplier, but should be targeted at low-income and vulnerable households that are fuel poor or at risk of fuel poverty); Legacy Spend (option for energy suppliers to continue to provide support through discounted/social tariffs and rebates); and Industry Initiatives (energy supplier-funded programmes and partnerships that assist those in or at risk of fuel poverty with a range of support, including benefit entitlement checks, debt advice and energy efficiency measures).

ACKNOWLEDGEMENTS

The authors wish to thank the Joseph Rowntree Foundation for supporting the project. We thank Katharine Knox, Christine Appleton, Josh Stott and Phillipa Fairburn for their work with us. We also thank the members of the project advisory committee: Brenda Boardman, Angela Druckman, Helena Titheridge, Claire Tyler, Ian Skinner, Richard Moore, Mike Harmer, Derek Lickorish and Robert Pugh. Extended thanks go to Ian Gough, for providing an additional review of the report, and Darryl Croft, for his work on the fuel and policy costs used in the analysis of UK climate change policy.

We would also like to acknowledge the role played by academic staff at the School for Policy Studies (SPS), University of Bristol, during the early stages of the project. Dr Demi Patsios carried out the initial data harmonisation and Dr Eldin Fahmy contributed to drafting the project interim report. SPS staff did not contribute to this final report. The results reported and conclusions drawn are the responsibility of the team at the Centre for Sustainable Energy.

ABOUT THE AUTHORS

Joshua Thumim is Head of Research and Analysis at CSE. He has extensive experience of research in the fields of renewable energy, energy policy-making and energy strategy. He recently led on the development of a National Heat Map for DECC, and is managing a project to develop a new National Housing Model for them. Prior to joining CSE in 2006, Josh was Strategy Adviser and then Principal Policy Officer with regard to energy at the Greater London Authority, where he was involved in managing and designing a wide range of research and implementation projects around themes of renewable energy deployment, energy efficiency and fuel poverty.

Ian Preston is a Senior Analyst at CSE. Having joined the organisation in 2001, he has more than a decade of experience working in sustainable energy practice and social research. He is a leading expert on the distributional impacts of energy policy, and his work in this area included the development and application of the Distributional Impacts Model for Policy Scenario Analysis, which he has applied in a number of different research projects to examine the social distributional impacts associated with UK climate change and energy policies.

Vicki White is a Research Project Manager and joined CSE in 2006. She has since worked extensively on both quantitative and qualitative research projects, leading on statistical analysis of survey data. A key area of expertise is in distributional impacts analysis. Utilising a dataset of UK household energy consumption, she has undertaken a number of different research projects to explore the social justice implications of UK climate change and energy policies and personal carbon trading.

Toby Bridgeman joined CSE in January 2010. He has a strong understanding of national surveys and statistics that cover housing, demographics, public attitudes and socio-economics. He has also acquired extensive knowledge of housing energy assessments and energy efficiency improvements. Toby manages the computer housing assessment modelling tool, developed by CSE and used in analysing housing stock datasets.

Christian Brand is a Senior Research Fellow in Transport, Energy and the Environment at Oxford University's Environmental Change Institute. His research profile spans more than 15 years of developing and delivering projects in consultancy and academic environments, focusing on integrated analysis of the interface between transport, energy and the environment. He has published widely on a range of topics, from the distributional impacts of personal transport on climate change, to developing and modelling climate change mitigation strategies in the transport and energy sectors, and the carbon and health evaluation of walking and cycling interventions.

The Joseph Rowntree Foundation has supported this project as part of its programme of research and innovative development projects, which it hopes will be of value to policy makers, practitioners and service users. The facts presented and views expressed in this report are, however, those of the authors and not necessarily those of JRF.

A pdf version of this publication is available from the JRF website (www.jrf.org.uk). Further copies of this report, or any other JRF publication, can be obtained from the JRF website (www.jrf.org.uk/publications) or by emailing publications@jrf.org.uk

A CIP catalogue record for this report is available from the British Library.

First published 2013 by the
Joseph Rowntree Foundation
ISBN: 978 1 85935 965 3 (PDF)
Project managed and typeset by
Cambridge Publishing Management Limited

Joseph Rowntree Foundation
The Homestead
40 Water End
York YO30 6WP
www.jrf.org.uk

JOSEPH
ROWNTREE
FOUNDATION

INSPIRING
SOCIAL
CHANGE