



Research on fuel poverty

The implications of meeting the fourth carbon budget

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1 Executive Summary

Introduction

The UK has introduced four successive legally binding carbon budgets for five-year periods from 2008 to 2027, set at levels recommended by the Committee on Climate Change (CCC). Whilst the first carbon budget target was met and the UK is on track to meet the second, the fourth carbon budget (2023-27) will require a more substantial move towards a low carbon economy across all sectors. The implications for fuel poverty of meeting the carbon budgets are an important policy consideration, which the CCC has a duty to consider (under Section 10 of the Climate Change Act (2008)). The CCC therefore commissioned the Centre for Sustainable Energy (CSE) to undertake research on fuel poverty in the UK, to help develop its understanding of the characteristics of households currently in or at risk of fuel poverty, and explore the implications for fuel poverty to 2030 of meeting the fourth carbon budget.

Overview of approach

This research study uses one particular modelling tool - the National Household Model (NHM). The NHM is the Department of Energy and Climate Change (DECC) new domestic energy policy modelling and analytical tool. CSE was commissioned by DECC to develop this application, which uses national housing condition survey data to create a detailed representation of the UK housing stock and its occupants. It therefore provides a 'bottom-up', household level modelling tool that enables analysts to create policy scenarios and explore the potential impacts on household energy demand (and associated fuel bills and emissions) over time.

The aim of this research was to develop the CCC's understanding of the characteristics of households currently in or at risk of fuel poverty and explore the implications for fuel poverty to 2030 of meeting the fourth carbon budget. For the latter, the CCC has its own estimations of both fuel prices changes to 2030 and measures needed in the residential sector to deliver emissions savings in line with meeting the fourth carbon budget.

For the purpose of this research, a scenario was developed in the NHM to model and estimate fuel poverty in the UK from 2013 (the baseline year) to 2030, with the CCC's fuel prices and measures projections simulated. Different approaches to how measures are allocated to houses in the simulation and how the costs of these measures are passed on to consumers through energy bills were also explored. Combining these different approaches resulted in a total of 23 different scenarios being simulated and analysed. For each scenario fuel poverty estimates are calculated using both the 10% definition and the Low Income High Cost (LIHC) definition. The latter has only been adopted in England, whilst the devolved nations continue to use the original definition. The CCC's remit covers the whole of the UK hence results have been generated to accommodate this.

Fuel poverty in the UK in 2013

10% definition

The results from modelling fuel poverty in the UK in 2013 using the NHM suggest that under the 10% definition (where required fuel expenditure exceeds 10% of household income), there were a total of 5.6 million fuel poor households in the UK. Whilst the majority (4.2 million) of these were in

England, rates of fuel poverty appear substantially higher in the devolved nations, with an estimated 44% of households in Northern Ireland being fuel poor (Summary table 1). The severity of fuel poverty experienced also appears worse in the devolved nations, with 16-17% of households in Wales and Northern Ireland needing to spend more the 16% of income on maintaining adequate warmth in the home.

Summary table 1. Fuel poverty estimates for the UK under the 10% definition (2013)

	England	Scotland	Wales	Northern Ireland	UK
Count (millions)	4.2	0.64	0.44	0.31	5.6
Percent of households	19%	27%	35%	44%	21%

Source: NHM modelling results (CSE, 2014)

Detailed analysis of the data and results from modelling fuel poverty in the UK in 2013, using the NHM, was undertaken to explore the characteristics of the fuel poor in each country. A popular classification (or segmentation) analysis technique (CHAID) was used to explore the relationship between a number of different socio-demographic and physical property characteristics and the likelihood of being fuel poor. The results identified some key groups and characteristics of the fuel poor in each country. Aside from lower income and/or high energy (required) bills, characteristics differ slightly across the UK nations, but recurring features identified in the analysis included: retired owner-occupiers in off-gas and/or rural properties; retired under-occupiers; out-of-work younger single adults with very low income in rented purpose-built flats.

LIHC definition

The ‘low income, high cost’ (LIHC) definition of fuel poverty applies thresholds to identify households with both lower than average income and higher than average fuel costs. It also includes a measure of the depth of fuel poverty, known as the ‘fuel poverty gap’. This assesses the extent to which the energy costs of a fuel poor household exceed the threshold (the national median).

Whilst the modelling applied in this study estimates fuel poverty under the LIHC definition for every country in the UK, this definition has only been adopted in England. The analysis therefore focuses more heavily on the LIHC results for England only.

The results from modelling fuel poverty in 2013 under the LIHC approach using the NHM, suggest some 2.4 million households were fuel poor under this definition in England (2.9 million households in the UK). (This is substantially *lower* – by nearly 200% - than estimated levels of fuel poverty under the 10% definition). The average fuel poverty gap as measured using the LIHC definition in England is estimated at £605 (£638 for the UK) and the aggregate gap some £1.4 billion (over £1.8 billion for the UK; Summary table 2).

Summary table 2. Fuel poverty estimates for the UK under the LIHC definition in 2013

	England	Scotland	Wales	Northern Ireland	UK
Count (millions)	2.38	0.27	0.14	0.07	2.86
Percent of households	11%	11%	11%	10%	11%
Mean fuel poverty gap	£605	£710	£949	£854	£638
Aggregate fuel poverty gap (£m)	£1,439	£189	£135	£61	£1,825

Source: NHM modelling results (CSE, 2014)

Detailed analysis (using CHAID) was undertaken to explore the key defining characteristics of households estimated to be LIHC fuel poor in England in 2013. The analysis identified 9 distinct groups, with different estimated levels of severity of fuel poverty (measured by the fuel poverty gap). The group with the highest average gap (of over £1,350) comprised mainly owner-occupying older adults, in detached, older (uninsulated, solid wall) dwellings in rural areas not connected to the gas grid. Their owner-occupying status and dwelling type suggests some of these households may be considered asset-rich and/or under-occupying.

Another key and quite different group identified (with an average fuel poverty gap of £774) consisted of small, electrically-heated, urban, rented dwellings (half of which were flats (mainly purpose-built) and over half with uninsulated solid walls).

Other key groups of LIHC fuel poor identified in the analysis included:

- *Urban families in larger, uninsulated houses*
- *Retired couples in newer 3-bed detached houses in urban and fringe areas*
- *Older private-sector dwellings without wall insulation, under-occupied by single retired*
- *Under-occupying single adults in 3-bed post-war semi's with insulated cavity walls*
- *Out-of-work lone parents in rented, older houses without insulated walls*

Overall, the distribution of types of households that are fuel poor under the LIHC definition varies in contrast to the 10% definition. Under the 10% definition households containing pensioners make up the largest single group of fuel poor, representing almost half of all fuel poor households. For the LIHC definition, the proportion of pensioners' households is considerably less but households of single adults under 60 and those containing children represent a much larger percentage of the total fuel poor.

Implications of results: understanding who are the fuel poor?

The results from the modelling and analysis of fuel poverty in the UK in 2013 provide some further understanding of the characteristics of households most likely to be fuel poor. These are important considerations in designing and targeting a fuel poverty alleviation programme, in terms of both whom to target and interventions and measures needed.

Modelling fuel poverty to 2030 and the impact of the fourth carbon budget

A range of scenarios were developed in the NHM to simulate and assess the impact on fuel poverty (under both the 10% and LIHC definitions) to 2030 of fuel price rises and improvement measures as projected by the CCC to meet the fourth carbon budget, without and with the costs of measures being passed on to household energy bills.

One set of scenarios explored the implications of simulating fuel price rises to 2030, with the CCC fourth carbon budget measures targeted specifically at the LIHC fuel poor. In this scenario, the model identifies the LIHC fuel poor in every year of the simulation, and priorities allocating measures (from the CCC's trajectory) to these dwellings. The model selects the measure that will minimise

their fuel bills as far as possible. Any remaining measures in each year of the simulation (after the LIHC fuel poor have been targeted) are allocated to non-fuel poor households.

The results from this targeted scenario can be compared to others to show the potential for the CCC's fourth carbon budget measures to address fuel poverty. For example, the results can be compared to the scenarios in which: no measures are simulated at all but fuel price projections applied (the 'counterfactual' scenario); fuel price projections and measures are simulated, with measures being allocated on a purely random basis (so some fuel poor households will receive measures but this is on an ad-hoc, non-targeted basis); fuel price projections and measures are simulated but the fuel poor are excluded from receiving any measures.

The results, summarised in the table below, suggest that the benefits from measures (reduced energy demand and therefore lower (required) fuel bills) could go some way to offsetting the impact of expected fuel price rises to 2030, but this outcome is highly dependent on how both the measures and costs of measures are distributed across the housing stock. Although entirely theoretical, the results from the modelling therefore highlight the importance of:

- (1) *Ensuring effective targeting of measures at fuel poor households to ensure they benefit and are protected from the impact of fuel price rises.*
 - The scenario results clearly show that if improvement measures are ineffectively targeted at fuel poor homes (represented to some extent by the 'random allocation scenario') or in the absence of any policies to ensure the fuel poor receive measures (as represented by the 'fuel poor get nothing' scenarios) fuel poverty levels escalate, both in the total number of (LIHC) fuel poor homes and the depth of fuel poverty experienced by those households.
- (2) *Designing domestic energy policy such that any cost pass-through to energy bills is done in such a way as to ensure low-income and vulnerable households are not unduly burdened.*
 - The scenarios simulating the cost-recovery of measures deployed on gas and electricity bills of all households highlight the potential for these costs to outweigh any benefits to fuel poor homes. Removing some of the more substantial costs (more expensive measures) goes some way to reducing this impact (as shown by the difference between no costs on bills, full and partial costs). This suggests the costs of a fuel poverty alleviation programme or at least the more expensive measures should not be paid for through energy bills.

Summary table 3. Impact of fuel prices and CCC measures on fuel poverty to 2030: LIHC definition, UK (*figures for England only shown in italics*)

	Count	%	Mean fuel poverty gap	Aggregate fuel poverty gap
2013 baseline	2.86 <i>(2.38)</i>	10.9% <i>(10.8%)</i>	£639 <i>(£605)</i>	£1.82 <i>(£1.44)</i>
2030 'counterfactual': policy costs, no measures^a	3.10 <i>(2.55)</i>	11.9% <i>(11.6%)</i>	£873 <i>(£814)</i>	£2.71 <i>(£2.07)</i>
(Sc.3a) CCC measures simulated at random, no cost recovery^b	3.04 <i>(2.53)</i>	11.5% <i>(11.5%)</i>	£713 <i>(£672)</i>	£2.17 <i>(£1.70)</i>
(Sc.4a) CCC measures, target 'LIHC fuel poor' with no cost recovery^c	1.19 <i>(1.01)</i>	4.5% <i>(4.6%)</i>	£330 <i>(£318)</i>	£0.39 <i>(£0.32)</i>
(Sc.4b) CCC measures, target 'LIHC fuel poor' with full cost recovery^d	1.27 <i>(1.29)</i>	4.8% <i>(5.9%)</i>	£371 <i>(£359)</i>	£0.47 <i>(£0.39)</i>
(Sc.4c) CCC measures, target 'LIHC fuel poor' with partial cost recovery^d	1.19 <i>(1.01)</i>	4.5% <i>(4.6%)</i>	£335 <i>(£337)</i>	£0.42 <i>(£0.34)</i>
(Sc.7a) CCC measures, 'LIHC fuel poor' get nothing, no cost recovery^e	3.66 <i>(3.04)</i>	14.0% <i>(13.8%)</i>	£1,014 <i>(£956)</i>	£3.71 <i>(£2.91)</i>
(Sc.7b) CCC measures, 'LIHC fuel poor' get nothing, full cost recovery^f	3.76 <i>(3.12)</i>	14.4% <i>(14.2%)</i>	£1,178 <i>(£1,120)</i>	£4.43 <i>(£3.50)</i>

Table notes: Results from modelling fuel poverty to 2030 using the NHM (CSE, 2014).

- a) The counterfactual scenario represents one in which no changes are simulated to the housing stock (i.e. no measures are deployed), but fuel prices projected to 2030 include expected price rises resulting from wholesale and systems costs and upstream policies (e.g. Carbon Price Floor, EU ETS, Renewables Obligation).
- b) This scenario simulates the deployment of measures as projected by the CCC to 2030 to meet the fourth carbon budget at random across the UK housing stock. The random allocation means some fuel poor households will be receiving measures on an 'ad hoc' basis. Fuel price projections are as per (a), as no costs of measures deployed are passed on to energy bills.
- c) This scenario simulates the deployment of measures as projected by the CCC to 2030 to meet the fourth carbon budget, with measures targeted first at fuel poor households (according to the LIHC definition) to minimise their fuel bills, in every year of the simulation. Any remaining measures after targeting the LIHC fuel poor are allocated at random to the remainder of the housing stock. Fuel price projections are as per (a), as no costs of measures deployed are passed on to energy bills.
- d) These scenarios simulates the deployment of measures as per (c) with fuel price projections are as per (a), but with an additional charge on electricity and gas bills to recover either the full cost of measures deployed in each year of the simulation on a p/kWh basis, or 'partial' costs of measures (in which the costs of boilers, solid wall insulation and PV are excluded).
- e) This scenario eliminates the LIHC fuel poor from receiving any of the measures deployed in the simulation.
- f) As (e) but with the full costs of measures deployed passed on to all household gas and electricity bills on a p/kWh basis.

Measures allocation and who remains fuel poor?

The scenarios modelled in this study show the potential for measures defined in the CCC's projections for meeting the fourth carbon budget to address fuel poverty through 'perfect targeting' at households classed as fuel poor according to the official definition(s); and, conversely, the implications if no policies or programmes are in place to ensure fuel poor households receive their share of measures (the 'fuel poor get nothing' scenarios).

Further analysis of the outputs from one simulation targeting the LIHC fuel poor (with partial costs of measures passed on to bills - scenario 4c in Summary table 4) was undertaken to explore: (1) the types and proportion of different measures being allocated to the fuel poor; and (2) the characteristics of households remaining in fuel poverty in 2030. The results are useful in showing the extent to which these measures can address the problem and where further measures and/or interventions are needed.

Summary table 4 shows the proportion of households who are fuel poor in the baseline year (2013) and receive measures over the lifetime of the scenario¹. The results suggest that over one third of the 2013 LIHC fuel poor households benefit from cavity wall insulation; 16% from solid wall insulation and 60% from loft insulation.

Summary table 4. Proportion of baseline year (2013) LIHC fuel poor households receiving measures over the lifetime of the scenario (to 2030)

	% of baseline LIHC fuel poor receiving measures over scenario lifetime				
	UK	England	Wales	Scotland	Northern Ireland
CWI (both)	34%	33%	38%	43%	28%
SWI	16%	17%	26%	5%	17%
Loft Insulation	60%	60%	55%	58%	75%
Floor insulation	62%	63%	61%	61%	51%
Heat pump	27%	25%	30%	36%	45%
Gas boiler	64%	68%	58%	49%	3%
Oil boiler	25%	23%	31%	34%	51%
Total LIHC fuel poor households in 2013 (m)	2.86	2.38	0.14	0.27	0.07

Source: NHM modelling results with CCC fuel price and measures projections (CSE, 2014)

As a result of simulating the CCC's fuel price projections and fourth carbon budget measures to 2030, with measures targeted at the LIHC fuel poor in every year of the scenario:

- Some 2.1 million (74%) of the starting (2013) 2.86 million UK LIHC fuel poor are estimated to be lifted out of fuel poverty by 2030 (annotation "B" Summary table 5).
- Around one quarter (26%) of the 2013 LIHC fuel poor are estimated to still be in fuel poverty in 2030 (annotation "A" in Summary table 5).
- Some 439,000 households move from being non-fuel poor in 2013 to in fuel poverty (LIHC definition) in 2030 (annotation "C" in Summary table 5).

The shifting thresholds that are used in the new LIHC definition are a key factor in the movement of households in and out of fuel poverty over time. Looking at the 'newly fuel poor' (households who were not LIHC fuel poor in 2013 but are in 2030) shows just under one third of these dwellings (29%) do not have wall insulation in 2030, suggesting these households are missing out on receiving measures in the simulation.

These findings about the allocation of measures should be considered within the context of the scenario modelled here. Whilst the LIHC fuel poor are targeted with measures to reduce their fuel bills, the measures available in each year of the simulation are limited to those contained in CCC's trajectory to 2030. The modelling does not therefore represent a scenario of '*what measures are*

¹ This scenario recalculates and identifies the (LIHC) fuel poor in every year of the simulation and targets these dwellings with measures. To do this, the median fuel cost threshold is recalculated every year, which takes account of changes in fuel prices and physical property characteristics of the housing stock (i.e. as a result of simulating the deployment of the CCC's measures) but assumes no change to the occupancy characteristics of the dwelling. As a result of this households defined as LIHC fuel poor is subject to change in every year of the scenario as the threshold shifts with simulated fuel prices changes and improvements to dwellings.

needed to alleviate fuel poverty'. Rather it allocates the measures in the CCC's projections as best it can to address the problem².

Summary table 5. Count and proportion of LIHC fuel poor households in the baseline year (2013) and scenario end³ (2030) (UK)

2013:	2030:			
	Non-fuel poor	Fuel poor	Total	
Non-fuel poor (row %)	23,024,280 (98%)	439,160 (2%)	23,463,440	(C) Non-fuel poor in 2013; become fuel poor by 2030.
Fuel poor (row %)	2,114,160 (74%)	744,840 (26%)	2,859,000	
Total	25,138,440 (95.5%)	1,184,000 (4.5%)	26,322,440	Estimated total fuel poor in 2013

(B) Lifted out of fuel poverty.

Estimated total fuel poor in 2030.

(A) Fuel poor in 2013 & remaining fuel poor in 2030.

Policy implications: targeting the fuel poor

The results from the range of scenarios modelled in this study demonstrate the potential for policy to address both emissions and fuel poverty, if designed with a delivery model that places sufficient impetus on the needs of fuel poor households. Targeting the fuel poor by definition is in practice likely to present questions and challenges around feasibility and cost-effectiveness. For example, the current paradigm of energy efficiency policy (specifically the ECO) that obligates suppliers to deliver measures typically result in 'least cost' approaches to delivery with focus on those areas where there are more opportunities for cost-effective measures (i.e. not solid walled properties) and where it is easier to deliver (i.e. not in rural areas).

Analysis undertaken for this study explored the key defining characteristics of fuel poor households in the UK (under both definitions). These results can be used to guide which household types should be prioritised in a fuel poverty alleviation programme. For example, older, private sector housing – and the private rented sector in particular – appears a key feature of the LIHC fuel poor. The latter adds impetus to the need to enforce (and enhance) regulations in the private rented sector. Additional characteristics identified amongst fuel poor households included: off-gas, rural, older properties; working-age families in larger, older, solid wall properties in urban areas (on gas); electrically-heated flats. In addition, the nature of the fuel poverty definition is such that low income households are more likely to be fuel poor. Identifying low-income/ vulnerable households is notoriously difficult and costly. Targeting based on the Index of Multiple Deprivation Income Domain offers one approach to identifying areas with a high proportion of households in receipt of benefits (therefore likely to be some of the poorest and most deprived areas). Due to the nature of the indicator this would be best combined with an area-based, local approach to scheme delivery. Cross-departmental working and better data sharing are two further approaches that could help identify low-income households and reduce the costs associated with finding target groups.

² This modelling doesn't include the churn in fuel poverty over time. In practice, there is likely to be significant changes in the occupancy characteristics of specific dwellings over a period of 15 years. However, the key point from the summary table is that a significant proportion of the fuel poor could gain from measures still remains.

³ Results from one scenario simulated in the NHM to model the CCC's fuel price projections and fourth carbon budget measures to 2030, in which the LIHC fuel poor are targeted with measures to minimise their fuel bills in every year of the simulation.

The physical nature of fuel poor households (e.g. solid walls and off-gas) highlights the need for schemes to move beyond the installation of lower cost measures (often as a single measure) and instead deliver packages of measures that will sufficiently raise the energy efficiency (SAP/ EPC) rating of the dwelling. A minimum standard for energy efficiency provides a more robust buffer protecting low-income households from the impacts of future fuel prices. The results from modelling the potential for the CCC's fourth carbon budget measures to off-set the impacts of fuel price projections to 2030 show that even with 'perfect targeting' some households remain fuel poor. This highlights the need for other schemes related to income maximisation to be implemented in parallel with a minimum energy efficiency target, such as benefits checks.

Policy implications: funding energy efficiency measures

Whilst not the focus of this research, the modelling undertaken as part of this study has briefly explored the implications of different approaches to funding energy efficiency and low carbon measures. Under any scenario where the costs of measures are recovered through domestic energy bills, fuel poverty appears worse. Any new policy that involves an element of cost pass-through to energy bills should first consider the social distributional implications ('who benefits, who pays?') and implement a 'safeguard' to ensure at risk groups are sufficiently protected from any policy impacts on bills. The types of households to which this may apply will depend on the policy design (both targeting method and cost recovery). Key groups of consumers identified as being particularly vulnerable to the impact of policy costs on bills under the current set of Government energy and climate change policies include: households with electric heating; people living in rural areas; people who are high energy users due to specific needs (e.g. long term ill/disabled).

Conclusions: the fourth carbon budget and fuel poverty

The results from the range of scenarios modelled in this study suggest that the combined impact of expected fuel price rises and measures needed to 2030 to meet the fourth carbon budget based on the CCCs projections need not adversely impact on fuel poverty levels. Rather, targeting measures specifically at fuel poor households could offset the impact of expected fuel price rises on fuel poverty levels to 2030. Whilst the results suggest this has few implications for the level of emissions reductions achieved, this is based on modelling estimates of the impact of measures; the reality of savings actually delivered as a result of measures is dependent on a range of factors (e.g. how occupants use energy in the home; how they respond to a measure; the performance of the technology and so on). Ensuring carbon emissions are delivered on the scale required in practice points to the need for an absolute, obligated reduction target.

Furthermore, ensuring policies designed to address both emissions and fuel poverty are complementary rather than conflicting necessitates specific delivery models that place sufficient impetus on the needs of fuel poor households. Effective delivery is dependent on (a) finding the fuel poor and ensuring measures are taken up by these households; (b) how policies and measures are paid for; (c) whether the benefits of measures actually translate into fuel bill savings or benefits are taken as warmth. The latter point is a fundamental caveat to the (theoretical) results from modelling the impacts of measures on fuel poverty: regardless of whether a household has been lifted out of fuel poverty by definition, in practice an improvement to the thermal efficiency of the dwelling will not necessarily result in the household spending less on fuel. This is where consideration of the wider benefits of insulating homes is pertinent. As illustrated by the case studies presented at the

end of this report, improvement measures that do not translate into actual bills savings for the householder can still be considered a success story if that householder is subsequently living in a warmer home, that has multiple benefits for health, mental and social well-being. The fact that these wider benefits cannot be (accurately, reliably or unambiguously) quantified in financial terms should not mean these benefits are ignored.

2 Introduction

The UK has introduced four successive legally binding carbon budgets for four five-year periods from 2008 to 2027, set at levels recommended by the Committee on Climate Change (CCC). We are currently in the second carbon budget period (2013-17). The first carbon budget target was met and the UK is on track to meet the second (although largely as a result of lower carbon emissions resulting from the economic downturn). Meeting the fourth carbon budget (2023-27) will require emissions to be reduced by 50% on 1990 levels in 2025 – requiring a more substantial move towards a low carbon economy across all sectors.

Low carbon policies required to deliver these emissions reductions have implications for fuel poverty. Some low-carbon policies may lead to increases in energy prices, particularly electricity prices. Policies which improve the energy efficiency standards of the housing stock or encourage local heat and/or electricity generation can reduce consumers' energy bills as well as making homes warmer and healthier to live in. However, the overall impact is more complex than this and depends on how the benefits of policies are distributed across households and how the costs of these policies are recovered from consumers.

The impact of carbon budgets on fuel prices and fuel poverty is therefore an important policy consideration, which the CCC has a duty to consider (under Section 10 of the Climate Change Act (2008)). The CCC has commissioned the Centre for Sustainable Energy (CSE) to undertake research on fuel poverty in the UK within the context of meeting the fourth carbon budget and measures needed in the residential sector to meet the budget.

2.1 Background

The CCC analysis published in late 2013⁴ suggested that whilst the fourth carbon budget will have little overall impact on fuel poverty levels, certain groups may be disproportionately affected. CSE's previous analysis and modelling of fuel poverty and the impacts of Government energy and climate policies is consistent with these findings⁵. Key at-risk groups include those in electrically-heated properties (who stand to bear a disproportionate share of policy costs passed on through electricity bills) and those living in properties with low energy standards, typically those with solid walls. Addressing these properties through measures like solid wall insulation, potentially alongside renewable heat technologies, may therefore be central to protecting these householders who are particularly vulnerable to fuel poverty.

Previous modelling and analysis by the CCC (amongst other research⁶) has shown solid wall insulation to be both effective in offering significant potential carbon savings, and cost-effective to install with associated fuel poverty mitigation benefits. Based on this understanding, the CCC's advice on the first four carbon budgets assumed high take up of solid wall insulation (some 2.3 million installations by 2022, rising to 3.5 million by 2030).

⁴ CCC, (2013). Fourth Carbon Budget Review.

⁵ Preston, I., White, V. & Croft, D. (2013) '*The hardest hit*': Going beyond the mean, Consumer Futures and the Fuel Poverty Advisory Group; Baker, W., Preston, I., White, V. (2008). Quantifying Rural Fuel Poverty, CSE report to eaga Charitable Trust.

⁶ Preston, I., Moore, R., Guertler, P. (2008). *How much?* – The cost of alleviating fuel poverty in England. Report to eaga Charitable Trust

The estimated costs for solid wall insulation, as well as its carbon saving potential have since been revised upwards and downwards respectively. As a result, the CCC's analysis suggests that from a carbon perspective, solid wall insulation is no longer as cost-effective as was initially thought. However, the CCC also recognised that solid wall insulation may have an important role in fuel poverty alleviation. Uptake scenarios for solid wall insulation therefore need to be reviewed in light of this new evidence, as well as recent changes to the Energy Company Obligation, which now requires a reduced "*minimum level of SWI (the carbon equivalent of 100,000 measures (4.0MtCO₂)) to be delivered by the end of March 2017 across all companies and both carbon elements of ECO, namely CSCO and CERO*"⁷.

2.2 Research aims and objectives

The aim of this research is to develop the CCC's understanding of the characteristics of households in or at risk of fuel poverty and assess the impacts on fuel poverty to 2030 of measures needed in the residential sector to meet the fourth carbon budget.

Five principle research objectives (tasks) were identified to deliver this aims:

Task 1. Baseline fuel poverty assessment: Model fuel poverty in the UK in 2013, under both the new 'low income, high cost' measure and the original 10% definition; and analyse housing stock data to explore the nature and severity of fuel poverty experienced by different household types.

Task 2. Modelling "counterfactual"⁸ fuel price projections to 2030: Model fuel prices to 2030, consistent with the CCC's existing pricing assumptions and by different tariff types to explore the implications for fuel poverty levels under a 'no policy intervention' scenario.

Task 3. Carbon budget modelling: Model and analyse the impact on fuel poverty in the UK of meeting the fourth carbon budget, applying the CCC's assumptions about measures needed in the residential sector to deliver the necessary emissions reductions to 2030. Modelling will take account of recent changes in uptake in of solid wall insulation and explore options of cost-pass through (funding of measures through taxation or with costs on customer bills) and targeting of measures at fuel poor households. Outputs will be analysed to explore the potential impacts on fuel poverty levels to 2030 of delivering measures at this scale in the domestic sector.

Task 4. Meeting the fourth carbon budget with fuel poverty alleviation: Building on the findings from tasks 1 – 3, CSE will consider the options for meeting the 4th carbon budget in parallel with addressing fuel poverty. This will include discussion of requirements for targeting measures and

⁷ DECC, (2014). The future of the Energy Company Obligation. Government response to the 5 March 2014 consultation. (14D/270 22). Published July 2014. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/342178/The_Future_of_the_Energy_Company_Obligation_Government_Response.pdf

⁸ "Counterfactual" is the term used by DECC in modelling fuel prices under a 'no policy intervention' scenario, whereby all policy costs and benefits are removed.

of the 'wider benefits' (e.g. to physical and mental health) associated with improving the thermal efficiency of homes of the fuel poor.

Task 5. Case study examples of solid wall insulation in fuel poor households: Provide 'real life' examples of 'fuel poor' households who have had solid wall insulation installed to illustrate the potential benefits of this measure in alleviating the realities of living in a cold home and facing unaffordable energy bills.

2.3 Report structure

This report is structured as follows:

Chapter 5 (task 1) presents the results of detailed modelling and analysis of the characteristics of fuel poor households under both definitions in each devolved nation in 2013.

Chapter 6 presents the results from modelling fuel poverty to 2030, including the 'no policy scenario' (task 2) and simulating installation of measures in the residential sector as projected by the CCC to meet the fourth carbon budget (task 3). This includes a number of different scenarios to explore the implications for both emissions reduction and fuel poverty to 2030 of different approaches to targeting and paying for measures.

Chapter 7 provides some discussion around the health implications of alleviating fuel poverty, drawing specifically on the (limited) available evidence around (a) the health benefits associated with improving housing energy performance and (b) the potential cost savings to the health sector from reduced demand for services resulting from improved, healthier internal living temperatures. This chapter includes the results of some additional modelling to simulate 'comfort-taking' (making fuel poor households warmer).

Chapter 8 brings all the modelling and analysis together, to present some discussion and conclusions around the nature of a programme to ensure measures are installed across the UK housing stock to deliver both the necessary emissions savings to meet the fourth carbon budget, whilst also addressing fuel poverty (task 4).

Chapter 9 presents the case studies of fuel poor households who have benefited from solid wall insulation (task 5).

First however a brief introduction and overview of the modelling tool used in this study (the National Household Model) is provided in Chapter 3 followed by an overview of the methodology, inputs and assumptions used in each stage of the modelling (Chapter 4).

3 The National Household Model

3.1 Introduction

The National Household Model (NHM) is the Department of Energy and Climate Change (DECC) new domestic energy policy modelling and analytical tool.

The NHM uses national housing condition survey data to create a detailed representation of the housing stock of Great Britain and its occupants. It combines this with a domain-specific and highly flexible modelling language that enables analysts to create policy scenarios and explore the potential impacts on domestic energy demand (and associated bills and emissions) over time. A key component of the NHM is the 'energy calculator' which calculates energy use by fuel and energy service at household level, based on the BREDEM-8 (2001) and SAP 2009 algorithms. See Box 3.1 for more information about the NHM. The next chapter provides more detail on the methodology and how the model was applied in this study, including some key limitations.

3.2 Developing the NHM for application in this research

As part of this study, the NHM was further developed with the agreement and oversight of DECC, adding new modelling and reporting needed to simulate and analyse the impact of the carbon budget on fuel poverty.

Developments implemented as part of this research included:

- extending the housing stock data underpinning the model to include Northern Ireland (for UK-wide representation) ;
- redeveloping and improving the Scotland housing stock representation;
- adding to the suite of existing housing and socio-demographic information accessible within the NHM for the purpose of reporting and targeting measures;
- ability to define tariffs by different methods of payment;
- new functionality to calculate the metrics needed to assess whether a household is, or is close to being, defined as fuel poor (using the 10% definition for the UK and the additional new definition for England);
- new language elements to simulate measures listed in the CCC's domestic sector projections to 2030;
- tools to simulate cost recovery (different approaches to model how costs of measures may be passed on to consumers – e.g. via energy bills or from general taxation).

Box 3.1. The National Household Model

DECC commissioned CSE to develop a domestic energy policy modelling and analytical tool to cover the whole of Great Britain. The resulting National Household Model (NHM) has been developed to replace several separate models previously used by DECC with a single application.

Representing the GB housing stock

Using information from national housing surveys (the English Housing Survey 2010-11 and Scottish House Condition Survey 2007-09⁹), the NHM creates a detailed representation of the physical property and occupancy characteristics of Great Britain's housing stock. The NHM allows analysts to simulate changes to the housing stock over time (e.g. simulating the installation of energy efficiency measures), to explore different policy scenarios and the potential impacts on domestic energy demand, household bills and emissions.

Modelling household energy demand

A key component of the NHM is the 'energy calculator'. This provides all the code and algorithms needed to estimate household energy demand, using a SAP-based approach. Taking information about the physical property characteristics from the housing stock dataset at a point in time (e.g. building fabric, insulation levels, heating systems) the energy calculator estimates fuel consumption needed to maintain a specified heating regime. The model is calibrated to apply the Government's standard assumptions for heating regimes (21 degrees in living areas, 18 degrees elsewhere), but these can be adjusted by the user as required.

Fuel prices are applied to the estimated energy demand to generate an annual fuel bill for the household. This forms the basis for calculating the SAP rating – an estimate of the energy efficiency of the building, based on the building's performance on energy costs per m².

Scenarios and reporting

All modelling and analysis in the NHM is constructed through 'scenarios', written by the user, through a browser-based user interface. Scenarios are expressed using a domain-specific language (structured as s-expressions¹⁰) that affords a very high degree of flexibility. The housing stock data underpinning the NHM encompasses a wide range of variables, including physical (e.g. dwelling type, age of property), geographical (e.g. region, rurality) and socio-demographics (e.g. tenure, income, number of occupants), all of which can be used within a scenario for policy modelling and/or reporting purposes. In addition there are a number of language elements designed specifically to meet the needs of DECC analysts; for example to enable modelling of the Green Deal Golden Rule and simulation of different energy efficiency and low-carbon measures.

A single scenario can therefore encompass a huge range of functions - from modelling the impact of very complex, multi-layered policies that simulate the installation of measures and fuel tariffs overtime, to a simple report to show characteristics of the housing stock, such as energy demand or SAP rating by different property types.

⁹ The Welsh housing stock model was created from the English Housing Survey 2010-11 using a reweighting process, guided by information available from the Living in Wales Survey 2008.

¹⁰ <http://en.wikipedia.org/wiki/S-expression>

4 Methodology

4.1 Fuel poverty definitions in the UK

The concept of ‘affordable warmth’ was placed firmly on the political agenda under the Warm Homes and Energy Conservation Act 2000 and the UK’s first Fuel Poverty Strategy (2001) formally adopted a measure of fuel poverty, whereby a household is defined as ‘fuel poor’ if it needs to spend more than 10% of its income on fuel to maintain a satisfactory heating regime (see Box 4.2 for details on how heating regime is defined and fuel costs are calculated in this context).

In 2011, the Government commissioned a detailed, independent review of the definition of fuel poverty for England, to ascertain whether the existing ‘10%’ definition remained fit for purpose, some 11 years after it was first adopted. The review (undertaken by Professor John Hills of London School of Economics, and hence often referred to as the ‘Hills Fuel Poverty Review’) highlighted a number of flaws with the original approach to measuring fuel poverty including its sensitivity to fuel price fluctuations and the potential for higher-income households living in energy inefficient homes to be (misleadingly) classed as ‘fuel poor’.

Hills (2013) therefore proposed a new approach to measuring fuel poverty, encompassing a ‘low-income, high cost’ (LIHC) measure. Under this indicator, thresholds are applied to income and fuel costs such that a household is defined as fuel poor if its income is below the poverty line (taking into account energy costs) and its energy costs are higher than is typical for their household type.

In addition the new definition includes a measure of the ‘**fuel poverty gap**’, to provide a measure of the severity of fuel poverty. The ‘gap’ assesses the extent to which a household falls above the energy cost threshold or, rather, the reduction in fuel bill required to lift the household out of fuel poverty. Box 4.1 provides a more detailed description of the LIHC approach to defining fuel poverty.

This definition is now used to determine levels of fuel poverty in England, whereas the devolved nations continue to use the 10% definition. This complicates the UK-wide assessment of fuel poverty. For the purposes of this study, we have applied both the 10% and the LIHC definition to the whole of the UK. For the LIHC definition, this is purely illustrative in recognition that this definition is not used in Scotland, Wales and Northern Ireland.

Box 4.1. Low-income, high cost definition of fuel poverty

The new 'low income, high cost' (LIHC) definition of fuel poverty encompasses a measure of both household income and fuel costs as follows:

- A **household's fuel costs** are based on the required spend on fuel and are adjusted for household size (using an equivalisation factor based on the number of people in the household). Equivalising fuel costs in this way effectively increases the bills of single person households and decreases the bills of multiple person households, with the intention of making them comparable.
- **Household income** is calculated on an 'after housing costs' (AHC) basis (deducting mortgage, payments, rent) and is equivalised to account for the composition of the household (number of adults and children). Equivalising income in this way effectively increases the incomes of single person households and reduces incomes for larger households, again with the intention of making them comparable.

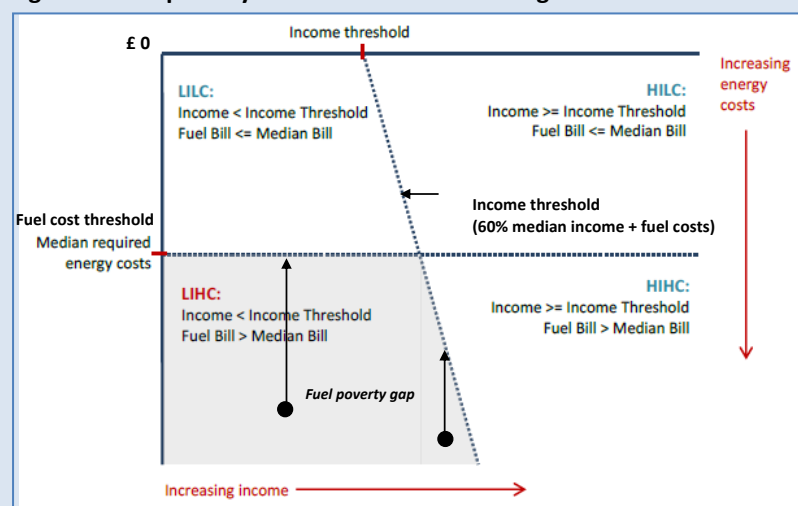
A threshold to define 'reasonable' fuel costs and 'low income' is then applied as follows:

- **Fuel cost threshold:** The national median of all households equivalised required fuel costs.
- **Income threshold:** 60% of the national median of AHC, equivalised incomes *plus* the equivalised required fuel costs for an individual household. Adding fuel costs to income has the effect of raising the income threshold for households with high fuel costs (or rather, households with higher fuel requirements also require a larger income to avoid being classed as 'low income' under this definition). This is why the income threshold on the figure below appears as a diagonal line).

Combining an income and fuel cost threshold gives four possible 'quadrants' for classifying the population as shown in Figure A: 'low-income, low energy costs' (top left); 'high-income, low energy costs' (top right); 'high-income, high energy costs' (bottom right); and 'low-income, high energy costs' (bottom left). It is this latter group who are considered 'fuel poor' under this definition.

In addition, the LIHC definition includes a measure of the depth of fuel poverty, known as the 'fuel poverty gap'. It assesses the extent to which the energy costs of a fuel poor household exceed the threshold for reasonable costs (i.e. the median).

Figure A. Fuel poverty under the Low Income High Costs Measures¹¹



¹¹ Adapted from: DECC, (2013) Fuel Poverty Report – Updated August 2013. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226985/fuel_poverty_report_2013.pdf

Box 4.2. Modelling household fuel costs and fuel poverty

For the purposes of determining fuel poverty, fuel costs are calculated based on a households 'required' expenditure on fuel to maintain a specified heating regime, rather than actual household energy consumption and fuel expenditure. These modelled fuel costs are calculated using a method developed by the Building Research Establishment (BRE) known as BREDEM ('Building Research Establishment Domestic Energy Model'). Household energy consumption for space heating, water heating, cooking and lights and appliances is calculated based on information about the physical characteristics of the property (e.g. the dwellings' heating system, characteristics and fabric) in combination with some assumptions about how dwellings are heated and occupied, as described below.

For the purpose of calculating the impact of measures on fuel poverty, the same physics-based model is used to estimate the new household energy demand. The fuel poverty assessment is a theoretical measure of household energy consumption and does not allow for households potentially under-heating and/or taking the benefit of improvement measures as warmth.

Heating regimes

For the purpose of modelling fuel poverty as part of this research a standard, consistent approach has been applied for assumed heating regime across all nations¹². This uses the standard heating regime as defined under SAP, 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 9 hours during weekdays and for 16 hours at the weekend. Adjustments are made however, for households that are more likely to be at home during weekdays (those containing very young children or the vulnerable or elderly). The heating regime for these households is set to 16 hours for all days of the week¹³.

Under-occupancy

With the exception of Scotland¹⁴, national fuel poverty calculations make adjustments to the assumed heating regime in dwellings identified as being 'under-occupied'. In this study, under-occupied dwellings are identified using housing survey data to determine whether there are both '*surplus bedrooms*' and '*surplus floor area*'. The former depends on the composition of the household¹⁵ and the latter is defined by the floor area of the property being over double that considered to be the "standard" living area required for the number of occupants¹⁶. If a dwelling is identified as being under-occupied according to these definitions then it is assumed that only half of the dwelling is heated (i.e. the estimated energy demand under standard assumptions is halved in these dwellings).

Annex I provides a more detailed discussion of the key differences in approach to calculating fuel poverty used in this study and by each nation.

¹² Scotland employs a different approach, which assumes an increased heating regime for pensioners.

¹³ This is closer, but not identical to the approach used in Scotland, which assumes a constant heating regime for pensioners of 23°C.

¹⁴ In Scotland, no adjustments are made for household size; instead all rooms are assumed to be heated, regardless of occupancy levels.

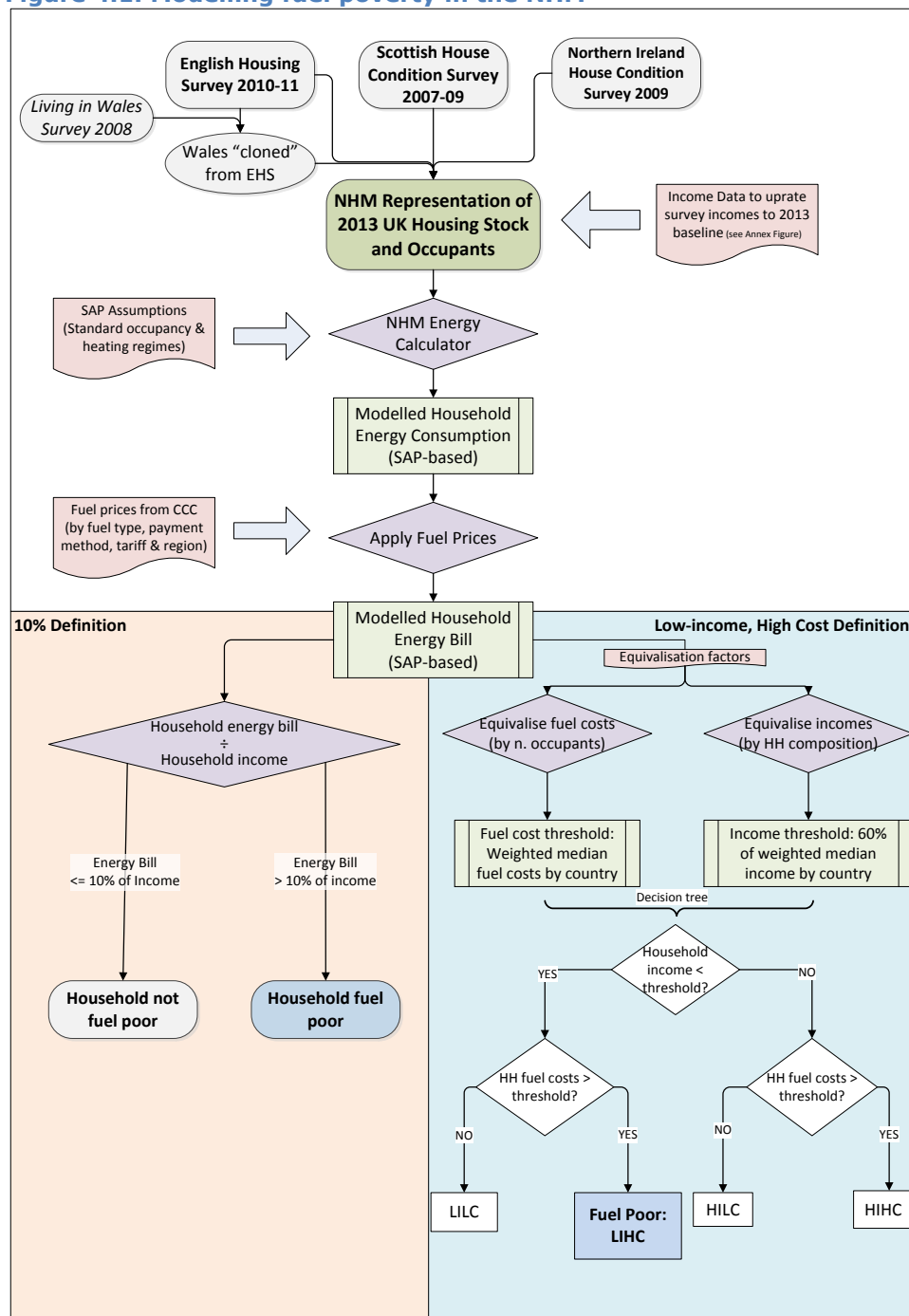
¹⁵ A dwelling is considered to have surplus bedrooms if: there are one or more extra bedrooms than *required* for homes without dependent children (children under 18 years) or there are two or more extra bedrooms than *required* for homes with dependent children.

¹⁶ This is defined by the Parker-Morris Standard, which specifies a standard living area (in m²) by number of occupants in the dwelling. See Table 3, page 37 of the '*Fuel Poverty Statistics Methodology and User Manual*' (URN 13D/215), DECC 2013. <https://www.gov.uk/government/publications/fuel-poverty-methodology-handbook-2013>

4.2 Modelling fuel poverty using the NHM

This study uses the National Household Model to estimate fuel poverty in the UK (historically in 2013, and going forward, under different scenarios to 2030) for both the LIHC definition and original 10% definition. For the former, the low-income, high cost thresholds are calculated on a national basis (i.e. by country). The key stages in modelling fuel poverty using the NHM are illustrated below. The key differences in the approaches used in generating the latest estimates of fuel poverty by DECC (for England), each of the Devolved Administrations and CSE (using the NHM for this study) are discussed in Annex I.

Figure 4.1. Modelling fuel poverty in the NHM



4.3 Modelling the fourth carbon budget and fuel poverty to 2030

In addition to modelling fuel poverty in 2013, this research explores the implications of the fourth carbon budget for fuel poverty to 2030.

This aspect of the modelling uses the CCC's projected time series of fuel prices and measures needed in the residential sector to deliver the necessary emissions reductions to 2030 (see Annex IV). CSE further developed the CCC's fuel price inputs to provide a more detailed breakdown by all fuel types, method of payment, tariff and region/country (see Annex II).

A number of different scenarios were modelled to explore the implications of these fuel prices and measures for fuel poverty to 2030. The scenarios apply different combinations of assumptions around how measures are distributed across the UK housing stock and how the costs of these measures are recovered, as follows:

- **Allocation of measures:** scenarios were developed to simulate:
 - random allocation of measures (all measures are deployed entirely at random across the UK housing stock);
 - 'perfect targeting' (households 'flagged' as being in fuel poverty (with scenarios for both definitions) are targeted with measures first, and an objective to minimise their fuel costs);
 - no targeting/fuel poor excluded from benefiting from any (or any major) measures (these scenarios assume that in the absence of any policy to support and enforce the installation of measures in low income/fuel poor homes, these households will not take-up any measures as they have insufficient capital means to do so).
- **Cost pass through to energy bills:** three distinct scenarios were developed to explore the implications of the costs of measures being passed on consumer energy bills:
 - no cost recovery (no costs passed on to energy bills – assumes measures funded through taxation or paid for by the householder);
 - 'full' cost recovery (where the total capital costs of all heating and insulation measures deployed are passed on through a p/kWh charge on mains gas and electricity equally);
 - 'partial' cost recovery (where the cost of all heating and insulation measures with the exception of boiler replacements, solid wall insulation and PV are passed on through a p/kWh charge on mains gas and electricity equally¹⁷).

Whilst these represent extreme (and unrealistic) scenarios the results will give an indication of the range of possible outcomes (e.g. a worst case scenario where the fuel poor/vulnerable households receive no measures but the full costs are passed on to all consumers; to perfect targeting of the fuel poor with no costs to consumers).

¹⁷ The cost of boilers were excluded on the rationale that these will be replaced by the householder, at their own expense, as part of boiler 'churn' (i.e. old boilers being replaced and new boilers installed in line with building regulations). The cost of solid wall insulation was excluded as this represents one of the more expensive measures which should arguably be supported through state funding. Solar PV also represents an expensive measure, which is covered in the FIT and is not part of the CCC's mix of measures hence was excluded from the cost calculations on this basis.

Within these scenarios there remain multiple approaches to the allocation of measures and recovering of costs that could be explored using the NHM. For the former, for example, the model can target both a subject (who/which households) and have an objective (e.g. select the measure that minimises fuel costs). For the latter, there are options to consider around both the sum of costs to be recovered (e.g. a cap could be applied to the sum passed on to bills in each year); the method of cost recovery (e.g. fuel type, p/kWh vs. p/customer basis); and whether additional costs, such as targeting and administration are included. These all have implications for resulting impacts on fuel poverty.

In addition to the combination of approaches to simulating the deployment of measures and cost recovery described above, some additional scenarios were developed to:

- Explore the implications of a reduced number of solid wall insulations (capped at 1 million by 2030);
- Simulate the potential for households to take the benefits of energy efficiency improvements as warmth (by simulating an increase in the internal temperature of fuel poor dwellings receiving measures in the NHM). Whilst fuel poverty is based entirely on a theoretical measure of required household spend on energy and therefore assumes any improvements in the energy efficiency of a dwelling equate to a reduction in energy demand and subsequently fuel poverty levels. In practice households – particularly those on a constrained income – may be under-heating the home to begin with and/or take the benefit of improvements as warmth (i.e. maintain the same heating regime but now feel warmer for the level of energy input). A scenario was therefore simulated to explore the extent to which measures may allow fuel poor households to be warmer.

4.4 “Counterfactual” scenarios

In addition to modelling the impact of measures in the CCC’s projections for the fourth carbon budget, two additional scenarios were run to first show the impact to 2030 of fuel price changes alone, in the absence of any measures being deployed¹⁸.

Electricity prices provided by the CCC for the purpose of this research comprise a number of different components¹⁹. These include ‘systems costs’ (cost of generation (excluding carbon p/kWh), losses, supplier costs & margin, balancing, transmission, distribution, metering) and ‘policy costs’ (e.g. EU ETS, RO, FIT etc), (plus VAT).

For the purpose of modelling the implications for fuel poverty of fuel price changes without policy intervention to 2030 (i.e. no changes simulated to the housing stock by way of energy efficiency/heating improvements) two fuel price scenarios were run to include:

- 1) Only ‘system costs’, to show a baseline under a ‘do nothing’ scenario; and

¹⁸ In its own modelling and analysis of the impact of policies on domestic energy bills, DECC terms this ‘no policy’ scenario the counterfactual.

¹⁹ Prices are based on the CCC’s figures and pricing assumptions used for 4th carbon budget review, revised for the purpose of this study to include updated electricity retail pricing data and updated costs for low carbon policies.

- 2) 'System' and 'policy costs' (excluding domestic energy efficiency policy costs as no improvements to the housing stock are simulated in this scenario) to show the implications of 'upstream' policy costs for fuel poverty.

The fuel price time series applied in the second of these is the same as that applied in modelling fourth carbon budget measures without cost recovery.

4.5 Summary of scenarios modelled

In total (including the baseline 2013 fuel poverty assessment (presented in detail in chapter 4); the two 'no policy intervention' (counterfactual) scenarios; the solid wall insulation sensitivity analysis; and comfort-taking scenarios) 24 scenarios have been simulated in the NHM as part of this research, as shown in Table 4.1 and Table 4.2 at the end of this section. Outputs from each scenario were generated to show the headline results in terms of impact on: fuel poverty levels (both definitions, by country, including the gap for the LHC definition); household emissions; household energy bills; measures allocated and costs.

The results represent modelled outputs from one modelling tool (the NHM), which are dependent on a number of assumptions and inputs, and should therefore be considered within these boundaries. Box 4.3 outlines some of the key limitations with the NHM in the context of this research.

It should also be noted that the NHM represents a 'bottom-up' household-level approach to modelling the impact of measures. The CCC has undertaken its own modelling and analysis to generate and quantify the measures needed in the residential sector to meet the fourth carbon budget, using a 'top-down' approach (e.g. using average values of estimated energy and emissions savings from different measures, in order to estimate the scale of deployment required to deliver savings to meet the fourth carbon budget). The resulting time series of measures provides a core input for the modelling presented in this study. The installation of these measures has been simulated across the UK housing stock to 2030 using the NHM. The NHM represents a household level modelling tool, in which impacts of measures are calculated on a house-by-house basis (using information about the physical property characteristics). This is a quite different approach to that applied by the CCC in developing measures projections. Thus whilst the *inputs* used in this study fully replicate the CCC's assessment of measures needed in the UK housing stock to meet the fourth carbon budget, the *outputs* will not be the same.

Box 4.3. Modelling limitations**Required vs. Actual household energy consumption**

The NHM has been developed on national housing survey data. These provide the information needed to assess household energy demand using a SAP-based approach, rather than an estimate of actual household energy consumption; the latter of which is typically lower. DECC therefore commissioned Cambridge Architectural Research to develop an approach to ‘calibrate’ the NHM modelled estimates of household energy demand to closer resemble actual household energy consumption. This involved matching a subset of the 2010 EHS records with actual metered consumption data. Stepwise linear regression was used to generate functions to estimate the difference between NHM derived estimates and the MPAN²⁰ measurements for around 8,000 gas and 10,000 electricity records. Post-calibrated total UK estimates were then aligned with DUKES data²¹.

Implications for this study

The focus of this study is on modelling the impact of the CCC’s projected measures to meet the fourth carbon budget on fuel poverty to 2030. Fuel poverty is measured using modelled required household energy demand rather than actual household energy consumption. The NHM energy calculation therefore provides the appropriate metric of household energy demand for this purpose. The ‘calibrated’ energy use values have been used however in providing an estimate of the carbon savings resulting from the simulation of the CCC’s measures across the UK housing stock. Whilst it is more appropriate to use the adjusted values in assessing emissions savings in order to give a more reasonable assessment of carbon reductions that may result from the installation of measures (as opposed to basing this on the SAP-based ‘required’ energy consumption value), energy savings from measures are still calculated entirely on a physics-based model. This assumes, for example, perfect installation and functioning of measures (when in practice measures are unlikely to perform as per laboratory specifications). The emissions savings reported are therefore still likely to represent an overestimate.

Housing stock occupancy ‘churn’

The modelling and analysis presented in this study assumes no change in household occupancy (e.g. moving house, children born, elderly people dying etc) nor change in employment/income status (e.g. unemployment, retirement etc) overtime. This has implications for fuel poverty estimates, which are measured on the income of the household (and, in the case of the new LIHC definition, the composition of the household).

To illustrate the implications of this with an example:

- The impact of a simulated energy efficiency improvement measure on the energy demand of a dwelling may be sufficient to lift the current occupants out of fuel poverty (for simplicity, under the old definition, this would simply be that their new required household energy bill now represents less than 10% of their income). The model assumes the occupants and income of that dwelling remain static; hence their fuel poverty status is only subject to change with rising energy costs over time (and the shifting LIHC threshold under the new definition).
- In reality however, there is likely to be a change in the occupancy and/or income status of that dwelling over time, either with the existing occupants (e.g. having a baby, a new job, retirement etc) or a change in occupancy (moving house). These changes may affect household income such that the dwelling is once again defined as being in fuel poverty, even with the improved level of energy efficiency. This would not be picked up in the modelling and analysis in this study due to the complexity and assumptions required in simulating such ‘churn’ in the housing stock.

²⁰ The MPAN is the ‘Meter Point Administration Number’ - a number assigned to an electricity or gas meter unique and specific to the meter location (a change in meter at an address will have the same MPAN).

²¹ Hughes, M., Terry, N. and Palmer, J. (2014) Calibrating the National Household Model: Adjusting model outputs. Internal report for DECC.

Table 4.1. Overview of scenarios modelled

Scenario	Description	Fuel price inputs
2013 baseline	2013 baseline with new carbon factors	2013 retail prices by region/country, fuel type and method payment
Sc.1.2030 no policy costs nor measures	2030 “counterfactual” fuel prices (no policy costs or measures; only changes in systems costs included)	CCC fuel price time series to 2030. Electricity costs include: “systems costs” only (cost of generation (excluding carbon pKWh), losses, supplier costs & margin, balancing, transmission, distribution, metering, plus VAT)
Sc.2.2030 policy costs excluding residential measures	2030 alternative counterfactual (“upstream” policy costs included; no residential policy interventions modelled - no measures deployed and no energy efficiency/low carbon heating costs included)	CCC fuel price time series to 2030. Electricity costs include: “systems costs” (cost of generation (excluding carbon pKWh), losses, supplier costs & margin, balancing, transmission, distribution, metering) and “policy costs” excluding energy efficiency (plus VAT)
Sc.3 – 8: 2030 CCC 4th CB measures	Fourth carbon budget modelling scenarios: see full breakdown below for combinations of cost-recovery and targeting of measures.	CCC fuel price time series to 2030. Electricity costs include: “systems costs” (cost of generation (excluding carbon pKWh), losses, supplier costs & margin, balancing, transmission, distribution, metering) and “policy costs” excluding energy efficiency (plus VAT).

Table 4.2. Modelling the 4th carbon budget: scenarios

No.	Modelling CCC 4 th CB: Allocation of measures				Cost recovery ^a
	Target 1	Objective 1	Target 2	Objective 2	
Sc.3a	None – fully randomised allocation	n/a	n/a	n/a	None
Sc.3b	None – fully randomised allocation	n/a	n/a	n/a	Full
Sc.3c	None – fully randomised allocation	n/a	n/a	n/a	Partial
Sc.4a ²²	Target LIHC fuel poor	Minimise fuel bills	None - remaining measures allocated at random		None
Sc.4b	Target LIHC fuel poor	Minimise fuel bills	None - remaining measures allocated at random		Full
Sc.4c ^{22,23}	Target LIHC fuel poor	Minimise fuel bills	None - remaining measures allocated at random		Partial
Sc.5a	Target 10% fuel poor	Minimise fuel bills	None - remaining measures allocated at random		None
Sc.5b	Target 10% fuel poor	Minimise fuel bills	None - remaining measures allocated at random		Full
Sc.5c	Target 10% fuel poor	Minimise fuel bills	None - remaining measures allocated at random		Partial
Sc.6a	Target LIHC fuel poor	Minimise fuel bills	All remaining households	Minimise emissions	None
Sc.6b	Target LIHC fuel poor	Minimise fuel bills	All remaining households	Minimise emissions	Full
Sc.6c	Target LIHC fuel poor	Minimise fuel bills	All remaining households	Minimise emissions	Partial
Sc.7a	Non-LIHC fuel poor with all measures (i.e. LIHC fuel poor get nothing)	Minimise fuel bills	Non-LIHC fuel poor with all measures (i.e. LIHC fuel poor get nothing)		None
Sc.7b	Non-LIHC fuel poor with all measures (i.e. LIHC fuel poor get nothing)	Minimise fuel bills	Non-LIHC fuel poor with all measures (i.e. LIHC fuel poor get nothing)		Full
Sc.7c	Non-LIHC fuel poor with all measures (i.e. LIHC fuel poor get nothing)	Minimise fuel bills	Non-LIHC fuel poor with all measures (i.e. LIHC fuel poor get nothing)		Partial
Sc.8a	Non-LIHC fuel poor with 'major' measures (i.e. LIHC fuel poor can get lights and appliances only)	Minimise fuel bills	Non-LIHC fuel poor with 'major' measures (i.e. LIHC fuel poor can get lights and appliances only)		None
Sc.8b	Non-LIHC fuel poor with 'major' measures (i.e. LIHC fuel poor can get lights and appliances only)	Minimise fuel bills	Non-LIHC fuel poor with 'major' measures (i.e. LIHC fuel poor can get lights and appliances only)		Full
Sc.8c	Non-LIHC fuel poor with 'major' measures (i.e. LIHC fuel poor can get lights and appliances only)	Minimise fuel bills	Non-LIHC fuel poor with 'major' measures (i.e. LIHC fuel poor can get lights and appliances only)		Partial

Table notes: a) In cost-recovery, 'none' means no costs of measures are passed on to energy bills; 'full' sees the capital costs of all heating, insulation and renewables passed on to consumers; 'partial' includes all heating, insulation and renewables costs, excluding replacement boilers, solid wall insulation and PV.

²² Plus: Sensitivity analysis scenario re-run with SWI cap at 1m.

²³ Plus: Simulating 'warmth' scenario re-run with 'comfort taking'.

5 Results: Fuel poverty in the UK in 2013

The results from modelling fuel poverty in the UK in the baseline year (2013) using the NHM were analysed in detail to explore the level and severity of fuel poverty by different socio-demographic variables.

In-depth statistical analysis of the characteristics of fuel poor households was also undertaken using a decision-tree method called CHAID ('Chi-square Automatic Interaction Detection', described further in section 5.3).

5.1 Results and data health warning

It is important to note that there will be some discrepancies between the figures presented in this report on fuel poverty levels in the UK in 2013 and the latest figures reported by DECC²⁴ (e.g. DECC estimates that under the LIHC definition there were 2.32 million fuel poor households in England in 2013, whereas this study suggests there were 2.38 million), due to differences in assumptions and inputs. These principally relate to:

- housing stock data (sources/ survey years) and any adjustments made to the energy efficiency of the stock (i.e. to allow for measures installed since the survey was undertaken);
- fuel prices (source, year and level of granularity);
- incomes (year and approach to uprating);
- methodological approaches and assumptions around heating regimes and under-occupancy.

Annex I provides a more detailed discussion of these key differences.

5.2 Fuel poverty in the UK under the 10% definition

5.2.1 Headline results

The results from modelling fuel poverty in the UK under the 10% definition using the NHM estimate that some 5.6 million (21%) of households were fuel poor in 2013 (Table 5.1). Northern Ireland had the highest rate of fuel poverty at 44% and England the lowest at 19%.

The average income of the fuel poor households is notably lower compared to the national average, at just over £12,600 compared to just under £28,000 for the UK as a whole. Whilst incomes of fuel poor households appear slightly higher in Wales and Northern Ireland compared to England and Scotland (Figure 5.1), the former two countries have higher rates of fuel poverty. This suggests that the price of fuel and physical property characteristics may be more influential in driving fuel poverty in these countries (as opposed to low income status). The average required household energy bill of fuel poor households appears some £400 higher in Wales and Northern Ireland (compared to the UK average required bill), providing further evidence of this.

Understanding the relative importance of the key factors driving fuel poverty - namely: fuel prices; (low) incomes; (poor) energy efficiency of the housing stock – can help shape the design, nature and targeting of a programme to address the issue. For example a fuel poverty alleviation programme

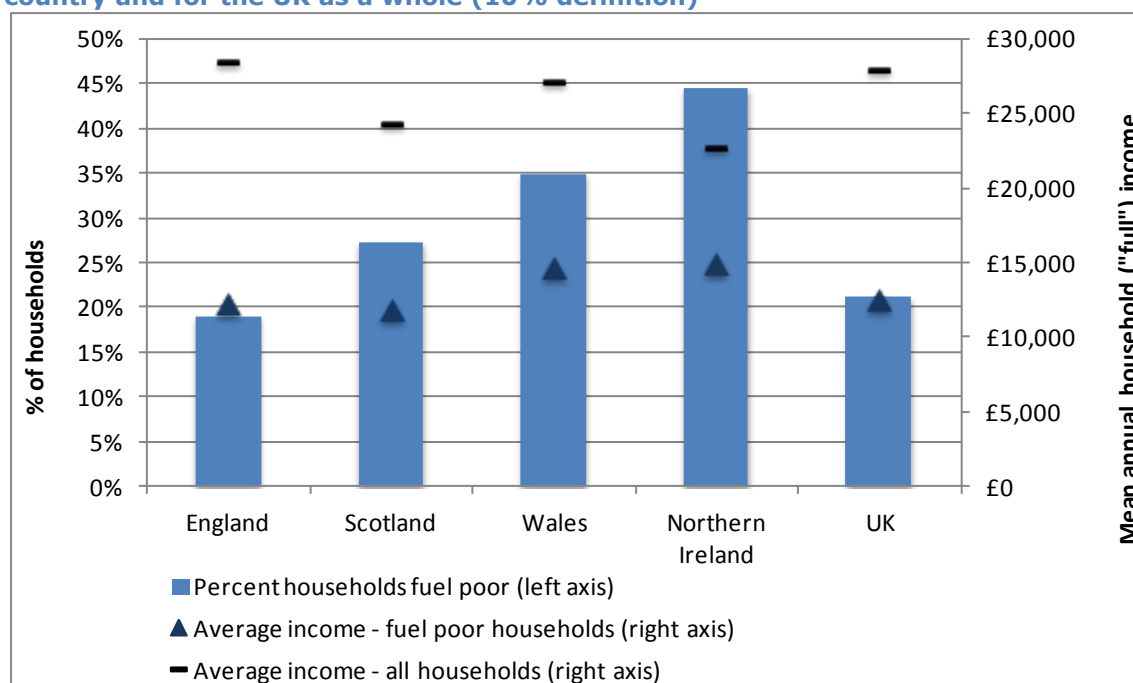
²⁴ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/319280/Fuel_Poverty_Report_Final.pdf

may focus on improving the energy efficiency of the housing stock (e.g. through fully funded, subsidised or incentivised measures); raising incomes (e.g. through benefits entitlement checks); or reducing the price consumers pay for their fuel (e.g. through special tariffs or encouraging switching); or a combination of these approaches.

Table 5.1. Fuel poverty rates in the UK under the 10% definition (2013)

		England	Scotland	Wales	Northern Ireland	UK
In fuel poverty (10% definition)	Count (millions)	4.2	0.64	0.44	0.31	5.6
	Percent of households	19%	27%	35%	44%	21%
	Mean Income	£12,332	£11,884	£14,714	£15,035	£12,619
	Mean Required Fuel Costs	£1,917	£1,928	£2,401	£2,315	£1,979
	Mean ratio	16%	16%	16%	15%	16%
Not in fuel poverty (10% definition)	Count (millions)	17.8	1.70	0.82	0.39	20.7
	Percent of households	81%	73%	65%	56%	79%
	Mean Income	£32,292	£28,984	£33,879	£28,961	£32,022
	Mean Fuel Costs	£1,337	£1,295	£1,778	£1,785	£1,360
	Mean ratio	4%	4%	5%	6%	4%
All households	<i>Count (millions)</i>	22.0	2.3	1.3	0.7	26.3
	<i>Mean Income (Full)</i>	£28,496	£24,322	£27,191	£22,789	£27,912
	<i>Mean Fuel Costs</i>	£1,447	£1,468	£1,995	£2,020	£1,491
	<i>Mean ratio</i>	5%	6%	7%	9%	5%

Figure 5.1. Proportion of households in fuel poverty and average income in 2013 in each country and for the UK as a whole (10% definition)



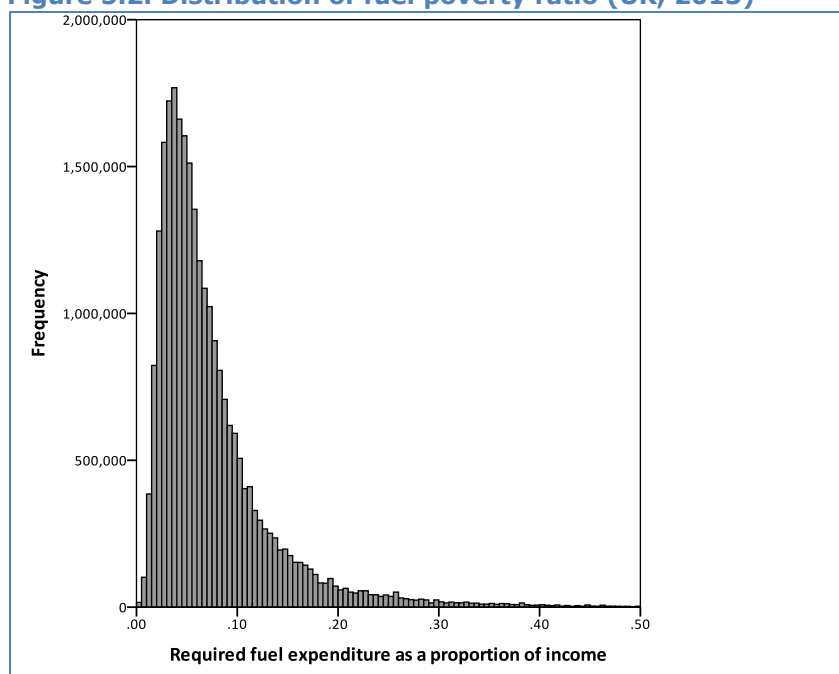
5.2.2 Severity of fuel poverty (10% definition)

The amount a household needs to spend on fuel to maintain adequate warmth (according to the standard definition of heating regime – refer to Box 4.2) as a proportion of its income provides a measure of the depth or severity of fuel poverty experienced by householders (the fuel poverty ratio).

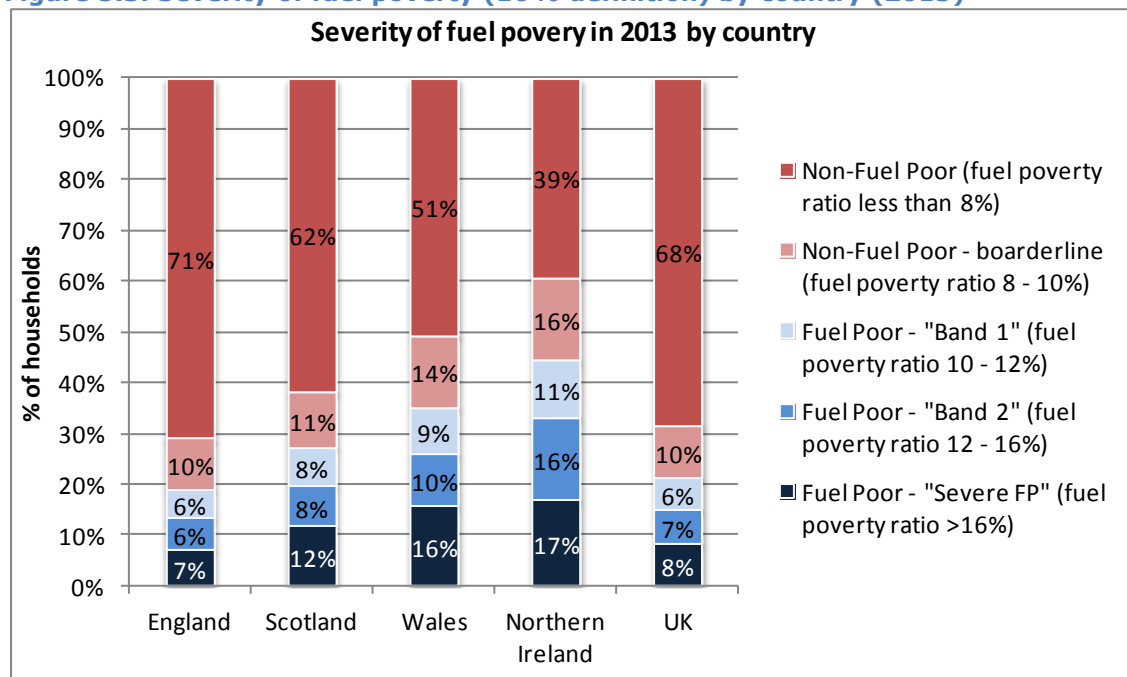
For fuel poor households (UK wide), required fuel expenditure represents around 16% of household income on average, compared to around 6% across the population as a whole (as shown by the ‘ratio’ in Table 5.1). These averages mask a wide distribution, as shown in Figure 5.2.

Banding the fuel poverty ratio into categories²⁵ provides further insight into the depth of fuel poverty experienced in each country. Figure 5.3 shows that some 7% of households in England need to spend more than 16% of household income on fuel (‘severe fuel poverty’) compared to 16% and 17% of households in Wales and Northern Ireland respectively.

Figure 5.2. Distribution of fuel poverty ratio (UK, 2013)



²⁵ Where categories have been defined as: “non-fuel poor” (fuel poverty ratio <8%); “borderline non-fuel poor” (ratio 8-10%); “Band 1 fuel poor” (fuel poverty ratio 10-12%); “Band 2 fuel poor” (fuel poverty ratio 12-16%); and “Severe fuel poor” (fuel poverty ratio >16%).

Figure 5.3. Severity of fuel poverty (10% definition) by country (2013)

5.2.3 Distribution of fuel poverty in 2013 under the 10% definition

This section presents analysis of fuel poverty in 2013 under the 10% definition by different geographic, physical property and socio-demographic variables.

Fuel poverty by region

As noted above, Northern Ireland and Wales had the highest proportion of households in fuel poverty in 2013 of all countries in the UK (a pattern consistent with previous years). Within England, London and the South East region had the lowest rates of fuel poverty and the South West and West Midlands the highest at around 24%. This reflects a combination of the nature of the housing stock, availability of fuels for heating (i.e. mains gas connectivity) and fuel prices and incomes in these areas (Figure 5.4).

There is a wide distribution of fuel poor households throughout the UK. However, with around 9-11% of the total fuel poor population being in each of the South East, East, South West, West Midlands and North West (Figure 5.5).

Figure 5.4. Proportion of households in fuel poverty by region and country (10% definition, 2013)

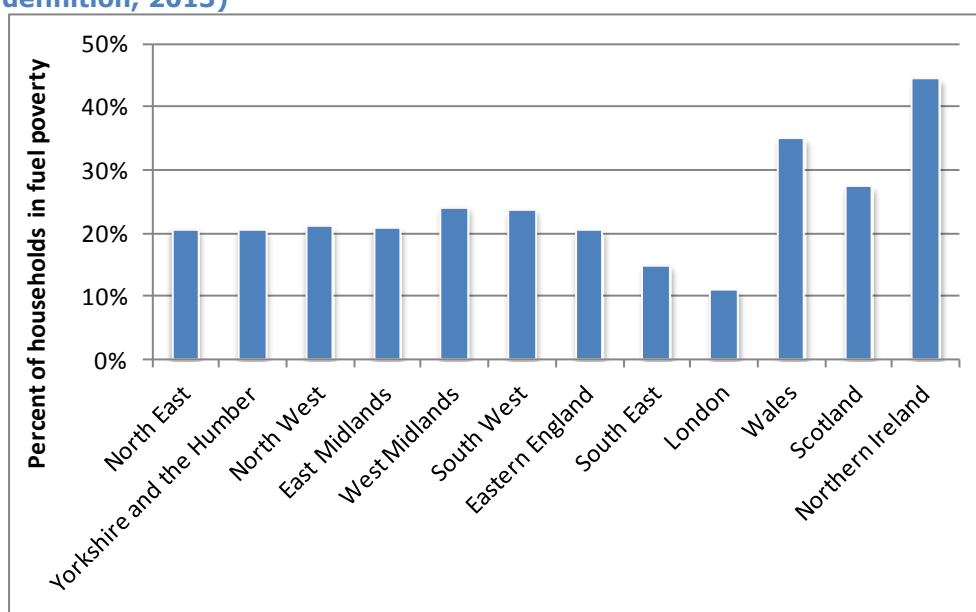
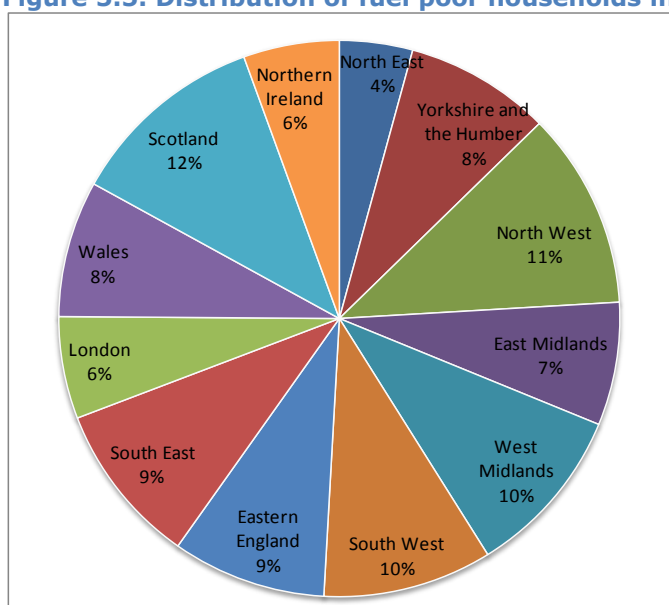


Figure 5.5. Distribution of fuel poor households in the UK (10% definition, 2013)

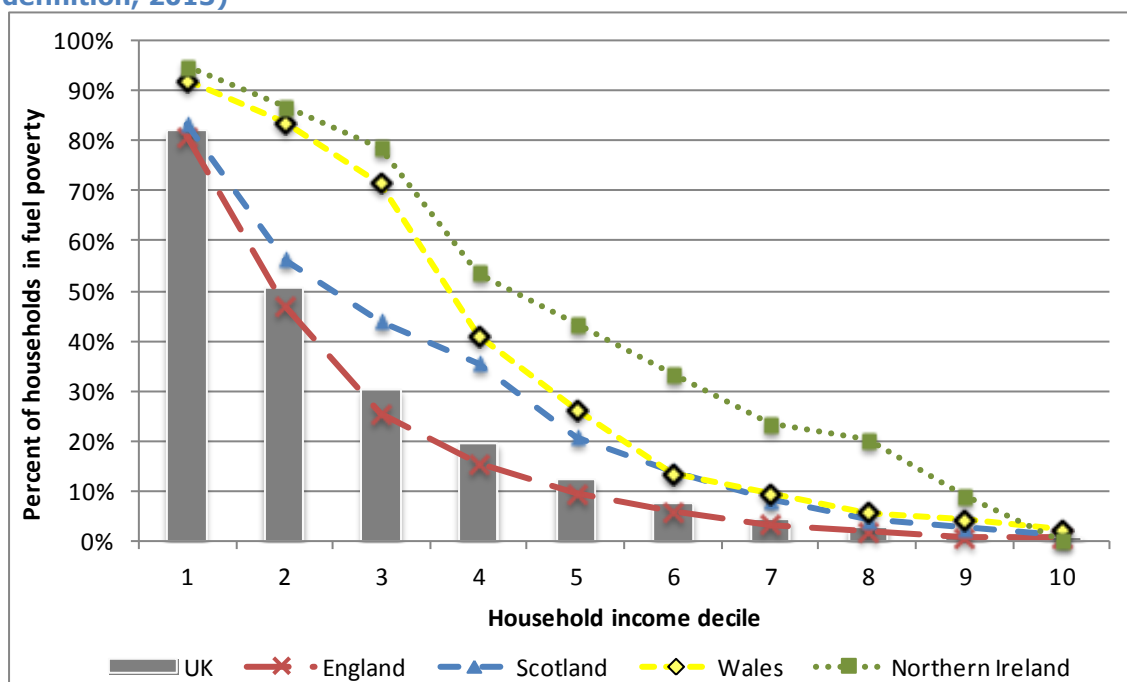


Fuel poverty by income decile

Detailed bivariate analysis was undertaken to explore the characteristics of the fuel poor population in each country of the UK in 2013 under the 10% definition. The results are summarised below.

There is a clear correlation between income and fuel poverty status, with over 80% of the lowest income decile being classed as fuel poor under the 10% definition in all countries of the UK in 2013, compared to fewer than 3% of the top income decile (Figure 5.6).

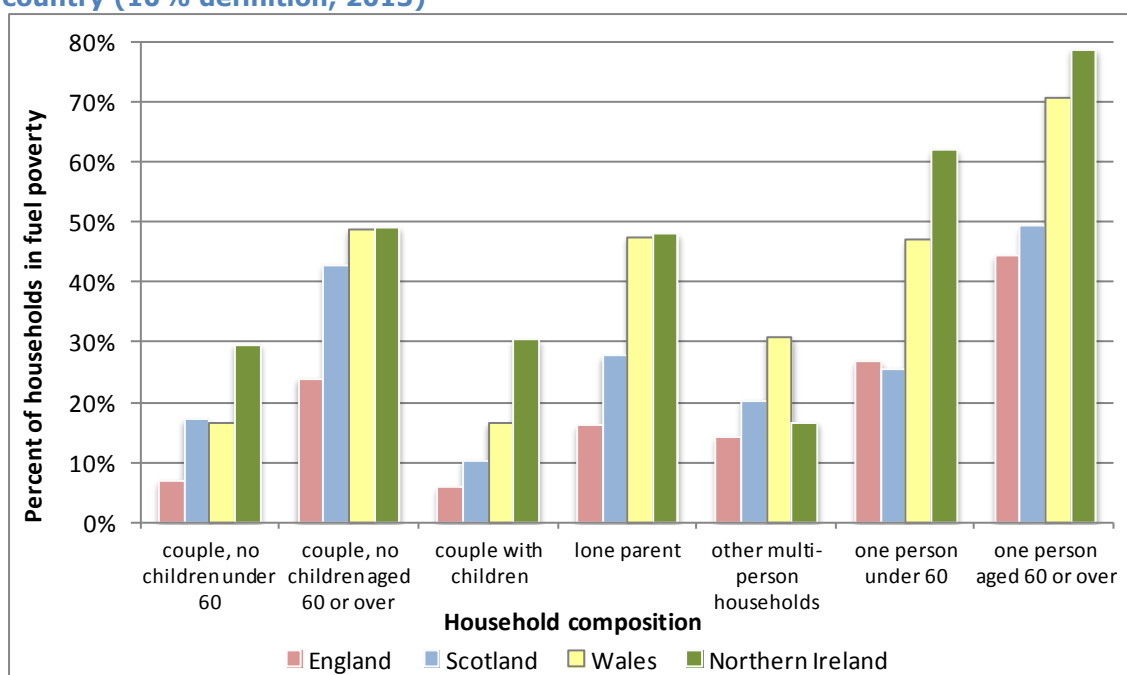
Figure 5.6. Proportion of households in fuel poverty by income decile and country (10% definition, 2013)



Fuel poverty by Household Composition, Age and Employment Status

In all countries, a higher proportion of single adults aged over 60 were in fuel poverty compared to other household types (Figure 5.7). In Northern Ireland and Wales nearly half of 'lone parent' households were classed as fuel poor.

Figure 5.7. Proportion of households in fuel poverty by household composition and country (10% definition, 2013)



Older person households (those with a household reference person aged 65 or over) account for nearly half (47%) of the fuel poor population in all nations, except Northern Ireland, where younger person households account for a higher proportion of the fuel poor population (Table 5.2). This pattern is further evident in the employment status of the fuel poor: retired households account for half of the total fuel poor population in all nations except Northern Ireland, where those out of work but under retirement age (hence 'unemployed' or 'other inactive') account for 26% and households in full time work make up a further 22% of the fuel poor population (Table 5.3). Wales also has a higher proportion of fuel poor households in full time work, compared to Scotland, England and the UK as a whole.

Table 5.2. Proportion of fuel poor households by age of Household Reference Person (HRP)²⁶ and country (2013) compared to the population as whole

	16 - 24	25 - 34	35 - 44	45 - 54	55 - 64	65 or over
England fuel poor	4%	6%	10%	14%	19%	48%
<i>England all</i>	3%	14%	20%	20%	17%	25%
Scotland fuel poor	4%	6%	9%	13%	20%	48%
<i>Scotland all</i>	4%	12%	19%	19%	18%	27%
Wales fuel poor	3%	5%	11%	14%	21%	46%
<i>Wales all</i>	2%	7%	20%	24%	20%	26%
Northern Ireland fuel poor	4%	10%	15%	17%	16%	37%
<i>Northern Ireland all</i>	3%	15%	20%	19%	15%	27%
UK fuel poor	4%	6%	10%	14%	19%	47%
<i>UK all households</i>	3%	14%	20%	20%	17%	26%

Table 5.3. Proportion of fuel poor households by employment status and country (2013) compared to the population as whole

	full time work	part-time work	retired	unemployed	full time education	other inactive
England fuel poor	16%	8%	53%	9%	2%	12%
<i>England all</i>	51%	8%	27%	4%	1%	9%
Scotland fuel poor	17%	7%	55%	5%	3%	13%
<i>Scotland all</i>	49%	7%	30%	3%	2%	10%
Wales fuel poor	26%	10%	50%	5%	2%	7%
<i>Wales all</i>	55%	9%	28%	2%	1%	5%
Northern Ireland fuel poor	22%	9%	37%	13%	1%	13%
<i>Northern Ireland all</i>	35%	7%	27%	11%	1%	12%
UK fuel poor	17%	8%	52%	8%	2%	12%
<i>UK all households</i>	51%	8%	28%	4%	1%	9%

Fuel poverty by tenure

In England, the owner-occupied sector has (marginally) the highest proportion of fuel poor households of all tenures; whilst in Scotland social housing (housing association (HA) and local authority (LA)) appears to have the greatest proportion of fuel poor and in Wales and Northern the private-rented sector has the highest percentage (Figure 5.8).

Looking at the distribution of the fuel poor sub-set of households across the different tenures compared to the population as a whole (by country and for the UK as a whole) shows there is

²⁶ The Household Reference Person (HRP) is the individual within a household that acts as a reference point for producing further derived statistics and for characterising a whole household according to characteristics of the chosen reference person. Where there is more than one adult in the house, the HRP is selected as being the most economically active person, or the elder member when this criteria is identical.

actually little difference between the two (Table 5.4). Some 69% of all fuel poor households in the UK in 2013 were in owner occupied dwellings; 14% in private rented dwellings and 16% in social housing; not dissimilar to the distribution of the population as whole at 68%, 15% and 17% respectively. This is due to interacting and conflicting effects of a number of factors, such as income, housing stock energy efficiency, heating fuels, household occupancy and location. For example, energy efficiency tends to be lower in the private rented sector and higher in social housing, thereby lowering the likelihood of the latter being in fuel poverty, whilst incomes are typically lower in social housing thereby increasing the likelihood of being fuel poor.

Figure 5.8. Proportion of households in fuel poverty by tenure and country (10% definition, 2013)

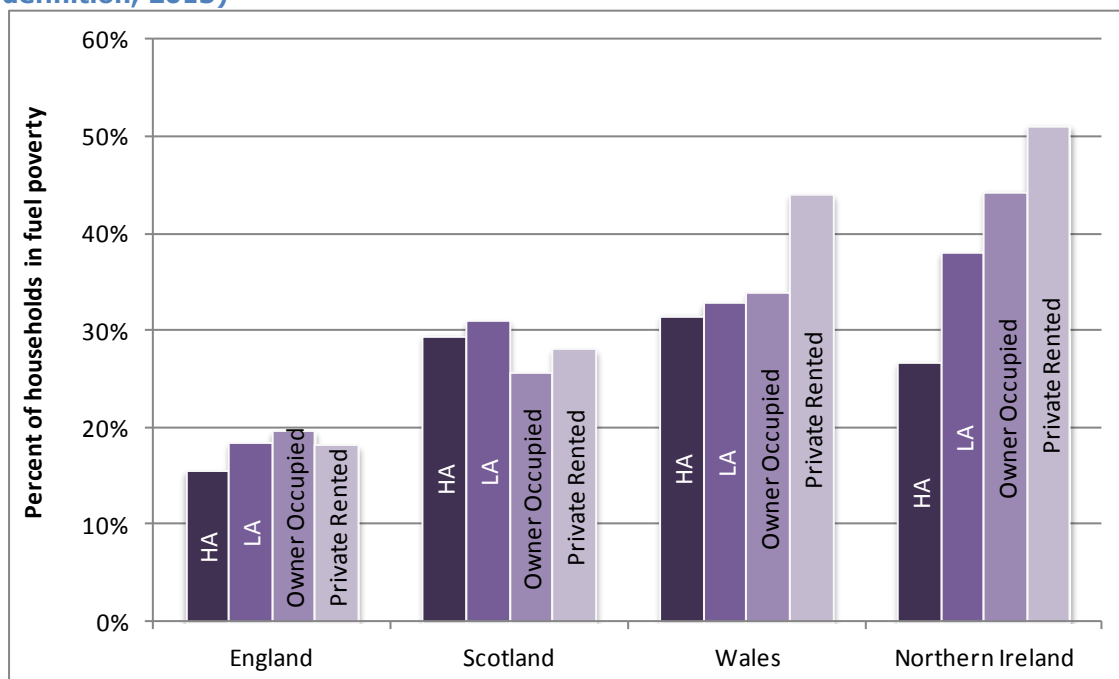


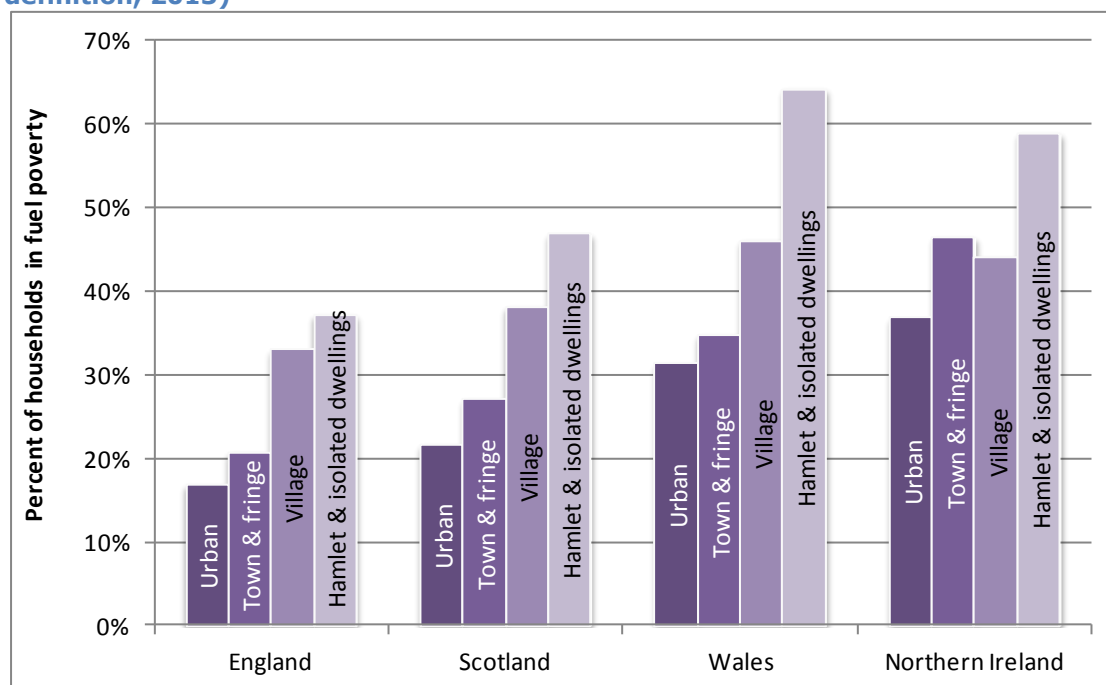
Table 5.4. Distribution of fuel poor households by tenure and country (10% definition, 2013) compared to the population as whole

	Housing Association	Local Authority	Owner Occupied	Private Rented
England fuel poor	7%	8%	70%	15%
<i>England all</i>	9%	8%	67%	15%
Scotland fuel poor	13%	18%	59%	10%
<i>Scotland all</i>	12%	16%	63%	9%
Wales fuel poor	2%	3%	83%	12%
<i>Wales all</i>	2%	3%	85%	10%
Northern Ireland fuel poor	1%	13%	66%	20%
<i>Northern Ireland all</i>	2%	15%	65%	18%
UK fuel poor	7%	9%	69%	14%
<i>UK all households</i>	9%	9%	68%	15%

Fuel poverty by physical property characteristics

A higher proportion of households in rural areas were in fuel poverty in 2013 compared to the proportions in urban areas, across all countries of the UK. This pattern is most prominent in Scotland where some 47% of households in the most isolated settlements were classed as fuel poor in 2013, over double that of the proportion of fuel poor in urban areas (22%, Figure 5.9).

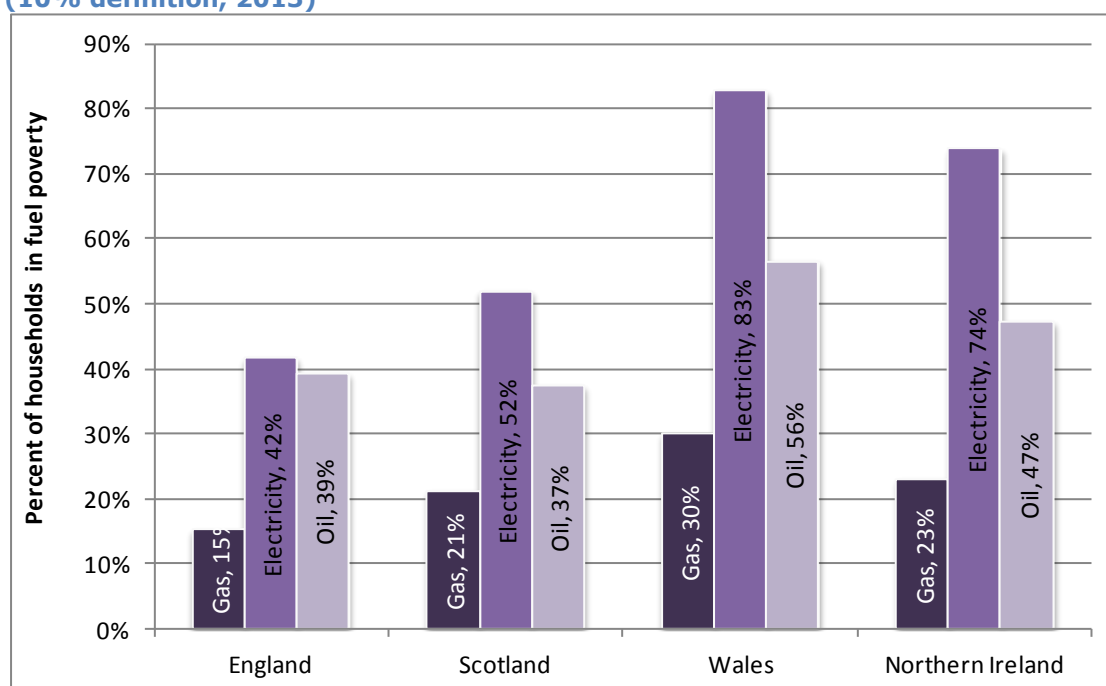
Figure 5.9. Proportion of households in fuel poverty by rurality in each country (10% definition, 2013)



It follows that households without mains gas (which are predominantly outside of urban areas) are also more likely to be in fuel poverty. Electrically- and oil-heated properties have the highest proportions of fuel poor. In Wales, over 80% of electrically-heated households were in fuel poverty in 2013 (Figure 5.10). However, this does represent relatively few households, as only around 4% of dwellings in Wales use electricity as their main heating fuel (some 50,000 households).

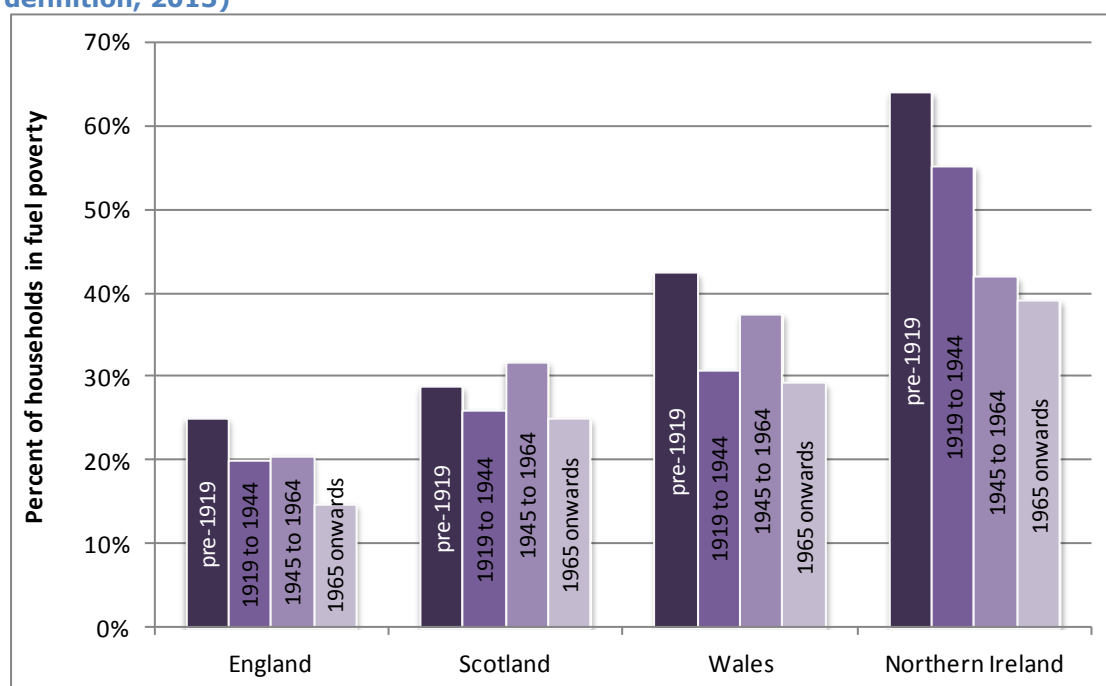
Nevertheless, electrically- and oil-heated properties account for a higher proportion of the fuel poor population compared to the population as whole in all countries. These fuels represent more expensive heating fuels compared to mains gas (on a per unit basis).

Furthermore, lower income households are more likely to be reliant on electricity for heating, thus further exacerbating their vulnerability to fuel poverty. Oil-heated properties on the other hand represent a mixed income demographic, hence there will be interaction effects associated with (but not limited to) the price of oil heating (increasing the likelihood of being fuel poor) and income of oil-heated households (generally higher therefore reducing the likelihood of being fuel poor).

Figure 5.10. Proportion of households in fuel poverty by main heating fuel and country (10% definition, 2013)**Table 5.5. Distribution of fuel poor households by main heating fuel and country (2013) and compared to the population as a whole**

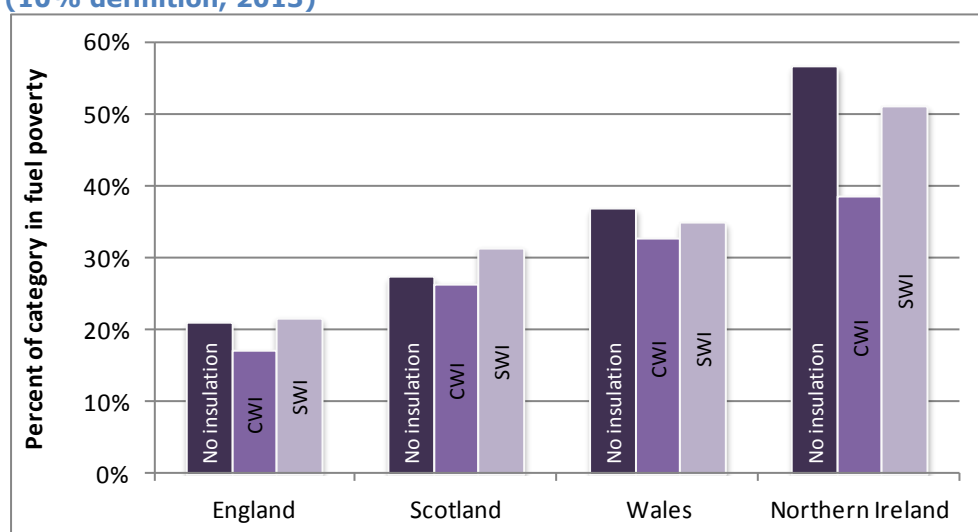
	Mains gas	Electricity	Oil
England fuel poor	68%	18%	9%
<i>England all</i>	85%	8%	5%
Scotland fuel poor	59%	28%	9%
<i>Scotland all</i>	77%	15%	7%
Wales fuel poor	74%	9%	14%
<i>Wales all</i>	86%	4%	8%
Northern Ireland fuel poor	8%	7%	81%
<i>Northern Ireland all</i>	15%	4%	76%
UK fuel poor	64%	18%	14%
<i>UK all households</i>	83%	9%	7%

There will be additional interacting factors underlying the patterns we see in fuel poverty levels and heating fuel (as with all the bivariate analysis presented in this section of the report). Factors such as the type, size and age of dwelling are also associated with oil-heated properties and will affect the likelihood of the household being in fuel poverty. For example, 32% of oil-heated properties in the UK were built pre-1919 (compared to 20% of mains gas heated properties). Fuel poverty is more prevalent in older dwellings (pre-1919) in England, Wales and Northern Ireland, whilst in Scotland 1945 to 1964 dwellings have the highest proportion of fuel poor households (Figure 5.11). The distribution of fuel poor households by dwelling age and country shows a mixed picture. Whilst in all countries a higher proportion of the fuel poor in 2013 lived in pre-1919 dwellings compared to the population as a whole (Table 5.6), in Scotland and Northern Ireland post-1964 dwellings account for the highest proportion of fuel poor households. In Wales pre-1919 houses account for the majority of fuel poor households at some 37%.

Figure 5.11. Proportion of households in fuel poverty by dwelling age and country (10% definition, 2013)**Table 5.6. Distribution of the fuel poor (10% definition, 2013) by dwelling age and country**

		pre-1919	1919 to 1944	1945 to 1964	1965 onwards
England	Non-fuel poor	20%	17%	20%	44%
	Fuel poor	28%	18%	22%	33%
	<i>All households</i>	21%	17%	20%	42%
Scotland	Non-fuel poor	18%	18%	19%	45%
	Fuel poor	20%	17%	24%	40%
	<i>All households</i>	18%	18%	20%	43%
Wales	Non-fuel poor	27%	15%	16%	41%
	Fuel poor	37%	13%	18%	32%
	<i>All households</i>	31%	14%	17%	38%
Northern Ireland	Non-fuel poor	8%	8%	18%	66%
	Fuel poor	18%	13%	16%	53%
	<i>All households</i>	12%	10%	17%	60%
UK	Non-fuel poor	20%	17%	19%	44%
	Fuel poor	27%	17%	21%	35%
	<i>All households</i>	21%	17%	20%	42%

Analysis of the distribution of fuel poor households by wall insulation type shows that dwellings without wall insulation have a higher proportion of fuel poor households than those with cavity wall insulation (Figure 5.12). The rate of fuel poverty appears high in dwellings that have received solid wall insulation, but looking at the overall distribution of fuel poor households shows that fewer than 7% of the fuel poor in each country are in these dwellings (Table 5.7).

Figure 5.12. Proportion of households in fuel poverty by wall insulation type and country (10% definition, 2013)**Table 5.7. Distribution of the fuel poor (10% definition, 2013) by wall insulation type and country**

		No insulation	Cavity wall insulation	Solid wall insulation
England	Non-fuel poor	48%	51%	1%
	Fuel poor	54%	45%	1%
	<i>All households</i>	49%	50%	1%
Scotland	Non-fuel poor	66%	29%	5%
	Fuel poor	66%	27%	6%
	<i>All households</i>	66%	28%	5%
Wales	Non-fuel poor	54%	46%	0%
	Fuel poor	58%	41%	0%
	<i>All households</i>	55%	44%	0%
Northern Ireland	Non-fuel poor	22%	73%	5%
	Fuel poor	37%	57%	6%
	<i>All households</i>	29%	66%	6%
UK	Non-fuel poor	49%	50%	1%
	Fuel poor	55%	43%	2%
	<i>All households</i>	50%	48%	1%

5.3 Who are the (10%) fuel poor?

The figures shown in the previous section provide some evidence of the types of households more likely to experience fuel poverty. However, this analysis is limited in depth, looking at only one factor at a time, when in reality there are a number of interacting factors driving fuel poverty (for example income, occupant age, employment status, dwelling type, tenure and energy efficiency standards

can all be interconnected). CHAID ('Chi-square Automatic Interaction Detection'²⁷) analysis offers a more detailed analytical approach to exploring the multiple factors associated with the likelihood of a household being in fuel poverty.

For the purpose of analysing housing survey-derived data, CHAID analysis offers a significant advantage in that it enables more detailed scrutiny of the data while maintaining a sufficient number of cases to avoid issues of small sample sizes. It therefore provides a statistically-robust approach to analysing the data by multiple variables at one time.

The analysis below shows the results from two CHAID models that explore the relationship between a number of different socio-demographic and physical property characteristics and the likelihood of being fuel poor (under the 10% definition: required fuel expenditure > 10% of household income). The analysis was run on a subset of the population to include only those households with a fuel poverty ratio >5% (to enable the model to pick up any key groups that may be 'borderline' or nearing fuel poverty).

Two models were run: one for England only (to allow for the larger sample size) and a second for the Devolved Nations, where the model was forced to split on country first (effectively providing three separate models of fuel poverty in each country). Other than region/country and node size criteria, the models were based on the same set of inputs. The 10% definition is no longer used in England so the results below are somewhat academic, but interesting and useful for comparative purposes (the next section of this report provides results from CHAID analysis of the LIHC definition in England).

5.3.1 Results from CHAID analysis of the 10% definition

The key parameters of the CHAID models, including variables selected as significant predictors of fuel poverty status and the predictive accuracy of the models are summarised below²⁸. The CHAID tree diagrams are included in Annex III. Within the parameters specified, the England-only model identified 17 different groups with 71% accuracy and the DA model identified 23 different groups with 67% accuracy²⁹. Combined, the CHAID analysis has therefore identified a total of 40 distinct groups of households across the UK. Of these, a total of 13 were predicted to be fuel poor, representing 3.67 million households. An additional four groups (1.78 million households) are in fuel poverty based on the mean fuel poverty ratio (calculated for the group from the dataset). (NB the total number of households identified as fuel poor by CHAID will not equate to the dataset total, due the nature of the modelling process).

²⁷ CHAID is a popular technique for performing classification or segmentation analysis. It is an exploratory data analysis method used to study the relationship between a dependent variable (for example, in the context of this study, a fuel poverty metric such as required fuel expenditure on heating as a proportion of income) and a set of predictor variables (for example, socio-demographics and physical property characteristics). CHAID builds a classification tree from the data, with clusters – or 'nodes' – in the tree defined by the ranges of values on the predictor variables. In doing this it minimises the variance in the dependent variable across the members of each node. This yields a set of clusters of cases with similar values for predictor and dependent variables.

²⁸ Income and SAP rating were intentionally excluded due to the inherent link with fuel poverty.

²⁹ CHAID provides a "percent correct" figured based on the number of cases (households) predicted correctly – i.e. the number of households the model predicts to be in fuel poverty compared the actual value.

Table 5.8. CHAID model summaries

	England	Wales	Scotland	Northern Ireland
Input data	Households with fuel poverty ratio >5%	Households with fuel poverty ratio >5% (n = 3.07 million across all DAs)		
Input sample size (weighted count)	12.3m	0.968m ^a	1.49m ^a	0.607m ^a
Independent variables selected by the model	Employment status Heating fuel Household composition Dwelling age Tenure Number of bedrooms Number of children	Country (forced) Employment status Household composition Rurality Dwelling age	Country (forced) Employment status Heating fuel Dwelling type Number of bedrooms Household composition Long-term sick	Country (forced) Number of adults Household composition Age of HRP Number of bedrooms
No. final nodes	17	7 (/23)	11 (/23)	5 (/23)
Model classification accuracy^b	71%	74% ^c	72% ^c	70% ^c
Actual no. & % fuel poor households	4.19 million 19%	442,000 35%	638,000 27%	308,000 44%
No. of fuel poor nodes & households identified by CHAID based on node status^d	4 nodes 3.16 million households 14% of households in England	3 nodes 401,000 households 32% of households in Wales	4 nodes 457,000 households 20% of households in Scotland	3 nodes 347,000 households 50% of households in Northern Ireland
No. fuel poor nodes & households identified based on node mean fuel poverty ratio^e	5 nodes 3.92 million households 18% of households in England	5 nodes 622,000 households 49% of households in Wales	5 nodes 657,000 households 28% of households in Scotland	3 nodes 347,000 households 50% of households in Northern Ireland

Notes:

a. Overall sample size for Devolved Nations CHAID model = 3.07m

b. This is the proportion of households correctly identified as fuel poor / non-fuel poor by CHAID.

c. Overall model for fuel poverty in the Devolved Nations = 67% correct

d. This is the number of households in every node classified as fuel poor by the CHAID model.

e. This is the number of households in every node that has an average fuel poverty ratio of >10%.

Key statistics for each fuel poor node (number and % of households (as a proportion of households in the country); and average (mean) required fuel costs, income and fuel poverty ratio for the node) are shown in Table 5.9. The table is ordered by node fuel poverty ratio, with the most severely fuel poor first (node 1). This shows that the most severely fuel poor group of households is in Northern Ireland, with an average fuel poverty ratio of 15%; followed by a group in Wales (also at 15%), Scotland (15%) and England at 14%. The predominant characteristics of all the fuel poor groups identified by CHAID for each country are described in more detail below.

Table 5.9. Summary of nodes identified as fuel poor by the two CHAID models

Node ID	Description of predominant characteristics of node	Count of HHs	% of HHs^a	Required spend on fuel	Income^b	Mean fuel poverty ratio^c	Actual % in fuel poverty^d
1	NI: Low income driven fuel poor – single retired adults	124,200	18%	£1,925	£12,617	15%	82%
2	Wales: Low income, high fuel costs due to house size, location and heating – retired, rural	103,320	8%	£2,751	£18,080	15%	78%
3	Scotland: Physical characteristics driving fuel poor status – retired owner-occupiers in larger, detached, rural houses	128,200	5%	£2,394	£16,239	15%	73%
4	England: High required fuel costs & lower income – retired, off-gas	986,200	4%	£2,347	£17,243	14%	69%
5	Scotland: Very low income driving fuel poor status, with just above average required fuel costs – retired, mainly single adults in less-rural semi's	125,000	5%	£1,673	£12,311	14%	73%
6	Wales: Low-income driven fuel poor, though poor energy efficiency may also be a factor – retired, urban, older dwellings	146,280	12%	£1,990	£15,860	13%	67%
7	Scotland: Very low income, average fuel costs – retired adults in terraced houses	100,800	4%	£1,542	£12,336	13%	64%
8	Scotland: Low income, average fuel costs – retired couples in semi-detached houses	103,400	4%	£1,738	£14,778	12%	60%
9	England: Very low income driven fuel poor (lower than average fuel costs) – unemployed	673,400	3%	£1,293	£11,292	11%	55%
10	England: Very low income, with average fuel costs – single, retired, owner-occupiers, in larger (3+ bed) houses with mains gas (under-occupiers)	804,600	4%	£1,494	£13,267	11%	63%
11	NI: Fuel costs driven fuel poor, average income – Two or more retired adults	100,200	14%	£2,321	£20,858	11%	52%
12	NI: Low income driven fuel poor, with lower than average fuel costs - Out-of-work or part-time employed, single adults, some with children (i.e. lone parents) in rented houses	122,800	18%	£1,670	£15,292	11%	57%
13	Wales: Lower income, average fuel costs – Younger (under age of retirement) out-of-work or in part-time employment	151,040	12%	£1,942	£18,206	11%	51%
14	England: Very low income driven fuel poor (lower than average fuel costs) - single, retired, owner-occupiers, in 2 or 4 bed houses with mains gas	694,400	3%	£1,339	£12,980	10%	50%
15	England: Very low income driven fuel poor (lower than average fuel costs) – all out-of-work adults without children, in small social-rented flats with mains gas	763,000	3%	£1,269	£12,334	10%	46%
16	Wales: Slightly lower income despite working full-time; Young professionals in private sector housing	119,120	9%	£1,957	£19,068	10%	46%
17	Scotland: Very low income driven fuel poor, lower than average fuel costs – younger, out-of-work single adults in small social-rented flats	199,200	9%	£1,311	£12,907	10%	42%

Notes:

a. Represent the % of households by country

b. Full household income as per the fuel poverty methodology (10% definition)

c. Average for node (= mean required fuel spend for node / mean household income for node)

d. Based on dataset count of households in fuel poverty

5.3.2 'Pen-portrait' descriptions of the (10%) fuel poor groups

The boxes below summarise the key characteristics of each fuel poor node identified by the CHAID analysis for each country. These results are important in the context of considering what a targeted fuel poverty alleviation programme might look like in each country (i.e. 'one size does not fit all').

Box 5.1. England 10% fuel poor

Whilst England is included for consistency, the results have less policy relevance as this definition is no longer used. The next section provides detailed descriptions of the LIHC fuel poor in England.

- **Node 4: Retired, owner-occupiers in off-gas** (61% electric, 32% oil heating) 2-3 bed detached houses (45%) or purpose-built flats (24%), half in rural areas and around half with uninsulated walls, and a quarter pre-1919 dwellings. One fifth are in south west England.
- **Node 9: All unemployed, mainly younger, single adults**, a quarter (26%) of who have children (i.e. lone parents). They are mainly renting - 41% social, 30% private - small (55% 2 or fewer bedrooms), purpose-built flats (27%) or terraced houses, in urban areas (19% in London), with mains gas but over half (56%) without wall insulation and a quarter in pre-1919. This group has lower than average fuel costs, but very low income is driving them into fuel poverty.
- **Node 10:** Another very low income group, with average required fuel costs, but unlike node 9, this group consists of all **retired, single adult, owner-occupiers**, in 3-bed mains gas-heated semi-detached, inter-war housing. Being single adult-households, under-occupancy is a feature here.
- **Node 14:** Similar to node 10 above, being very low income (lower than average fuel costs): **all single, retired, owner-occupiers**, in 2 or 4-bed (18%, hence under-occupied as all single-adults), detached houses, with mains gas heating.
- **Node 15: A younger group of mainly single adults, all 'not working'** (under age of retirement), in 1-2 bed social rented predominantly purpose-built flats (31%). Being small properties, with mains gas heating and social housing (typically higher standard of energy efficiency) it is their low income driving their fuel poor status.

Box 5.2. Wales fuel poor

Four distinct groups of fuel poor households were identified by CHAID for Wales:

- **Node 2: Retired, owner-occupiers**, in 3-4 bed detached houses, all in rural areas, with a third oil-heated (57% still mains gas). With a third of the group being single-adult households, under-occupancy may be an issue. This group has very high required fuel expenditure (which reflects the dwelling size, location and heating fuel) and slightly lower than average income.
- **Node 6: Retired couples and single adults**, who own their 3-bed semi-detached and terraced houses, in urban areas with main gas heating. This appears a predominantly low-income driven group of fuel poor, though poor energy efficiency may also be a factor, with some dwellings being older dwellings (36% pre-1919) and over half (57%) without wall insulation.
- **Node 13: Younger demographic of part-time working (61%) or out-of-work** (under the age of retirement), adults. There is a mix of singles and couples, but a high proportion have children (hence a high occupancy group of larger families). There is a mix of tenancy (72% owners, 17% social, 11% PRS), but mainly 3-bed semis in more urban areas with mains gas. They are lower income and have average required fuel costs.
- **Node 16:** This is an interesting group with slightly lower income despite **working full-time**. The demographic suggests **young professionals**, mainly single adults, but some multi-person households (27%), either owner-occupiers or privately renting (22%), in urban areas with mains gas or electricity (13%). There is a mix of terraced housing and flats (10% purpose-built and 10% converted flats). Over a third (38%) are pre-1919 dwellings. With required fuel costs around average and household income only slightly lower than average, this group is only just in fuel poverty.

Box 5.3. Scotland fuel poor

Five groups of fuel poor households were identified by the CHAID model for Scotland:

- **Node 3:** This node represents a group of **retired owner occupiers in larger, detached houses, in rural areas**. Half have uninsulated walls and 18% have oil heating (though 69% have mains gas). Whilst this group has lower than average income, their required fuel expenditure is almost £1,000 higher than the average for Scotland, suggesting it is this (related to the physical property characteristics of their homes) driving their severe fuel poor status.
- **Node 5:** Unlike node 3, this group has nearer average fuel costs, but very low income being **retired, single, older people in 3-bed semi-detached houses** in town and fringe areas some electrically-heated (16%) but 80% mains gas. There is a mix of owner-occupiers (66%) and social housing (30%). Being predominantly (76%) single-adult households, under-occupancy may be a feature here.
- **Node 7:** Another group of very low income, **retired** household with around average fuel costs. This node consists of a mix of couples and single adults, all in terraced houses, some **social housing** (39%) and some **owner occupiers** (57%). They are mainly in town and fringe areas, with mains gas heating and 2-3 bedrooms. This suggests it is their very low income driving their fuel poor status.
- **Node 8:** Similar to node 7 above (**retired couples, owner occupiers**, in urban and town and fringe areas with mains gas and 2-3 bedrooms) but all in **semi-detached** houses. Slightly higher income than node 7 but also with slightly higher required fuel costs.
- **Node 17:** This group represents a **younger demographic of non-working** (all households have an HRP described as 'other inactive', which is not working but neither registered unemployed nor retired). They are mainly **single adults, some with children** (19% lone parents), in **1-2 bed, social rented** purpose-built flats with mains gas or electric (20%) heating. With lower than average fuel costs, it is their very low income driving their fuel poor status.

Box 5.4. Northern Ireland fuel poor

Three distinct groups of fuel poor households in Northern Ireland were identified by CHAID:

- **Node 1:** The most severely fuel poor group (across the UK as a whole) consists of **all single, mainly retired adults**, with very low income. They live mainly in 2-3 bed properties, with **electric (14%) or oil heating (70%)**. They mainly own their homes, but a quarter (27%) are in social housing. With slightly lower than average required fuel costs, this represents more of 'low income' driven fuel poor group.
- **Node 11:** This group consists of **all couples, mainly retired**, owner-occupiers, in detached, 3-4 bed, houses in **rural areas with oil heating**. Their income is around average, but required fuel expenditure around £300 more than the average household, hence this group is more of a 'high fuel costs' driven fuel poor.
- **Node 12:** Unlike the previous two groups, this node represents a **younger demographic, of out-of-work or part-time employed, single adults, some with children** (i.e. lone parents, 48%) in rented (35% private, 33% social), 3-bed terraced houses, with **oil (64%) or mains gas (23%) heating**. The required fuel costs of these households is lower than average, suggesting it is their low income that is the key driver of their fuel poor status.

5.3.3 Implications of CHAID analysis

These different groups of fuel poor households show that fuel poverty is not the result of one or two factors but a range of different housing conditions and socio-economic situations. As a result, a range of strategies, data and interventions are required to identify and assist different target groups.

The CHAID analysis identifies some key characteristics of fuel poor households that could guide the design of engagement and intervention strategies. For example, in urban areas, fuel poverty appears more likely to affect younger single adult households on very low incomes, living in smaller private sector homes heated by mains gas (e.g. England Node 9). Whereas a fuel poor group in more rural areas predominantly comprised retired households living in comparatively larger detached houses heated by electricity or oil (i.e. off the gas grid).

5.4 Fuel poverty in the UK under the 'low income, high cost' definition

Whilst only England has adopted the new 'low income, high cost' approach to measuring fuel poverty, this method has been applied to all nations for consistency and comparative purposes, but the more detailed, distributional analysis focuses on England only.

5.4.1 Headline results: LIHC fuel poverty in 2013

Under the new 'low-income, high-cost' definition of fuel poverty some 2.9 million (11%) households in the UK were fuel poor in 2013, with some 2.38 million in England. This is around half that defined as fuel poor under the original 10% definition (Table 5.3). The proportions vary little across each nation (this phenomenon is a direct consequence of the 'low income high cost' methodology, which uses relative thresholds of median incomes and fuel costs to calculate fuel poverty³⁰).

The fuel poverty gap provides a more useful indication of variations in fuel poverty levels between nations under the LIHC definition³¹. The average fuel poverty gap appears lowest in England at around £605 and highest in Wales at nearly £950. This suggests a greater 'depth', or more severe fuel poverty in the latter country (which corresponds with the findings from analysis of the 10% definition). The total (aggregate) fuel poverty gap for England in 2013 was some £1.4 billion, rising to over £1.8bn for the UK as a whole.

³⁰ See Annex B of the DECC fuel poverty report:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/319280/Fuel_Poverty_Report_Final.pdf

³¹ The fuel poverty gap is a measure of the extent to which a household falls below the energy cost threshold; or, rather, the reduction in fuel bill required to lift the household out of fuel poverty – see Box 4.1, page 15 for further details.

Table 5.10. Fuel poor households in the UK under the LIHC definition (2013)

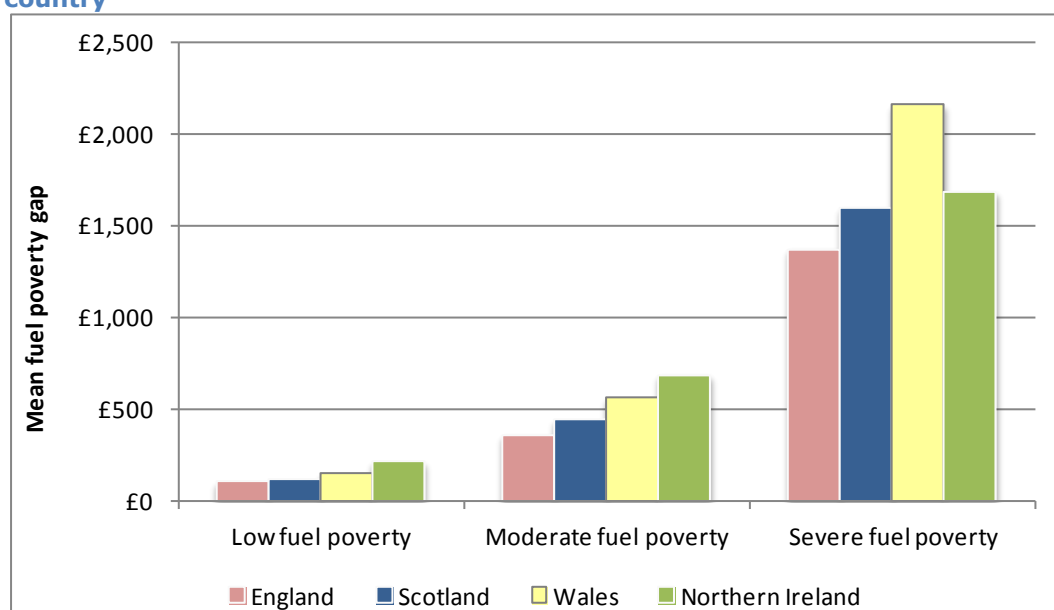
		England	Scotland	Wales	Northern Ireland	UK
In fuel poverty (LIHC definition)	Count (millions)	2.38	0.27	0.14	0.07	2.86
	Percent of households	11%	11%	11%	10%	11%
	Mean Income	£13,791	£11,350	£14,638	£12,160	£13,565
	Mean Required Fuel Costs	£1,866	£2,014	£2,729	£2,622	£1,942
	Mean fuel poverty gap	£605	£710	£949	£854	£638
	Aggregate fuel poverty gap (£m)	£1,439	£189	£135	£61	£1,825
Not in fuel poverty (LIHC definition)	Count (millions)	19.6	2.07	1.12	0.62	23.5
	Percent of households	89%	89%	89%	90%	89%
	Mean Income	£30,276	£25,985	£28,784	£24,017	£29,660
	Mean Required Fuel Costs	£1,397	£1,398	£1,902	£1,950	£1,436
All households	Count (millions)	22.0	2.3	1.3	0.7	26.3
	Mean Income	£28,496	£24,322	£27,191	£22,789	£27,912
	Mean Required Fuel Costs	£1,447	£1,468	£1,995	£2,020	£1,491
	"Low income" threshold (mean)	£12,760	£12,514	£11,596	£11,094	£12,638
	"Fuel costs" threshold	£1,266	£1,291	£1,726	£1,822	£1,323

5.4.2 Severity of fuel poverty (2013, LIHC definition)

As noted above, the fuel poverty gap provides a measure of the depth of fuel poverty under the LIHC definition. Table 5.11 shows the size of the gap for each country by 'terciles' (three equal sized groups of LIHC fuel poor households). The top tercile in England (the most severely fuel poor 33%) has a fuel poverty gap of between around £550 to over £7,500. The most severely fuel poor third of LIHC fuel poor households in Wales has an average fuel poverty gap of over £2,150 – notably higher than in all other countries which suggests a wide distribution in the gap in this nation.

Table 5.11. Fuel poverty gap split into three equal sized bands (by number households) for each country (2013, LIHC definition)

Country	Tercile category	Count	% of fuel poor HHs	Fuel poverty gap			
				Mean	Median	Minimum	Maximum
England	"Low" fuel poverty	793,000	33%	£99	£96	£0	£205
	"Moderate" fuel poverty	792,800	33%	£352	£339	£205	£560
	"Severe" fuel poverty	792,800	33%	£1,365	£1,047	£560	£7,523
Scotland	"Low" fuel poverty	88,600	33%	£105	£98	£1	£228
	"Moderate" fuel poverty	88,600	33%	£437	£425	£228	£726
	"Severe" fuel poverty	88,600	33%	£1,588	£1,305	£727	£5,699
Wales	"Low" fuel poverty	47,520	33%	£140	£151	£0	£268
	"Moderate" fuel poverty	47,640	33%	£557	£539	£268	£929
	"Severe" fuel poverty	47,440	33%	£2,154	£1,631	£929	£9,416
Northern Ireland	"Low" fuel poverty	23,800	33%	£209	£164	£3	£460
	"Moderate" fuel poverty	24,400	33%	£680	£704	£461	£866
	"Severe" fuel poverty	23,800	34%	£1,678	£1,183	£866	£7,214

Figure 5.13. Average fuel poverty gap of each tercile of the LIHC fuel poor in 2013 by country

5.4.3 Distribution of LIHC fuel poor in England (2013)

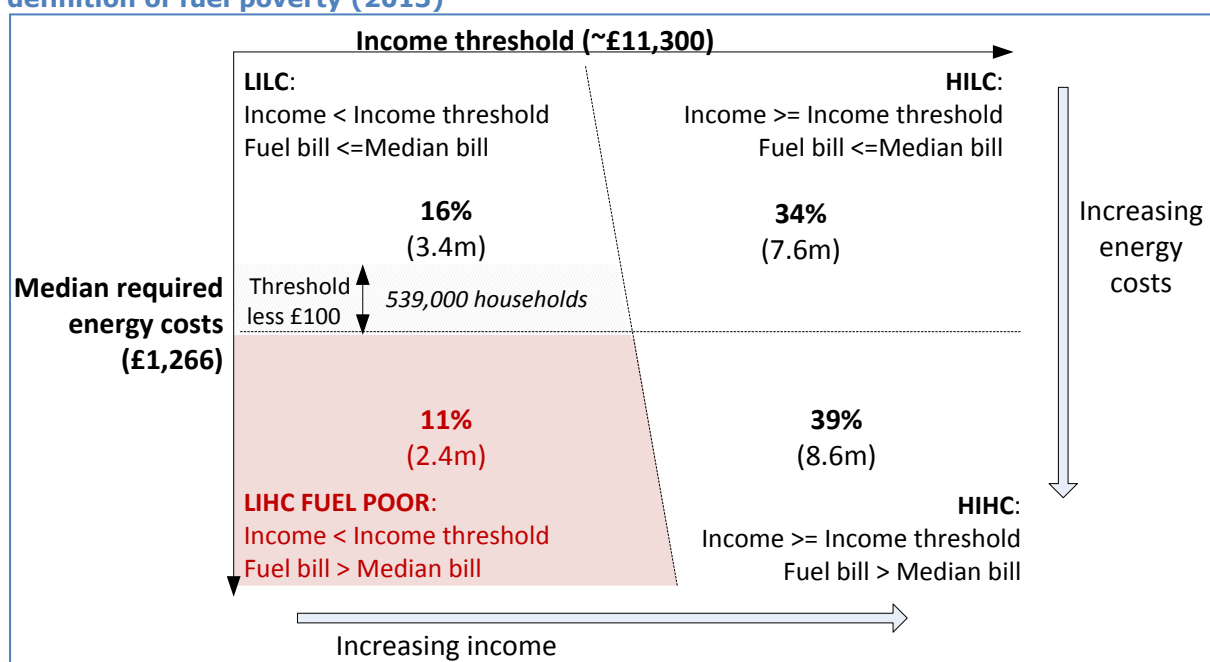
Given that only England has (so far at least) adopted the LIHC definition of fuel poverty, the detailed analysis of the distribution of fuel poor under this definition is limited to England only. This relates to all analysis presented in this section.

Figure 5.14 shows the distribution of households in England across the four 'quadrants' of the 'low-income, high-cost' definition of fuel poverty. The bottom left hand segment represents the fuel poor households – those with lower than average incomes, but higher than average fuel costs. The top left segment (some 3.4 million) represents households with low income, but lower than average required fuel costs. Households in this segment that have fuel costs nearing the threshold are at risk of being in fuel poverty, e.g. if fuel price rise and their incomes remain below average. Similarly, households in the bottom-right segment (the 'high income, high cost' group) could also be pushed into fuel poverty if their income fell but required fuel costs remained the same.

Analysis of the sensitivity of households to being pushed into fuel poverty is challenging, due to the moving threshold of the low-income, high-cost definition (e.g. an increase in required energy costs due to an increase in fuel prices would affect multiple houses, thus moving the median required fuel cost threshold for the population as whole). Some analysis was undertaken however, to quantify the number of households who have lower than average income and required energy costs within £100 of the current fuel cost threshold (represented by the shaded striped area in Figure 5.14 below).

The results identified a total of around 540,000 households in this low-income, borderline required fuel costs group. As noted above however, an increase in their required household fuel costs of £100 or less would not necessarily deem them LIHC fuel poor due to moving threshold.

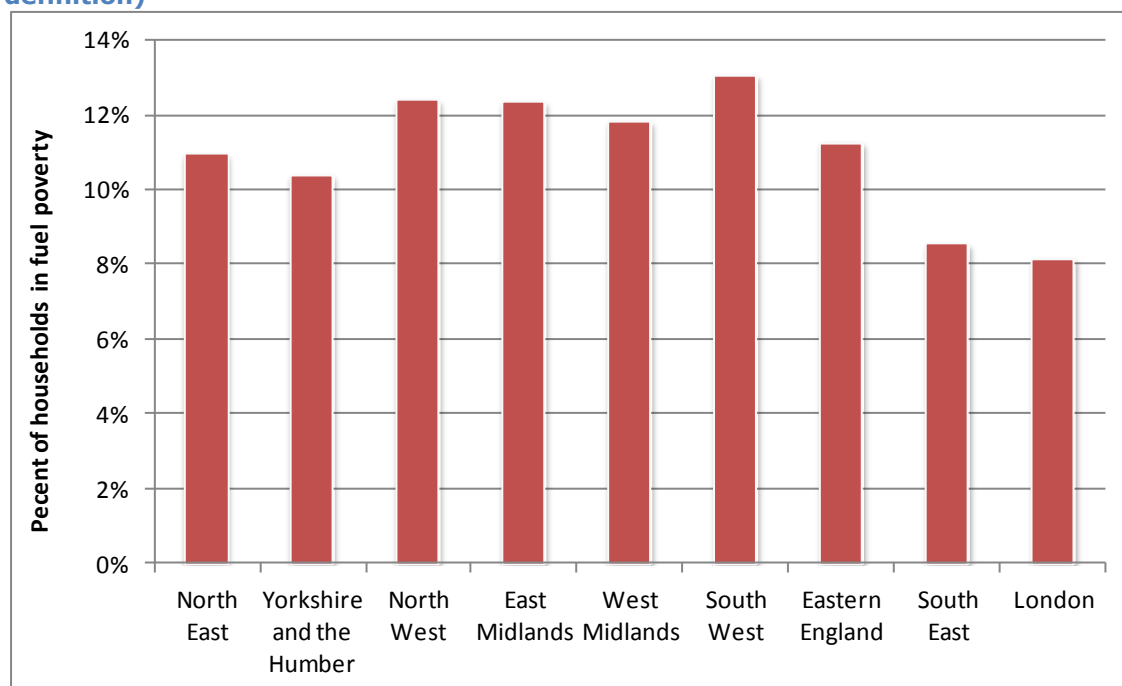
Figure 5.14. Distribution of households in England across the four quadrants of the LIHC definition of fuel poverty (2013)



Proportion of LIHC fuel poor households in each region

In England, fuel poverty rates under the LIHC definition in 2013 appear highest in South West and East Midlands (Figure 5.15).

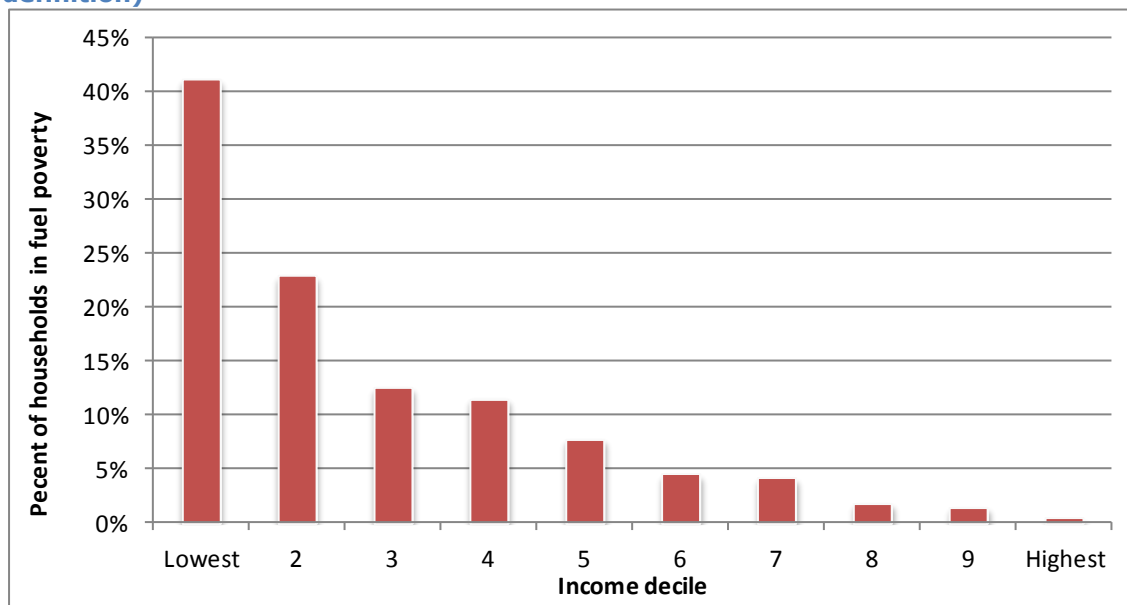
Figure 5.15. Proportion of fuel poor households in each region of England (2013, LIHC definition)



Proportion of LIHC fuel poor by income decile

A higher proportion of low income households were in fuel poverty in 2013 under the LIHC definition, as would be expected with income being integral to how fuel poverty is calculated under this approach (Figure 5.16).

Figure 5.16. Proportion of fuel poor households by income decile in England (2013, LIHC definition)



LIHC fuel poor by socio-demographic and physical property characteristics

Figure 5.17 to Figure 5.22 below show the proportion of fuel poor households by different spatial, physical property and socio-demographic variables. For comparative purposes the proportion of fuel poor households under the 10% definition is also shown (England only).

This shows that under the LIHC definition we see the highest proportions of fuel poor households in each of the following categories:

- Lone parents and single adult households under 60 (Figure 5.17)
- Properties in rural areas (Figure 4.17)
- Electrically heated dwellings (Figure 4.18)
- Private rented sector (Figure 4.19)
- Unemployed households (Figure 4.20)
- Larger dwellings (by number of bedrooms) (Figure 4.21)
- In properties without wall insulation (Figure 4.22)

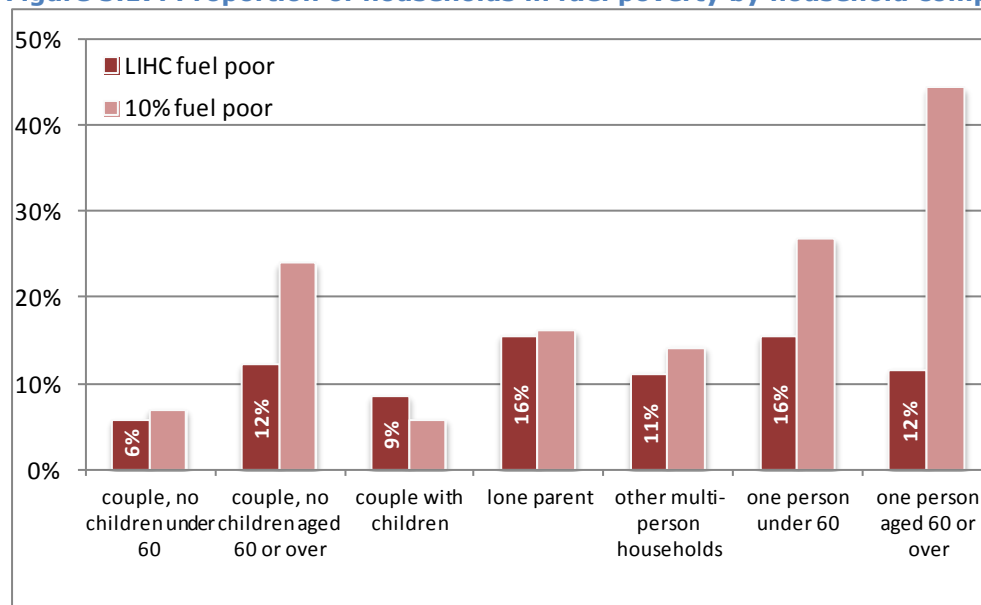
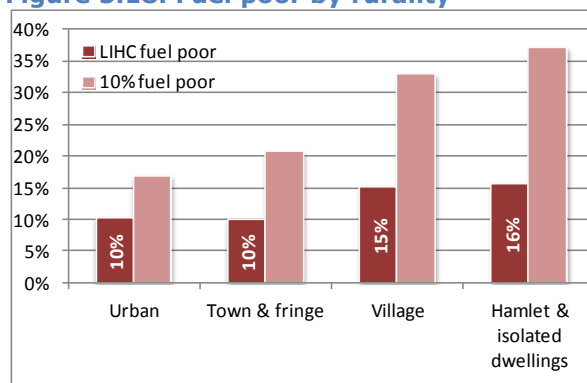
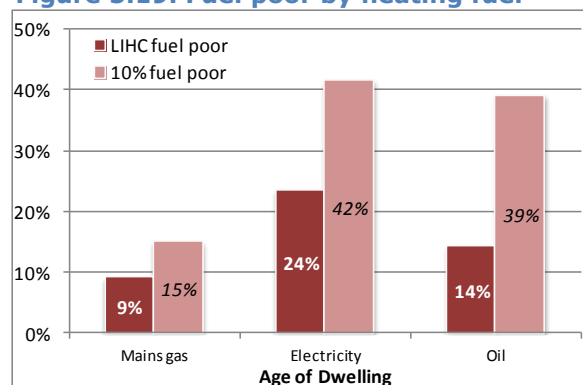
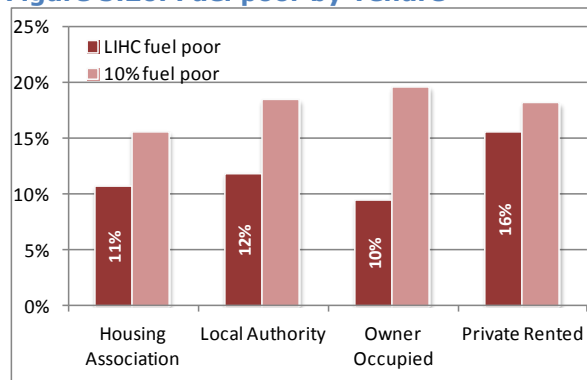
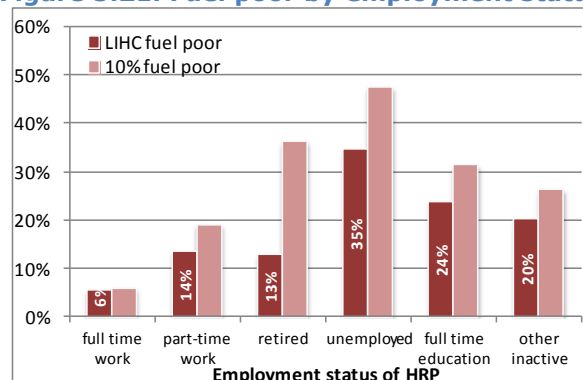
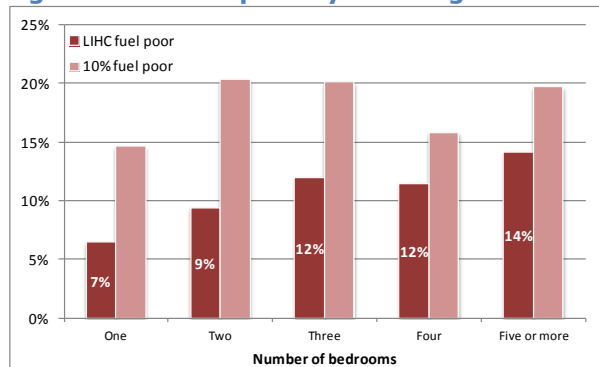
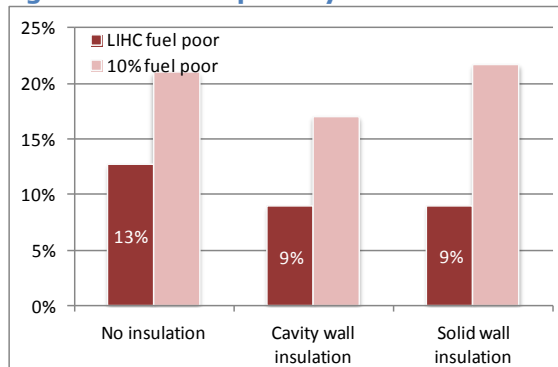
Figure 5.17. Proportion of households in fuel poverty by household composition**Figure 5.18. Fuel poor by rurality****Figure 5.19. Fuel poor by heating fuel****Figure 5.20. Fuel poor by Tenure****Figure 5.21. Fuel poor by employment status**

Figure 5.22. Fuel poor by dwelling size**Figure 5.23. Fuel poor by wall insulation**

5.4.4 Distribution of the LIHC fuel poor in England compared to the 10% fuel poor

The figures above show the proportion of LIHC fuel poor households by various factors. It is also useful to look at the *distribution* of fuel poor households (i.e. the total fuel poor population in England) across different socio-demographic descriptors. In doing this analysis, the distribution of households in fuel poverty under the '10%' in England is also shown. The tables below therefore illustrate some of the key differences between the types of households that make up the LIHC fuel poor population compared to the original 10% definition. The results highlight a shift in emphasis from the characteristics of the 'classic fuel poor' under the 10% definition (typically being owner occupiers, single adult households, over 60's and retired) to a greater proportion of private rented sector dwellings, couples and younger, working adults and larger dwellings.

It is worth noting at the outset the overall disparity in the households defined as fuel poor under each definition: around 42% of households classed as fuel poor under the 10% definition in 2013 in England were also fuel poor under the LIHC definition (Table 5.12), compared to 73% of the reverse.

Table 5.12. Overlap between the two fuel poverty definitions (England, 2013)

Proportion of 10% fuel poor also LIHC fuel poor:	42%
Proportion of LIHC fuel poor also 10% fuel poor:	73%

Box 5.5. Comparison of characteristics of the fuel poor population under the LIHC and 10% definition (England, 2013)

Tenure	Housing Association	Local Authority	Owner Occupied	Private Rented
LIHC Fuel Poor	9%	9%	60%	22%
10% Fuel poor	7%	8%	70%	15%

Household composition	couple, no children under 60	couple, no children aged 60 or over	couple with children	lone parent	other multi-person HH	one person under 60	one person aged 60 or over
LIHC Fuel Poor	9%	20%	18%	11%	7%	19%	16%
10% Fuel poor	7%	22%	7%	7%	5%	18%	34%

Age of HRP	16 - 24	25 - 34	35 - 44	45 - 54	55 - 64	65 or over
LIHC Fuel Poor	5%	9%	17%	21%	18%	29%
10% Fuel poor	4%	6%	10%	14%	19%	48%

Employment status	full time work	part-time work	retired	unemployed	full time education	other inactive
LIHC Fuel Poor	26%	11%	33%	11%	3%	16%
10% Fuel poor	16%	8%	53%	9%	2%	12%

Dwelling size	less than 50	50 to 69 sqm	70 to 89 sqm	90 to 109 sqm	110 sqm or
LIHC Fuel Poor	4%	11%	30%	21%	34%
10% Fuel poor	5%	16%	30%	17%	31%

	No insulation	CWI	SWI
LIHC Fuel Poor	58%	42%	1%
10% Fuel poor	54%	45%	1%

5.5 Who are the LIHC fuel poor?

5.5.1 Modelling LIHC fuel poverty

CHAID analysis was undertaken to further explore the key characteristics of the 'low income, high cost' fuel poor households in England.

Several iterations of CHAID analysis were attempted, using different input variables (dependent and independent) and modelling criteria. This included attempts at modelling the quadrants, to include identification of households who may be at risk from being in fuel poverty; and a simple model to predict LIHC (yes/no). These inputs delivered weak models however (for example, a CHAID model with 'in fuel poverty (LIHC definition)' as the dependent variable only correctly identified 5% (about 120,000 households) as LIHC fuel poor; similarly a model using the quadrants as the dependent

variable only identified around 9% (207,000) LIHC fuel poor). These models were therefore deemed of limited use in terms of understanding the key defining characteristics of the low income high cost fuel poor.

CHAID analysis was therefore undertaken instead on the fuel poverty gap. The gap is only applicable to households in the LIHC quadrant, hence the model was run on this subset of households only (Figure 5.24). As a result, it does not provide any information on the characteristics of households nearing fuel poverty under this definition (as was the case with the CHAID analysis of the 10% definition).

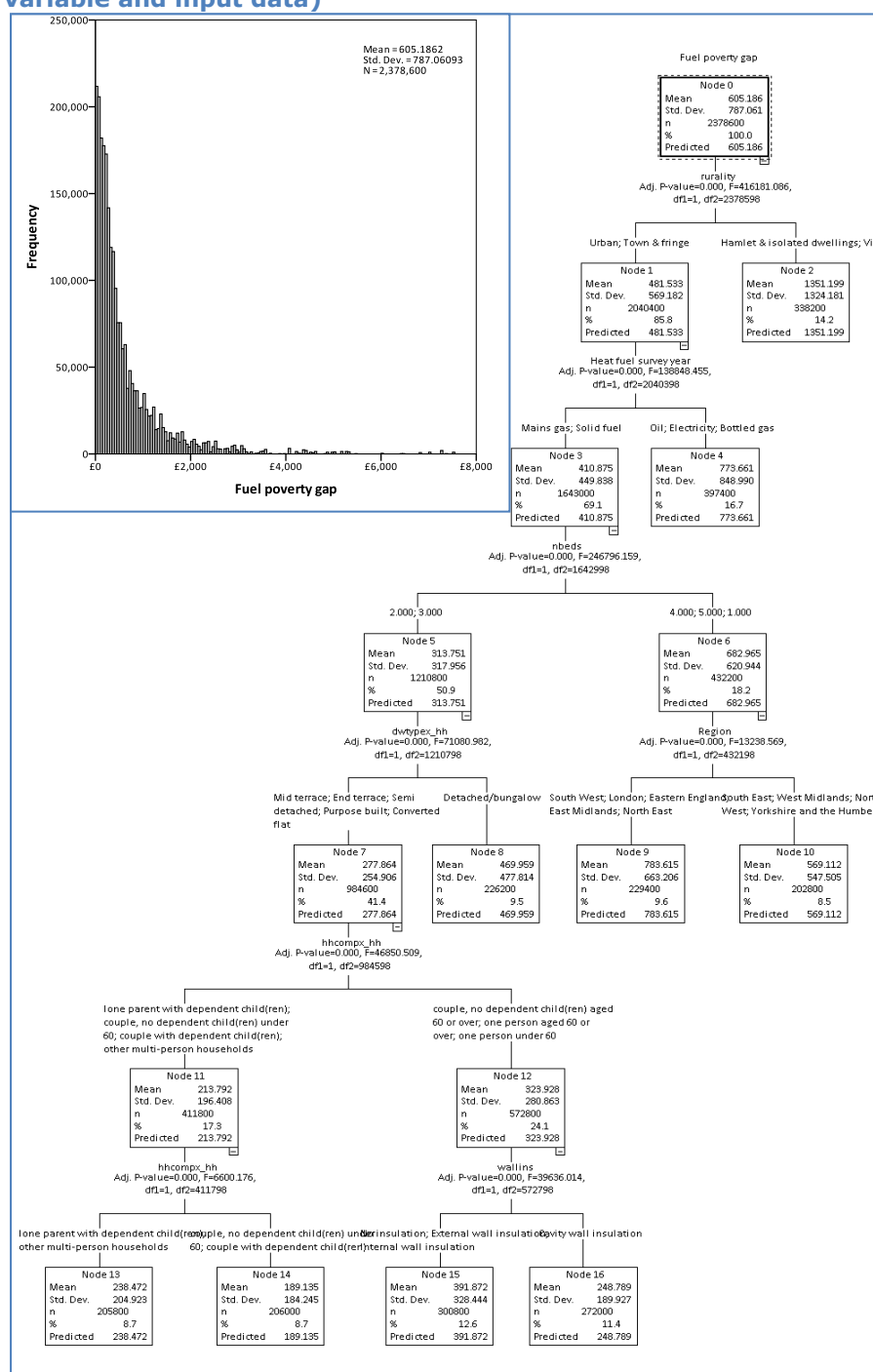
5.5.2 Results

The variables selected by the CHAID model as significant predictors of fuel poverty gap (illustrated in the CHAID tree diagram (Figure 5.24) below) included:

- urban/rural identifier
- heating fuel
- number of bedrooms
- dwelling type
- household composition
- wall insulation
- region

As the dependent variable in this model is a numeric value (the gap in £), CHAID assigns a predicted value to each household in the node, equal to the mean gap for the group as a whole. Within any one node there will be a range about this mean, but CHAID is designed to split the population in such a way that the variation of the dependent variable is minimized within the segments and maximized among the segments³². The results are therefore a set of distinct households grouped according to their likely depth of fuel poverty, as measured by the fuel poverty gap. Within the parameters specified, CHAID identified 9 different groups. These are described in further detail below.

³² Unlike in the previous CHAID models presented in this report, which had a categorical dependent variable (fuel poor/non-fuel poor), for a scale dependent variable the risk estimate is a measure of the within node variance (the average of the squared differences between data points and the mean of the node). A lower variance indicates a better model, but the variance is relative to the unit of measurement.

Figure 5.24. CHAID model of the fuel poverty gap and histogram of the gap (dependent variable and input data)

The nature of the low income, high cost definition of fuel poverty dictates that all fuel poor households have lower than average (equivalised) income. (Hence income was not included as a parameter in the model).

Key statistics for each node are shown in Table 5.13, ordered by the predicted value, with the most severely fuel poor group (largest fuel poverty gap) first. The key characteristics of each node are summarised below.

Table 5.13. Summary of nodes identified by the CHAID model of the fuel poverty gap

Node ID	Count	% of LIHC Fuel Poor population	% of all HHs in England	Mean Fuel Poverty Gap*	Equivalised fuel bill	Equivalised income	Old FP ratio	% Fuel Poor (10%)
2	338,200	14%	2%	£1,351	£2,657	£8,566	18%	85%
9	229,400	10%	1%	£784	£2,013	£7,101	12%	59%
4	397,400	17%	2%	£774	£2,092	£8,416	17%	86%
10	202,800	9%	1%	£569	£1,790	£6,905	10%	52%
8	226,200	10%	1%	£470	£1,764	£8,363	13%	75%
15	300,800	13%	1%	£392	£1,723	£7,268	17%	88%
16	272,000	11%	1%	£249	£1,551	£9,468	15%	87%
13	205,800	9%	1%	£238	£1,497	£8,524	11%	62%
14	206,000	9%	1%	£189	£1,435	£6,215	9%	36%
All LIHC FP	2,378,600	100%	11%	£605	£1,891	£7,970	14%	73%
All England	22,022,200		100%		£1,444	£22,824	5%	19%

* Predicted value assigned by CHAID model; equal to the mean fuel poverty gap for all households in the node

Node 2. Most severely fuel poor: Rural, off-gas households with older occupants.

- All households are in rural areas and largely off-gas (33% oil, 29% electric);
- Incomes appear slightly higher on the unequivalised scale, which reflects the fact that these are mainly couples.
- Occupants are mainly couples (53% or HMOs, 11%), without children (73%) and older (45% with HRP 65+) and retired (46%). Those under retirement age are predominantly inactive (11%) or in full time employment (27%).
- Mainly private sector housing (66% owner occupied, 20% private rented) and older (33% pre-1919), 2-3 bed, detached (62%) houses with uninsulated walls (54%).
- One fifth (22%) is in the East and South West regions (19%);
- 35% of households in this group have a long-term sick occupant and 83% are classed as "vulnerable".
- **85% of households in this node are also fuel poor under the 10% definition. This group is similar to node 4 under the 10% fuel poverty CHAID model.**

Node 9. Urban families in larger, detached, solid-wall uninsulated houses

- This group represents a working-age bracket (29% 35-44) with an HRP working full (39%), part-time (14%) or inactive (16%).
- It is dominated by private sector housing (73% owner occupied and 20% private rented).
- All dwellings have mains gas, being mainly in urban areas (91%). A third are in London and 25% are in South West.
- Properties are larger (all 4 or more bedrooms) detached and semi-detached houses, mainly older (39% pre-1919) and 64% without insulated walls.
- There is a mix of couples with children (33%) or lone parents (16%) or multi-adult households (13%), but generally larger families (21% have 3 or more children).

- There are fewer long-term sick but 73% are classed as 'vulnerable' (due to children in home).
- 59% of households in this group are fuel poor under the 10% definition

Node 4. Small, urban, electrically-heated, rented flats

- 86% fuel poor under 10% definition;
- Small (69% 1-2 bed), electrically-heated (92%), flats (38% purpose-built, 10% converted flats)
- Newer properties (48% post-1965); but over half without wall insulation
- Mixed tenure but mainly rented (33% social; 31% PRS);
- Out-of-work (unemployed (15%) or 'inactive' (20%) or retired (33%));
- Mixed occupancy but mainly single adults (48%) and without children;
- 38% long-term sick, 79% vulnerable and 7% disabled.

Node 10. Working age families and multi-adult households in larger urban detached and semi's

- Only half (52%) fuel poor under 10% definition;
- Higher income on unequivalised scale (Table 5.14)
- Working-aged HRP (58% 35-54) and working full (40%) or part-time (16%);
- All mains gas and urban areas;
- Mainly detached (39%) or semi's and larger dwellings (4+ bedrooms), half without wall insulation
- Private sector (68% owner occupied, 24% private rented);
- Mainly couples (56%) or HMOs (24%), and larger families (59% have children, 22% with 3 or more)
- High proportion in North West (38%) and South East (31%);
- 79% vulnerable (due to children).

Table 5.14. Comparison of mean equivalised and unequivalised income for each node

Node ID	Household income	
	Equivalised household income (LIHC definition)	Full household income (10% definition)
2	 £8,566	 £14,435
9	 £7,101	 £18,841
4	 £8,416	 £11,682
10	 £6,905	 £19,738
8	 £8,363	 £13,077
15	 £7,268	 £8,937
16	 £9,468	 £9,389
13	 £8,524	 £14,104
14	 £6,215	 £18,697
All LIHC Fuel Poor	£7,970	£13,791
All England	£22,824	£28,496

Table notes: size of bars illustrates level of income

Node 8. Retired couples in newer 3-bed detached houses in urban and fringe areas

- 75% fuel poor under 10% definition;
- Retired couples (54%) who own their home;
- Newer dwellings (51% post-1965);
- All detached, 3-bed and in urban but more town and fringe areas (22%);
- 40% long term sick and 87% vulnerable.

Node 15. Older private-sector dwellings without wall insulation, under-occupied by single retired

- Very low income (on equivalised and non);
- 88% fuel poor under 10% definition;
- Single adults without children in 3-bed terraced or semi-detached houses (under-occupiers);
- Older dwellings (43% pre-1919, 31% 1919-1944) and 95% without wall insulation
- Private sector (61% owner-occupied, 22% private rented);
- Retired (40%) or unemployed (20%) but nearing age of retirement;
- Urban areas with mains gas heating;
- 38% LT sick

Node 16. Under-occupying single adults in 3-bed post-war semi's with insulated cavity walls

- 87% fuel poor under 10% definition (low income on both scales);
- Post-war housing (44% 1945-65)
- 3-bed semi-detached, with mains gas heating in urban areas;
- All with insulated cavity walls
- Mixed tenancy (22% social; 72% owner-occupied);
- Mainly single older (51% over 65) adults, all without children (under-occupying)
- A quarter (23%) in North West and 15% North East;
- 43% long term sick and 82% vulnerable.

Node 13. Out-of-work lone parents in rented, older houses without insulated walls

- 63% fuel poor under 10% definition;
- Out-of-work (22% unemployed, 32% inactive) or part-time (16%) working
- Lone parents (67%) or HMOs (33%);
- Younger HRP (35% under 35) and 70% with children in the home;
- Mains gas-heated, rented (39% private rented, 27% social), 3-bed terraced and semi-detached houses;
- Older dwellings (32% pre-1919, 24% 1919-1944);
- 72% without wall insulation.

Node 14. Working families in inter-war housing without insulation

- Higher income on unequivalised scale and only 36% fuel poor under 10% definition;
- Working full (55%) or part-time (14%);
- Inter-war and post-war housing with mains gas heating
- Mix of rented (24% private rented, 21% social) and owner-occupied (55%);

- No single adult households – mainly working age (68% 35-54) couples, 59% of whom have children;
- In 3-bed semi-detached houses;
- 68% without wall insulation;
- Urban, 21% in London;
- 8% receiving disability benefit

Comparing the results of the LIHC CHAID with the 10% CHAID model (for England only) shows that there are some overlaps in the groups identified. For example:

- 85% of the most severely LIHC fuel poor group are also fuel poor under the 10% definition and a third of this group fall into node 4 of the 10% CHAID model: **rural, off-gas** properties were a key defining feature of both these groups.
- Node 4 of the LIHC model also overlaps with node 4 of the 10% CHAID model. Looking at the key characteristics of these groups suggests in this instance it is the presence of **electric heating** and **flats** that align.
- One fifth of LIHC node 15 and node 13 are also in node 9 of the 10% CHAID groups. The key overlapping characteristics of these nodes relates to them being **older properties without solid wall insulation**.

5.6 Chapter summary

This chapter has presented some lengthy and detailed analysis of fuel poor households in the UK in 2013, as modelled using the NHM.

These results provide some further understanding of the characteristics of households most likely to be in fuel poverty, which are important considerations in designing and targeting a fuel poverty alleviation programme. The adoption of the new definition of fuel poverty in England, combined with fuel poverty being a largely a devolved issue, suggests results from this analysis may be of more relevance and use at the individual country level, rather than for the UK as a whole. The nodes identified by the CHAID model of fuel poverty under the 10% definition provide some clear descriptions of groups to target in Wales, Scotland and Northern (see Box 5.2, Box 5.3 and Box 5.4 respectively), whilst the results from the analysis of the LIHC definition should be used for England.

Later in this report we return to these groups, to explore the extent to which groups are benefiting from measures simulated in the modelling of the CCC's projections to 2030; which households are lifted out of fuel poverty as a result; which remain and which households become fuel poor overtime.

6 Modelling fuel poverty to 2030

This chapter presents the results from modelling (using the NHM) to explore the implications for fuel poverty to 2030 of meeting the fourth carbon budget's expectations for the residential sector. The main inputs for this modelling were the CCC's projected time series of measures needed in the residential sector to deliver the necessary emissions savings; and fuel prices projected to 2030 (also provided by the CCC with additional development by CSE to provide a more detailed breakdown by region, fuel, method of payment and tariff type). Chapter 4 (section 4.3 onwards) provides a full description of the modelling inputs, assumptions and method.

As described in Chapter 4, multiple scenarios were modelled to explore the implications for fuel poverty of simulating the deployment of the CCC's projected measures and fuel prices. The scenarios apply (in various combinations) different assumptions around how the measures are allocated across the UK housing stock and if/how much of the costs are passed on to consumers through energy bills. For reference, the scenarios are summarised again below (Table 6.1).

Table 6.1. Scenarios for modelling the 4th carbon budget in the residential sector and implications for fuel poverty to 2030

Scenario	Description	Key points
Sc.1	2030 "counterfactual" fuel prices scenario	No measures deployed and fuel prices stripped of all policy costs to show only the impacts of expected changes in systems costs to 2030.
Sc.2	2030 alternative counterfactual	No measures deployed and no domestic energy efficiency/low carbon policy costs included in the fuel prices, but "upstream" policy costs are included (EUETS, RO etc).
Sc.3 - 8	The CCC's projected measures for meeting the 4 th carbon budget in the domestic sector to 2030	All measures in the CCC's projections simulated. The key differences between each scenario relate to whether measures are randomly distributed or targeted; if targeted, at whom and with what objective; and whether the costs of measures are recovered through energy bills, as shown below
Sc.3 a-c	Random allocation: All measures distributed at random across the UK housing stock (where opportunities to install measure)	a) No costs passed on through consumer energy bills b) Full costs of measures passed on to energy bills c) Partial costs: all measures costs excluding SWI, boilers & PV passed on to energy bills
Sc.4 a-c	LIHC fuel poor targeted with measures first aiming to minimise their fuel costs; Remaining measures distributed at random	a) No costs passed on through consumer energy bills b) Full costs of measures passed on to energy bills c) Partial costs: all measures costs excluding SWI, boilers & PV passed on to energy bills
Sc.5 a-c	"10%" fuel poor targeted with measures first to minimise fuel bills; remaining measures at random	a) No costs passed on through consumer energy bills b) Full costs of measures passed on to energy bills c) Partial costs: all measures costs excluding SWI, boilers & PV passed on to energy bills
Sc.6 a-c	LIHC fuel poor targeted with measures first aiming minimise fuel bills; Secondary targeting of remaining measures to minimise emissions.	a) No costs passed on through consumer energy bills b) Full costs of measures passed on to energy bills c) Partial costs: all measures costs excluding SWI, boilers & PV passed on to energy bills
Sc.7 a-c	Non-LIHC fuel poor targeted with all measures (i.e. LIHC fuel poor excluded from receiving any measures)	a) No costs passed on through consumer energy bills b) Full costs of measures passed on to energy bills c) Partial costs: all measures costs excluding SWI, boilers & PV passed on to energy bills
Sc.8 a-c	Non-LIHC fuel poor targeted with main measures (i.e. LIHC fuel poor excluded from receiving any heating and insulation measures; still receive some lighting and appliances)	a) No costs passed on through consumer energy bills b) Full costs of measures passed on to energy bills c) Partial costs: all measures costs excluding SWI, boilers & PV passed on to energy bills

Running multiple scenarios inevitably generates a complex picture of outputs. The results presented in the section that follows focus on the key statistics to show the implications of each scenario for fuel poverty in the UK and by country in 2030, under both definitions. To help understand these outputs, the implications of the *two principal differences* between scenarios – namely different approaches to allocating measures and different approaches to recovering costs – are summarised first below.

6.1.1 The implications of targeting in the modelling scenarios

This study applies a ‘bottom-up’ approach in modelling the impact of fuel price rises, energy efficiency and low carbon measures on UK household energy consumption and bills. The energy savings – and therefore emissions reductions – resulting from the simulation of measures depends on the types of households that receive them. As energy demand is calculated in the NHM for every household represented in the housing stock dataset (using detailed data about the physical property characteristics), the impact of a scenario in which measures are allocated to more larger dwellings (for example) may result in greater overall reductions than had the measures been allocated to smaller properties. Targeting of measures at specific household types and for a specific purposes (e.g. minimise fuel bills) will therefore influence the level of emissions savings even though the inputs, in terms of total number and types of measures in the simulation, remain the same.

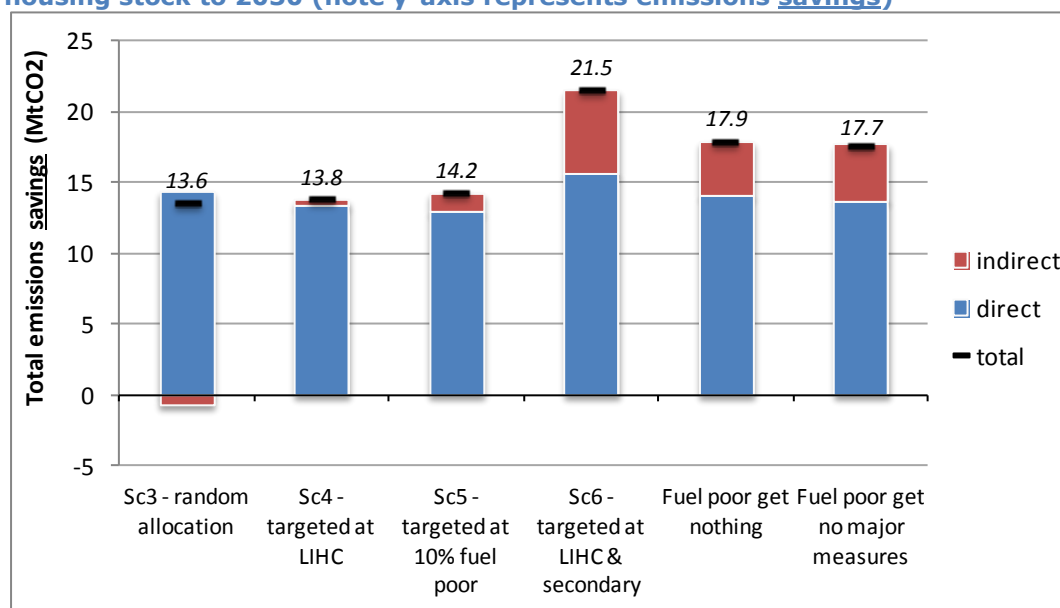
The impact on total residential emissions of simulating the installation of measures in the CCC’s projected time series under the different approaches to targeting is shown below (Figure 6.1)³³. The results show that the level of emissions reduction achieved differs slightly according to the presence or absence of targeting in the scenario. Some of the scenarios (namely the random allocation – scenario 3) show a slight overall increase in indirect emissions (note the y-axis scale shows cumulative emissions savings hence a negative value represents an increase). There will be a number of different factors driving these patterns, including the installation of heat pumps, the types of households (e.g. size, dwelling type, heating fuel etc) receiving measures in each simulation, and the inclusion of the heat replacement effect (see Box 6.1).

Scenario 6 results in the greatest overall emissions savings, which is to be expected as this scenario included an element of ‘secondary targeting’ to deliver measures to households in order to minimise emissions as far as possible (after first targeting the LHC fuel poor).

The scenarios targeting the fuel poor (Sc.4 and Sc.5) appear to deliver slightly greater emissions savings than the random allocation scenario (Sc.3) but less than the scenarios in which fuel poor households are excluded from receiving any (or any major) measures (Figure 6.1). Excluding the fuel poor is likely to result in a higher proportion of larger dwellings receiving measures; hence we may expect a greater level of overall emissions savings, as observed here.

³³ For the purpose of showing the impact of measures only carbon emissions factors have been held constant here. In addition, whilst there are three sets of outputs from each scenario (no cost recovery, full costs on bills and partial costs on bills), only one result for emissions are shown here. There is some difference in the emissions savings between each run due to the randomness within the model and interacting effects when targeting measures to reduce fuel bills with and without the costs of measures on bills. These differences are marginal however and the focus of this project is the impact of measures on fuel poverty rather than emissions.

Figure 6.1. Total impact on residential emissions of simulating measures across the UK housing stock to 2030 (note y-axis represents emissions savings)



Box 6.1. Heat pumps, heat replacement and interaction effects

There are some 4 million heat pumps in total in the CCC's 4th carbon budget scenario to 2030, with over 300,000 being installed every year from early 2020's. This will result in some fuel switching (households moving away from fossil fuel heating and effectively to electrically-driven heating) and therefore some increase in electricity demand. This may explain the slight overall increase in indirect emissions observed in the random allocation scenario (note the y-axis scale shows cumulative emissions savings hence a negative value represents an increase). The absence of any targeting in this scenario means measures are not allocated on any particular basis (in reality there is likely to be some rationale driving the installation of measures – e.g. fuel bill saving to the householder; carbon saving to an obligated supplier) hence this scenario is difficult to unpick and explain.

The modelling applied here also includes implementation of the heat replacement effect. This assumes that as household appliances become more efficient, thereby giving off less residual heat, households will need to increase their heating fuel use to compensate for this and maintain the same indoor temperature. The impact of new appliances on electricity demand (indirect emissions) in an electrically-heated home is therefore dampened by the need for a slight increase in electricity use for heating. The types of households receiving measures in the scenarios will affect the overall results observed. Under the fuel poor targeted scenarios a greater proportion of low income households will be receiving measures. These are more likely to be smaller dwellings and electrically-heated (electric heating is more prevalent in lower income households³⁴ and the average electricity consumption for LIHC fuel poor is around 1,000kWh higher than non-fuel poor). This may explain some of the variation we see in the level of direct and indirect emissions savings under the different scenarios.

³⁴ E.g. see: White, V., Roberts, S. and Preston, I. (2010). Understanding 'high use low income' energy consumers. Report to Ofgem. Available at: http://www.cse.org.uk/pdf/understanding_high_use_low_income_energy_consumers.pdf

6.1.2 The implications of different approaches to cost recovery in the scenarios

Figure 6.2 and Figure 6.3 show the impact on the unit price of gas and (peak) electricity of passing on the (capital) costs of measures deployed in these scenarios to household energy bills. The pattern (the peaks and troughs) reflect the time series of measures simulated (i.e. a peak reflects a year when more/more expensive measures are installed³⁵). The 'no costs on bills' represent the counterfactual fuel prices as supplied by the CCC for the purpose of this research. Fuel poverty levels will be higher in any scenario in which cost-recovery is applied, being highest under the 'full costs' scenario, due to higher fuel prices.

Figure 6.2. Impact on gas unit price of passing on costs of measures

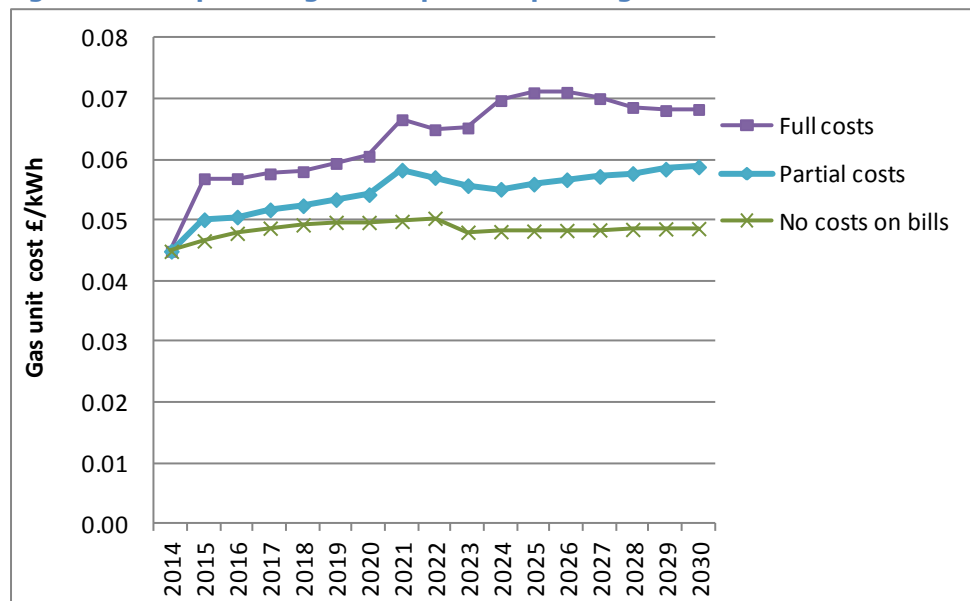
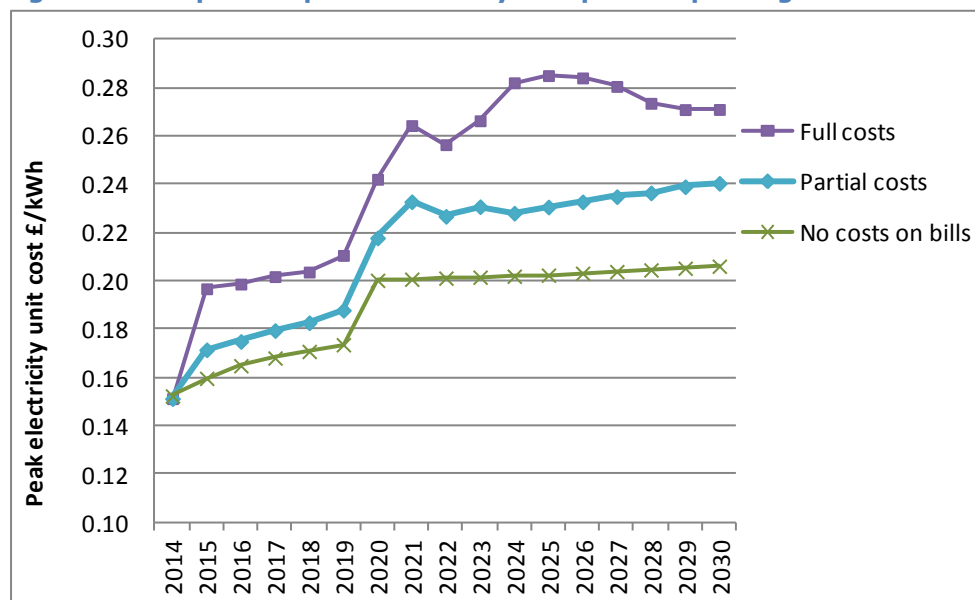


Figure 6.3. Impact on peak electricity unit price of passing on costs of measures



³⁵ Whilst the total cost of measures in each year – and therefore the cost passed on to bills – is dependent to some extent on the households that receive the measure (as the cost of some measures is related to the size of the house in which it is installed – see Annex IV – the effect varies little from one scenario, hence just one figure is shown here to be indicative of all scenarios.

6.2 Impact on fuel poverty: headline results for each scenarios

The results presented here show the headline results from each scenario, in terms of implications for fuel poverty (in the UK and by country, under both definitions) in 2030 and emissions reductions.

6.2.1 Scenario 1. Counterfactual fuel prices to 2030: systems costs only

Impact on fuel poverty in 2030 under the 10% definition

Under a counterfactual fuel price scenario, where only "system costs" are included in projected fuel prices to 2030, fuel poverty levels increase by around 3% on the 2013 baseline (an additional 713,000 households), to 24% for the UK as a whole (Figure 6.4). There appears a distributional impact across the different nations, however, with fuel poverty levels in England, Wales and Scotland increasing by 2-3% whilst in Northern Ireland fuel poverty levels increase to 63% in 2030 (Figure 6.5). This is due to the reliance on more expensive fuels for heating (lack of mains gas) and the projected increases in prices for these fuels under this scenario.

Impact on fuel poverty in 2030 under the LIHC definition

The impact of a counterfactual fuel price scenario on fuel poverty levels under the LIHC definition is less pronounced, with an additional 92,000 households in fuel poverty in 2030 (11.2%) compared to the 2013 baseline (10.9%) (Figure 6.4). The LIHC method is such that the fuel cost threshold will have shifted up to reflect the new, higher median fuel costs resulting from the fuel price rises. There will be some differential impact however (hence some households are pushed into fuel poverty) as a result of reliance on different fuels for heating fuel.

Figure 6.4. Impact of the counterfactual fuel price scenarios on fuel poverty in the UK in 2030 (both definitions)

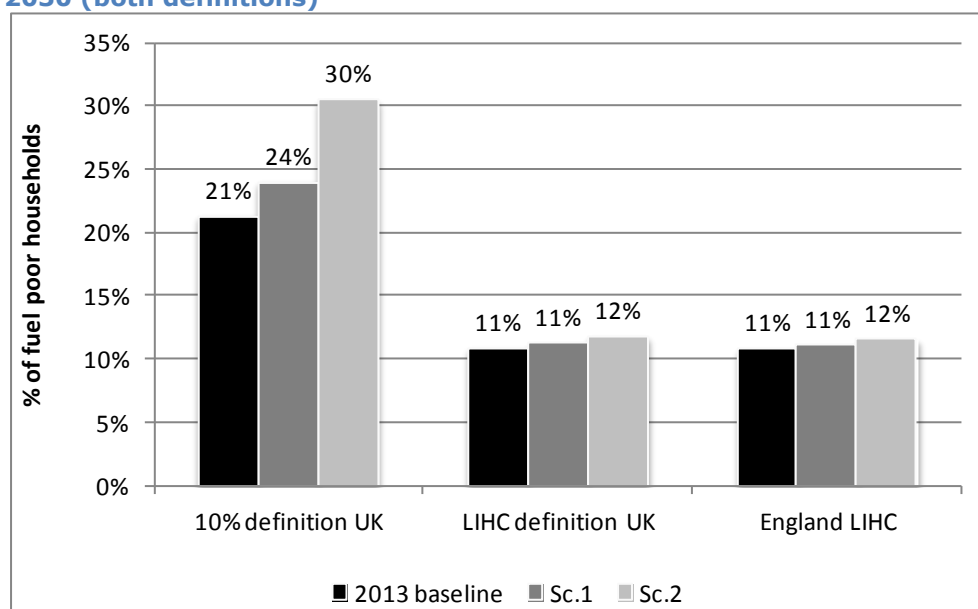
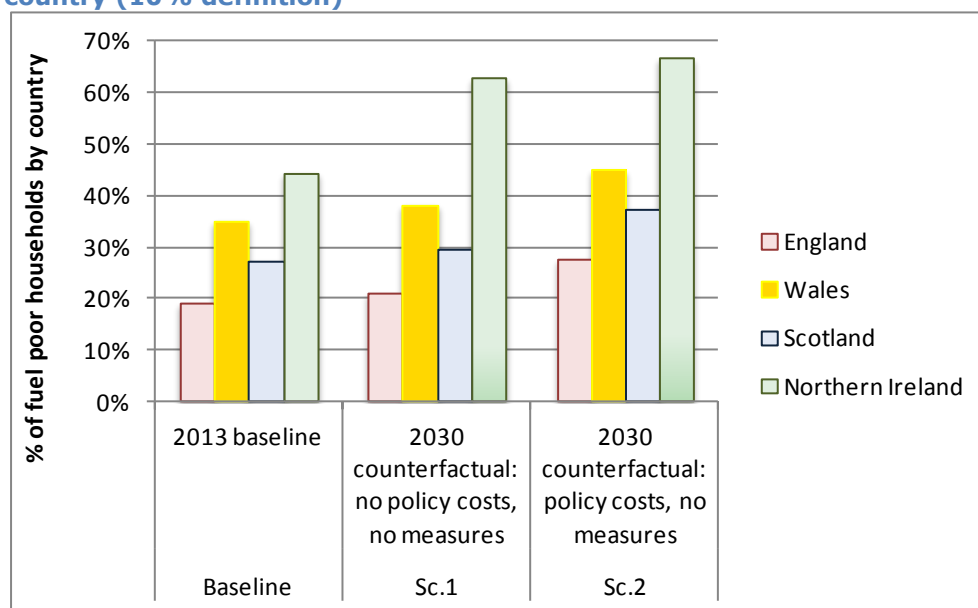


Figure 6.5. Impact of the counterfactual fuel price scenarios on fuel poverty in 2030 by country (10% definition)**Table 6.2. Impact of the counterfactual fuel price scenarios on fuel poverty in 2030 under the LIHC definition (UK)**

		In fuel poverty (m)	% fuel poor	Mean fuel poverty gap	Aggregate fuel poverty gap (£bn)
2013	2013 baseline	2.86	11%	£639	£1.82
Sc.1	2030 counterfactual: no policy costs, no measures	2.95	11%	£774	£2.28
Sc.2	2030 counterfactual: policy costs, no measures	3.10	12%	£874	£2.71

6.2.2 Scenario 2. Counterfactual fuel prices to 2030: systems and policies costs (excluding "energy efficiency")

Impact on fuel poverty in 2030 under the 10% definition

This scenario provides a baseline against which to compare the CCC carbon budget scenarios. The fuel tariffs applied here reflect the CCC's fuel price projections to 2030 including all system and policy costs with the exception of "energy efficiency" (as no measures are installed under this scenario). With fuel prices increasing but no changes made to the energy efficiency of the housing stock, fuel poverty levels increase substantially under this scenario, to 30% for the UK (Figure 6.4) as a whole (some 8 million fuel poor households), and 70% in Northern Ireland under the 10% definition (Figure 6.5).

Impact on fuel poverty in 2030 under the LIHC definition

There is relatively little change in the proportion of fuel poor households under the LIHC definition again, due to the moving threshold, but the fuel poverty gap increases to an average of over £870, and £2.7bn across the UK as a whole (Table 6.2) – an increase of £0.88bn on the 2013 baseline.

6.2.3 Scenario 3: Random allocation of measures

This group of scenarios shows the impact of the CCC's projections for measures needed in the UK residential sector to deliver emissions savings in line with the 4th carbon budget, whereby installation of measures is simulated 'at random' across the UK housing stock (amongst those properties that are suitable for each measure). It should be noted that whilst there is no targeting of measures in these scenarios (beyond the dwelling being suitable and the measure not making them worse off), within this 'random allocation' some fuel poor households will be receiving measures. In reality, in the absence of any targeting, fuel poor households would be unlikely to get any share of the measures because they do not have the capital means to do so. The random allocation scenario is therefore an *underestimate* of fuel poverty levels in the absence of any targeting (the final set of scenarios developed simulate this, by excluding fuel poor households from receiving measures).

As with all the scenarios, this initial 'random allocation' scenario was modelled without any costs of measures put on energy bills; with the full (capital) costs of insulation, heating and renewable energy measures passed on to mains gas and peak electricity (equal proportion of costs on each, on p/kWh basis); and with partial costs passed on to energy bills (where partial excludes boilers, SWI and PV costs).

Impact on fuel poverty in 2030 under the 10% definition

Simulating the installation of measures (which includes 3.5 million solid walls insulated by 2030; and all lofts and cavity walls insulated by around 2022) at random across the UK housing stock and without adding the costs of these measures to energy bills leaves 22% of UK households in fuel poverty under the 10% definition (scenario 3a, Figure 6.6). This figure is (as we would expect) lower than the counterfactual fuel price scenario (sc.2), and similar to the 2013 baseline. The results suggest therefore that the measures simulated here are effectively protecting further households from being pushed into fuel poverty as a result of fuel price rises to 2030 (as per scenario 2), but insufficient to reduce fuel poverty levels compared to the 2013 baseline.

The differential impact across nations should again be noted, with fuel poverty in Northern Ireland still higher than the 2013 baseline, even with measures being installed (Sc.3a, Figure 6.7).

Running the same simulation of measures, again deployed at random across the UK housing stock, but with the full cost of these measures recovered through (peak) electricity and gas bills (on a p/kWh basis) results in fuel poverty levels increasing by 2030, to some 33% across the UK as a whole (scenario 3b, Figure 6.6). This reflects the fact that a total cost of some £168bn is now being added to all household bills, whilst around 18 million unique dwellings are benefiting from measures.

With the costs of boilers, solid wall insulation and PV excluded from the sum being passed on to bills (reducing the total cost of measures being deployed to around £71bn), fuel poverty levels are still higher in 2030 than the 2013 baseline (Sc.3c, Figure 6.6), but appear lower than the counterfactual scenario (Sc.2) where no measures are deployed. This suggests that even with some costs of energy efficiency and low carbon measures being passed on to energy bills, the benefits of the measures are sufficiently offsetting the impact of fuel price rises to 2030. This result is only true at the aggregate UK level however. There will be a wide distribution of households better and worse off (e.g. those receiving a measure may see their bill go down in 2030 compared to the counterfactual scenario;

whilst others experience a significant increase in their household energy bill; the effect across different countries of the UK is indicative of this distributional impact).

Figure 6.6. Impact of scenario 3 on fuel poverty in the UK in 2030 (both definitions)

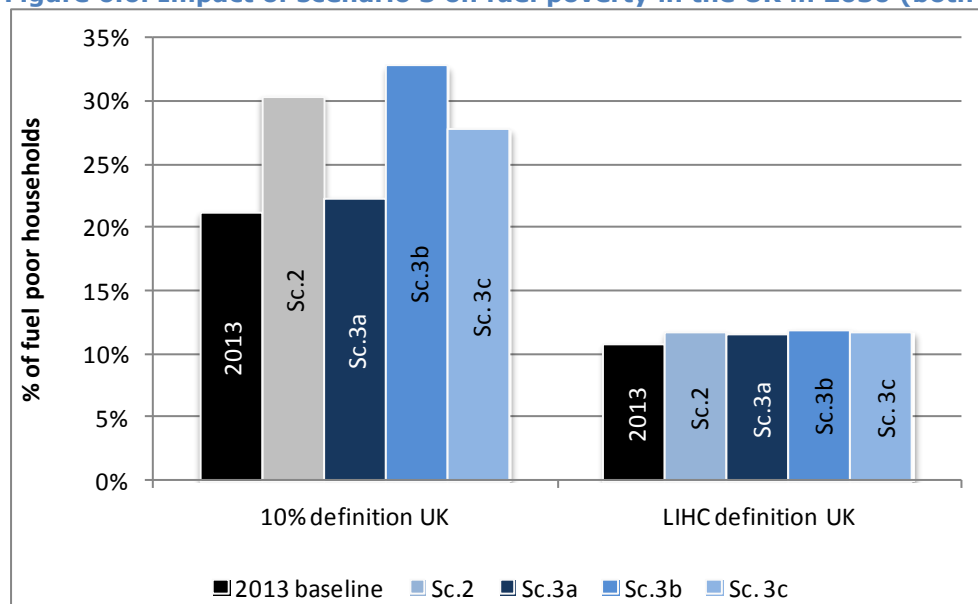
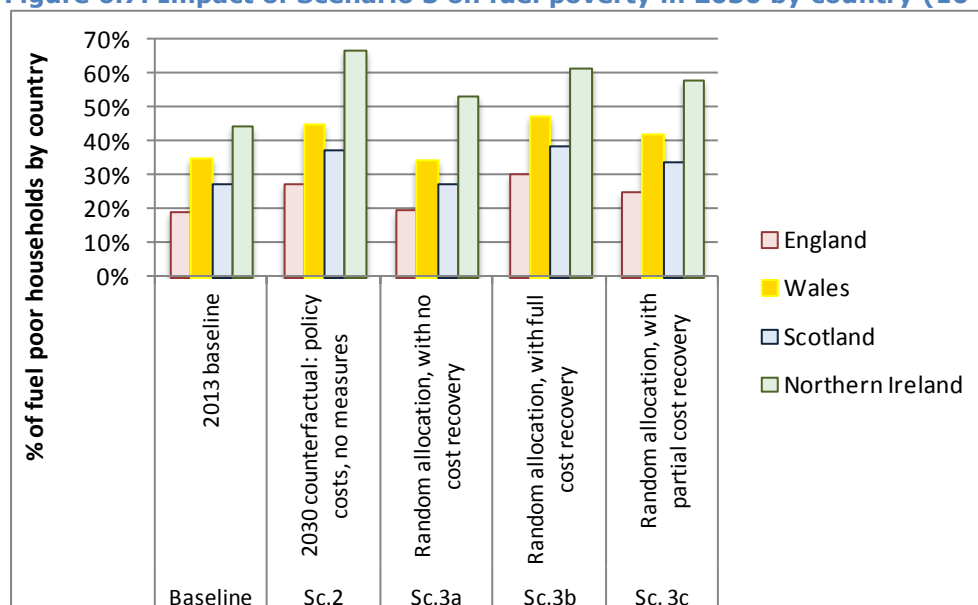


Figure 6.7. Impact of Scenario 3 on fuel poverty in 2030 by country (10% definition)



Impact on fuel poverty in 2030 under the LIHC definition

With measures allocated at random and no costs passed on to energy bills, fuel poverty levels under the LIHC definition remain around 2013 baseline levels (scenario 3a, Figure 6.6m right hand cluster of bars), again suggesting the impact of the energy efficiency measures deployed off-set the fuel price rises to 2030. The average and aggregate fuel poverty gap is slightly higher than baseline levels under this scenario however, at £713 and £2.17bn respectively (Figure 6.1, Sc.3a).

Running the same simulation of measures, deployed at random across the UK housing stock, but with the full cost of these measures recovered through (peak) electricity and gas bills (on a p/kWh

basis) results in fuel poverty levels under the LIHC definition increasing to 3.15 million (2.60m in England) by 2030 with an aggregate fuel poverty gap of nearly £2.5bn.

Table 6.3. Impact of Scenario 3 on fuel poverty in 2030 under the LIHC definition (UK)

		In fuel poverty (m)	% fuel poor	Mean fuel poverty gap	Aggregate fuel poverty gap (£bn)
2013	2013 baseline	2.86	11%	£639	£1.82
Sc.2	2030 counterfactual: policy costs, no measures	3.10	12%	£874	£2.71
Sc.3a	Random allocation, with no cost recovery	3.04	12%	£713	£2.17
Sc.3b	Random allocation, with full cost recovery	3.15	12%	£786	£2.47
Sc. 3c	Random allocation, with full partial cost recovery	3.10	12%	£747	£2.32

6.2.4 Scenario 4: Targeting measures at LIHC fuel poor

This group of scenarios shows the impact of the CCC's projections for measures needed in the UK residential sector to deliver emissions savings in line with the 4th carbon budget, whereby LIHC fuel poor households are targeted and prioritised to receive measures first. In each year of the simulation the model prioritises installing measures in (LIHC) fuel poor households that will result in the greatest reduction in fuel bill (i.e. targeting has both a 'subject' (the LIHC fuel poor) and an 'objective' (minimised fuel costs). Any remaining measures are then distributed at random across the UK housing stock. This scenario effectively simulates "perfect" targeting of measures at LIHC fuel poor households.

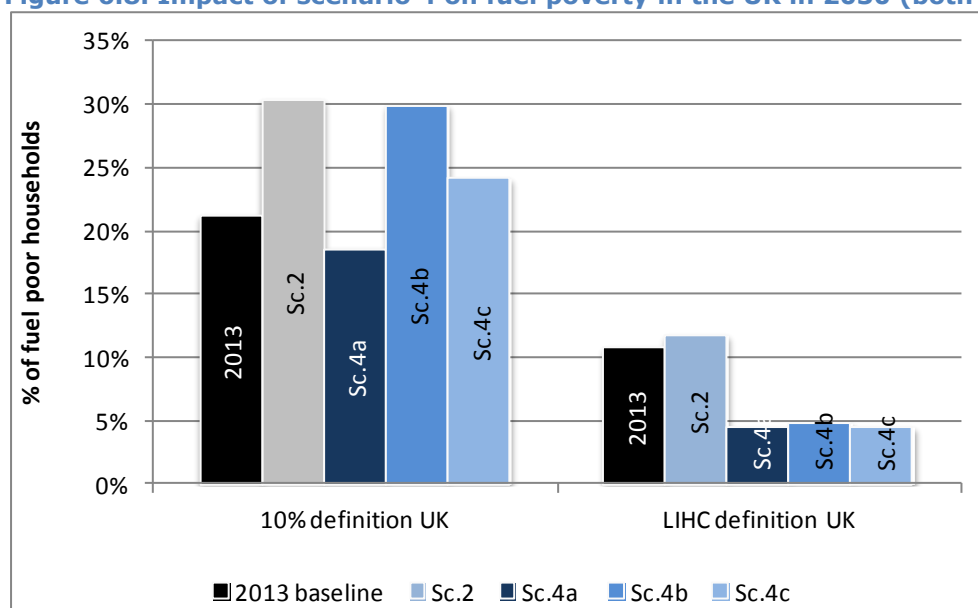
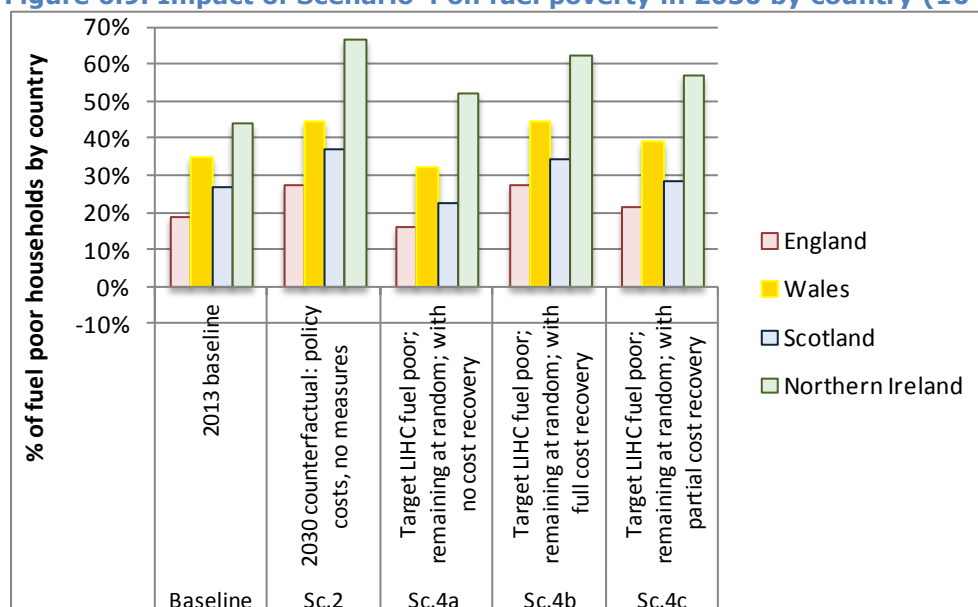
Impact on fuel poverty in 2030 under the 10% definition

As a result of targeting measures at the LIHC fuel poor (and without any measures costs passed on to energy bills), fuel poverty levels under the 10% definition fall to just 2% below the 'random allocation' scenario, thus remaining high at 19% across the UK as a whole in 2030 (Sc.4a in Figure 6.8; and 52% in Northern Ireland, Figure 6.9). With full measures cost recovery on energy bills, fuel poverty under the 10% is nearing the counterfactual fuel price scenario (under which no measures are deployed) (Sc.4b in Figure 6.8).

This suggests therefore that targeting the LIHC fuel poor fails to target a significant proportion of the "10% fuel poor". This reflects the disparity in the households defined as fuel poor under each definition: only around 39% of households classed as fuel poor under the 10% definition in 2013 were also "fuel poor" under the LIHC definition (UK, Table 6.4)

Table 6.4. Overlap between the two fuel poverty definitions (UK, 2013)

Proportion of 10% fuel poor also LIHC fuel poor:	39%
Proportion of LIHC fuel poor also 10% fuel poor:	76%

Figure 6.8. Impact of scenario 4 on fuel poverty in the UK in 2030 (both definitions)**Figure 6.9. Impact of Scenario 4 on fuel poverty in 2030 by country (10% definition)**

Impact on fuel poverty in 2030 under the LIHC definition

The impact of “perfect” targeting of the projected measures at the LIHC fuel poor results in fuel poverty levels under this definition falling to around 5% in 2030 for the UK as a whole (Sc.4a in Figure 6.8, right hand cluster of bars). This reduction is broadly consistent across all countries (LIHC fuel poor at 3-5% across each country). The average fuel poverty gap is reduced by around half the baseline to £330 and the aggregate gap for the UK stands at £0.39bn (Sc.4a, Table 6.5). Even with the cost of measures passed on to bills, fuel poverty under this definition remains lower than the 2013 baseline (Sc.4b, Table 6.5). This suggests the measures included in this simulation are effective in protecting a high proportion of LIHC fuel poor and at-risk households from fuel price rises to 2030 (even where those fuel price rises include the recovery of costs of measures).

Table 6.5. Impact of Scenario 4 on fuel poverty in 2030 under the LIHC definition (UK)

		In fuel poverty (m)	% fuel poor	Mean fuel poverty gap	Aggregate fuel poverty gap (£bn)
2013	2013 baseline	2.86	11%	£639	£1.82
Sc.2	2030 counterfactual: policy costs, no measures	3.10	12%	£874	£2.71
Sc.4a	Target LIHC fuel poor; remaining at random; with no cost recovery	1.19	5%	£330	£0.39
Sc.4b	Target LIHC fuel poor; remaining at random; with full cost recovery	1.27	5%	£371	£0.47
Sc.4c	Target LIHC fuel poor; remaining at random; with partial cost recovery	1.19	5%	£355	£0.42

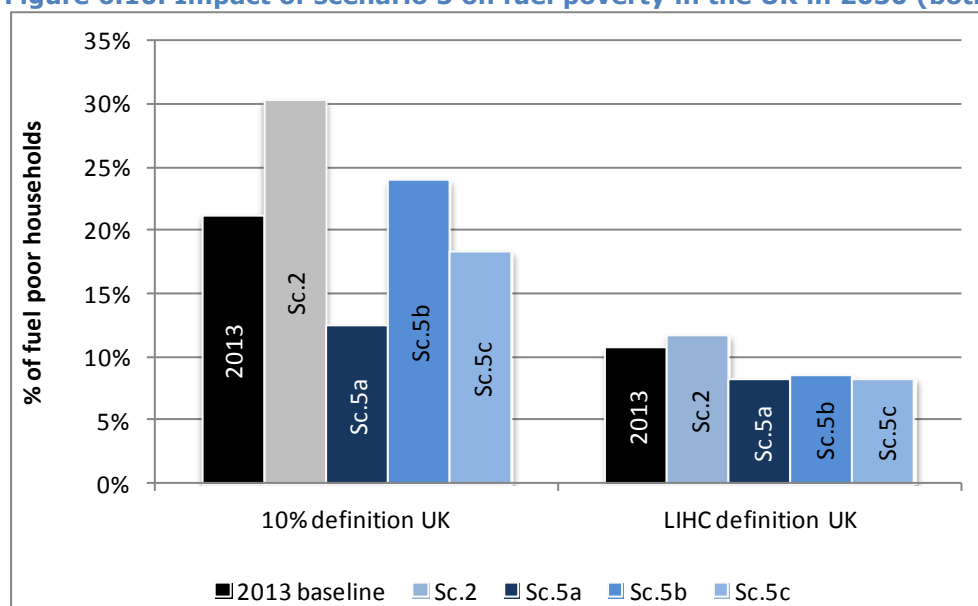
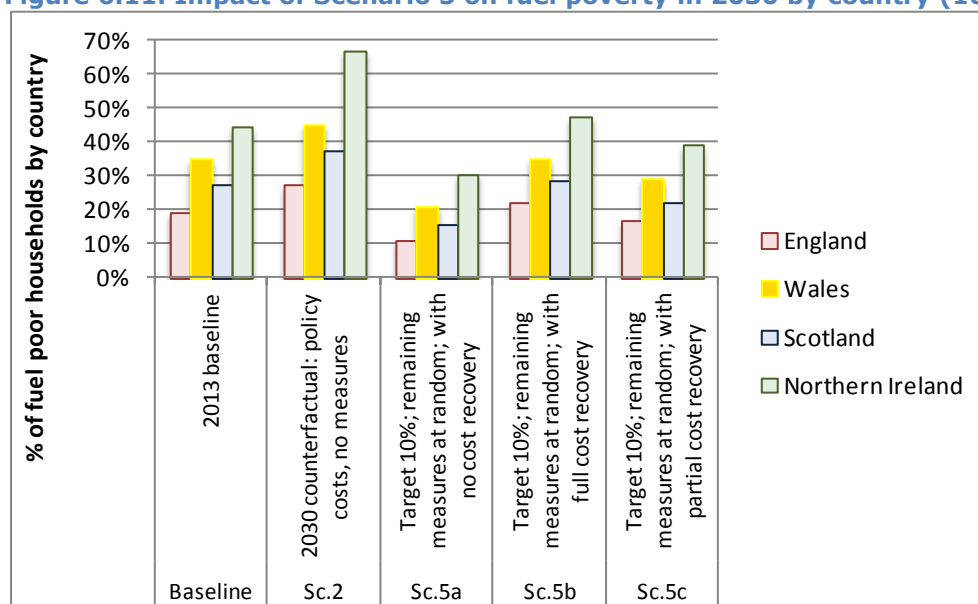
6.2.5 Scenario 5: Targeting measures at the “10%” fuel poor

This scenario prioritises the installation of measures that will minimise fuel costs in households classed as fuel poor under the 10% definition in every year of the simulation. Any remaining measures are then allocated at random. The number of households defined as fuel poor under the 10% definition is around twice that of the LIHC definition, hence a greater number of households are prioritised each year (before any measures remaining are allocated at random).

Impact on fuel poverty in 2030 under the 10% definition

In this scenario the number of households classed as fuel poor under the 10% definition reduces 13% for the UK as a whole (Sc.5a, Figure 6.10). Although still high at 30% in Northern Ireland (Sc.5a, Figure 6.11) this is the lowest level of all the scenarios modelled here (i.e. limiting the measures to those included in the CCC’s projections). Compared to a scenario of random allocation of measures, there are some 2.3 million fewer fuel poor households in the UK in 2030 under this targeted scenario.

With the full cost of measures passed on through energy bills, fuel poverty levels in the UK 2030 appear lower than under the counterfactual scenario (in which no measures are deployed) but still high at around 24% (Sc.5b, Figure 6.10). This again highlights the need for additional measures to ensure at-risk households are protected from fuel price rises if domestic energy policy costs being passed on to energy bills.

Figure 6.10. Impact of scenario 5 on fuel poverty in the UK in 2030 (both definitions)**Figure 6.11. Impact of Scenario 5 on fuel poverty in 2030 by country (10% definition)****Impact on fuel poverty in 2030 under LIHC definition**

Targeting measures at the “10% fuel poor” also results in a reduction in fuel poverty under the LIHC definition. In the scenario modelled here, the number of LIHC fuel poor in 2030 is around 2.2 million (Sc.5a, Figure 6.10, right hand cluster of bars); the average fuel poverty gap around £430 and the aggregate gap stands at around £0.9 billion (Table 6.6). Whilst higher than in the previous LIHC targeting scenario, these figures are lower than the 2013 baseline, counterfactual scenario and scenario of random allocation of measures. This reflects the overlap in households defined as fuel poor under the 10% and LIHC: around 76% of the LIHC fuel poor are also classed as fuel poor under the 10% definition (Table 6.4 above). Given that only England has adopted the LIHC definition, and over three quarters of the LIHC fuel poor in 2013 were also classed as fuel poor under the 10% definition, there may be an argument for any UK-wide targeting of fuel poverty schemes to be guided by the 10% definition.

Table 6.6. Impact of Scenario 5 on fuel poverty in 2030 under the LIHC definition (UK)

		In fuel poverty (m)	% fuel poor	Mean fuel poverty gap	Aggregate fuel poverty gap (£bn)
2013	2013 baseline	2.86	11%	£639	£1.82
Sc.2	2030 counterfactual: policy costs, no measures	3.10	12%	£874	£2.71
Sc.5a	Target 10%; remaining measures at random; with no cost recovery	2.17	8%	£428	£0.93
Sc.5b	Target 10%; remaining measures at random; with full cost recovery	2.26	9%	£558	£1.26
Sc.5c	Target 10%; remaining measures at random; with partial cost recovery	2.19	8%	£488	£1.07

6.2.6 Scenario 6: Targeting measures at the “LIHC” fuel poor with secondary targeting to minimise emissions

This scenario prioritises the installation of measures that will minimise fuel costs in households classed as fuel poor under the LIHC definition in every year of the simulation (exactly as per scenario 4), but with the addition of ‘secondary targeting’ in the allocation of remaining measures. In every year of the simulation any measures that are not allocated to fuel poor households will be selected for households on the basis of minimising emissions as far as possible. This scenario was developed to show the potential for emissions reductions within the limits of the measures included in the CCC’s projections.

Impact on fuel poverty in 2030 under the 10% definition

In this scenario the number of households classed as fuel poor under the 10% definition is very similar to that of scenario 4, as would be expected as the initial fuel poverty targeting criteria is the same. (Any difference is due to an element of randomness that remains in modelling of this nature).

Impact on fuel poverty in 2030 under the LIHC definition

As above, the number of LIHC fuel poor households in 2030 under this scenario is broadly the same as in scenario 4 which also targeted the LIHC fuel poor (1.2m LIHC fuel poor in 2030 in the UK).

Emissions

The main difference in impact of this scenario compared to Scenario 4 is the effect on emissions savings achieved. The ‘secondary targeting’ prompts the model to select the measures that will deliver the greatest emissions savings. As a result, the total emissions reduction achieved across the UK housing stock as whole increases to 20% on the 2013 (NHM) baseline. This was discussed and illustrated in Figure 6.1 (page 58).

6.3 What happens if the fuel poor get nothing?

Under all the scenarios presented so far at least some fuel poor households (under both definitions) will be receiving some measures – even in the ‘random allocation’ scenario, where the only criteria for allocating measures relate to physical property criteria/constraints.

In the absence of any policy intervention to specifically target and offer financial support to low-income households, it is unlikely that the fuel poor will take-up measures as they do not have the capital means to do so.

A final set of scenarios therefore explore the implications for LIHC fuel poor households if they receive (1) no measures at all from those included in the CCC’s projections; (2) no main heating and insulation measures, but some new appliances³⁶. As with all the previous scenarios, these simulations were run without any costs of measures on bills; with full costs on bills; and with partial costs on bills (Table 6.7). The latter two of these therefore represent a worse-case-scenario where higher income, non-fuel poor households are benefitting from the installation of energy efficiency and low carbon measures, but all households – including the fuel poor – pay a proportion towards the costs.

The headline results and implications for fuel poverty levels in 2030 of these scenarios are shown below. Beyond the impact on fuel poverty levels, a further finding from these simulations shows that by restricting the model to allocating measures only to non-LIHC fuel poor, it is prevented from distributing the full count of hard-to-treat cavity insulations. There are some 1.4 million of these measures in the scenario (based on the CCC’s projections). Eliminating the LIHC fuel poor from receiving any of these results in a surplus of around 225,000 (16% of the total), therefore suggesting that some 225,000 LIHC fuel poor households live in properties with hard-to-treat cavities. This finding should be treated with some caution however, as the input housing stock data upon which the NHM is built lacks the detailed and accurate information on hard-to-treat cavities, hence this represents a modelled variable in the stock data.

Table 6.7. Scenarios descriptions where LIHC fuel poor excluded from measures

Scenario no.	Scenario description
Sc. 7a	LIHC FP get nothing; no cost recovery
Sc. 7b	LIHC FP get nothing; full cost recovery
Sc. 7c	LIHC FP get nothing; partial cost recovery
Sc. 8a	LIHC FP get no major measures (some apps & lighting); no cost recovery
Sc. 8b	LIHC FP get no major measures (some apps & lighting); full cost recovery
Sc. 8c	LIHC FP get no major measures (some apps & lighting); partial cost recovery

6.3.1 Impact on fuel poverty if fuel poor households get nothing (scenario 7)

Impact on fuel poverty in 2030 under the 10% definition

In this scenario some households classed as fuel poor under the 10% definition will still be receiving some measures (as the scenario only eliminates LIHC fuel poor from benefitting from measures, but

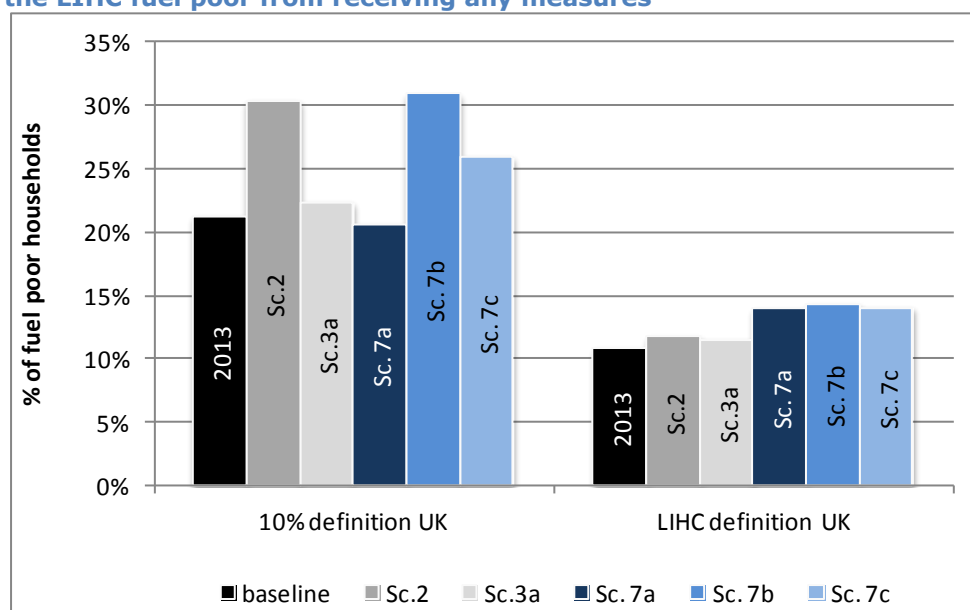
³⁶ These are allocated at random across the housing stock in this scenario, as per previous random allocation scenario.

due to the differences between the two definitions, this will not eliminate all “10%” fuel poor; 61% of the 10% fuel poor still stand a chance of receiving a measure - Table 6.4).

As a result of restricting all measures to only non-LIHC fuel poor households, and without any costs passed on to energy bills, some 21% (5.4 million) households in the UK are in fuel poverty under the 10% definition in 2030 (Sc.7a, Figure 6.12). This is lower than both the counterfactual scenario in which no households get measures (resulting in 30% of households being fuel poor, Sc.2 in Figure 6.12) and slightly lower than the ‘random allocation’ scenario (22% fuel poor in 2030, Sc.3a in Figure 6.12). This suggests therefore that a slightly higher number of 10% fuel poor have benefited from measures when the LIHC restriction was applied. This reflects the fact that under this scenario the model has slightly fewer households to choose from in distributing measures, hence the 10% fuel poor (who are not LIHC fuel poor) have slightly ‘higher odds’ of being allocated a measure in the simulation.

With the full cost of measures passed on through energy bills and LIHC excluded from benefiting from measures, fuel poverty levels under the 10% definition in the UK 2030 increase to 31% (Sc.7b, Figure 6.12); falling back to 26% if partial costs are passed on to bills (Sc.7c Figure 6.12).

Figure 6.12. Impact on fuel poverty in the UK in 2030 (both definitions) of eliminating the LIHC fuel poor from receiving any measures



Impact on fuel poverty in 2030 under LIHC definition

The results from the scenario in which no LIHC fuel poor households benefit from any home improvement measures or new higher efficiency lighting and appliances by 2030 (and without any measures cost passed through to bills) suggest fuel poverty levels in the UK under the LIHC definition could increase to 14%, or some 3.66 million households (Sc.7a, right hand cluster of bars in Figure 6.12). The average fuel poverty increases to over £1,000, with an aggregate gap of £3.7 billion (Table 6.8).

In this scenario measures are still deployed across the remainder (non-LIHC fuel poor) of the housing stock (as per the CCC's projections). If the costs of these measures are fully recovered through energy bills, the proportion of LIHC fuel poor could increase further still to some 14.4% (Sc.7b in Figure 6.12), with some 3.76 million households in the UK, 3.12 million of which are in England. Under this scenario the average fuel poverty gap appears at its highest of all scenarios modelled here, at nearly £1,180 and the aggregate gap at £4.4 billion (Table 6.8).

6.3.2 Impact on fuel poverty if fuel poor households get no main measures (scenario 8)

Scenario 7 described above eliminated all LIHC fuel poor households from benefiting from any of the measures in the simulation. If this restriction is applied only to the main heating and insulation measures, with appliances and lighting (i.e. improvements in product efficiency) still distributed at random, fuel poverty levels appear slightly lower (as would be expected as now some fuel poor households will be seeing small reductions in their household electricity demand). Under this scenario, and without any costs of measures passed on the energy bills, a fifth of households in the UK are classed as fuel poor under the 10% definition; and 13.8% under the LIHC definition.

Looking at the difference in the number of fuel poor households in the previous scenario and this one, suggests that through the benefits of new appliances only, some 91,000 and 33,000 households are protected from being in fuel poverty in 2030 under the 10% and LIHC definition respectively.

Table 6.8. Implications for fuel poverty in 2030 of measures not reaching the fuel poor

Scenario	10% definition		LIHC definition		Mean fuel poverty gap	Aggregate fuel poverty gap (£bn)
	In fuel poverty (m)	% fuel poor	In fuel poverty (m)	% fuel poor		
2013 2013 baseline	5.59	21%	2.86	11%	£639	£1.82
Sc.2 2030 counterfactual: policy costs, no measures	8.01	30%	3.10	12%	£874	£2.71
Sc.3a Random allocation, with no cost recovery	5.88	22%	3.04	12%	£713	£2.17
Sc.3b Random allocation, with full cost recovery	8.64	33%	3.15	12%	£786	£2.47
Sc. 3c Random allocation, with partial	7.31	28%	3.10	12%	£747	£2.32
Sc. 7a LIHC FP get nothing; no cost recovery	5.40	21%	3.66	14.0%	£1,014	£3.71
Sc. 7b LIHC FP get nothing; full cost recovery	8.10	31%	3.76	14.4%	£1,178	£4.43
Sc. 7c LIHC FP get nothing; partial cost recovery	6.79	26%	3.68	14.1%	£1,102	£4.06
Sc. 8a LIHC FP get no major measures (some apps & lighting); no cost recovery	5.31	20%	3.62	13.8%	£887	£3.21
Sc. 8b LIHC FP get no major measures (some apps & lighting); full cost recovery	8.13	31%	3.74	14.3%	£1,000	£3.74
Sc. 8c LIHC FP get no major measures (some apps & lighting); partial cost recovery	6.76	26%	3.68	14.0%	£940	£3.45

6.4 Sensitivity analysis on solid wall insulation count

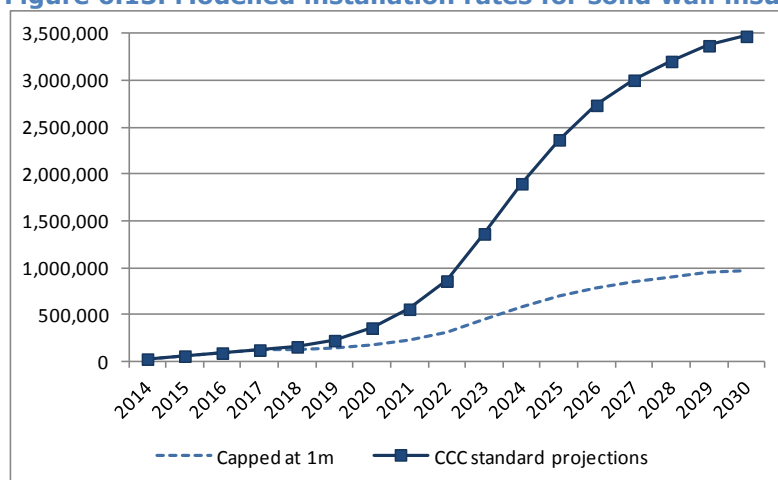
The modelling undertaken for this research utilises the CCC's projections of measures needed in the residential sector to deliver emissions reductions in line with the fourth carbon budget. This includes some 3.5 million solid walls being insulated by 2030 (2.3 million external and 1.2 million internal). The CCC's trajectory of installations was adjusted for the purpose of this modelling to reflect the latest activity and policy position. The scenario therefore assumes relatively slow uptake of solid wall insulation to 2017 (in line with the proposed minimum target of 100,000 solid walls insulated under the ECO³⁷); with a later peak in annual installation rates in the mid-2020's, tailing off slightly towards 2030 as the 3.5 million is achieved (Figure 6.13).

³⁷ DECC, 2014. The Future of the Energy Company Obligation.

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/335002/future_energy_company_obligation_government_response.pdf

This trajectory requires a significant increase in annual installation rates compared to current levels (in 2013 some 28,000 dwellings received solid wall insulation³⁸). A further scenario was developed to explore the implications of a lower rate of solid wall insulation, capped at 1 million by 2030³⁹. This scenario was simulated as per scenario 4, which targets the LIHC with measures first to minimise their fuel bills (and all remaining measures being allocated at random to the rest of the housing stock). The 1m solid wall capped-scenario was run without any cost-recovery on energy bills and with partial costs on bills. Apart from the reduced count of solid wall insulation, all other inputs and modelling assumptions were held constant.

Figure 6.13. Modelled installation rates for solid wall insulation



6.4.1 Results: reduced solid wall insulation simulated under Scenario 4

Table 6.9 shows the impact on fuel poverty under the LIHC definition of reducing the total number of solid wall installations to 1 million by 2030. As we may expect, fuel poverty appears slightly worse under the reduced SWI scenario, with an increase in the gap of £2 million (without any costs of measures on energy bills; scenario 4a in the table below), rising to £25 million with partial costs of measures on bills (scenario 4c in Table 6.9).

Table 6.9. Impact of Scenario 4 on fuel poverty in 2030 under the LIHC definition (UK)

	Fuel poor households	Mean fuel poverty gap	Aggregate fuel poverty gap (£bn)
2013 baseline	2.86m	£639	£1.82
Sc.2 2030 counterfactual: policy costs, no measures	3.10m	£874	£2.71
Sc.4a: Target LIHC fuel poor; remaining at random; no cost recovery	1.19m	£330	£0.39
Sc.4a + SWI cap: As above, but with Solid Wall insulation capped at 1 million installations	1.13m	£350	£0.40
Sc.4c: Target LIHC fuel poor; remaining at random; partial cost recovery	1.19m	£355	£0.42
Sc.4c + SWI cap: As above, but with Solid Wall insulation capped at 1 million installations	1.15m	£392	£0.45

³⁸ DECC, 2014. Green Deal, Energy Company Obligation (ECO) and Insulation Levels in Great Britain, Quarterly report: to December 2013. Table 2.1: Insulated homes in Great Britain, March 2008 to December 2013. <https://www.gov.uk/government/publications/green-deal-energy-company-obligation-eco-and-insulation-levels-in-great-britain-quarterly-report-to-december-2013>

³⁹ The 1 million figure stems from previous analysis of cost-effective installation rates by the CCC.

Whilst the total number of solid wall insulations deployed in this scenario has been reduced by 2.5 million, the impact on fuel poverty is somewhat limited as measures are still targeted at the (LIHC) fuel poor first. In the previous scenario without the cap of SWI (i.e. 3.5 million solid walls insulated by 2030), some 550,000 LIHC fuel poor households received solid wall insulation (this is over the lifetime of the scenario). Lowering the total number of solid wall insulations to 1 million, but maintaining targeting of measures at (LIHC) fuel poor households reduces the number of fuel poor households receiving this measure by only around 100,000 to 2030 (Figure 6.14). Therefore whilst the total number of SWI's is lower, the proportion going to LIHC fuel effectively increases due to the targeting of these households (Figure 6.15).

Figure 6.14. Number of LIHC fuel poor households receiving SWI in total to 2030

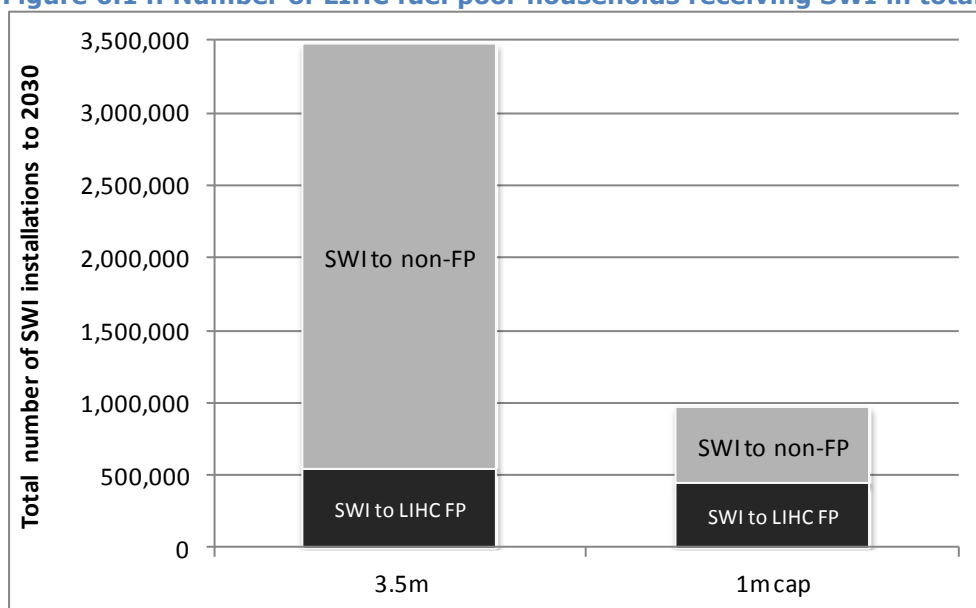
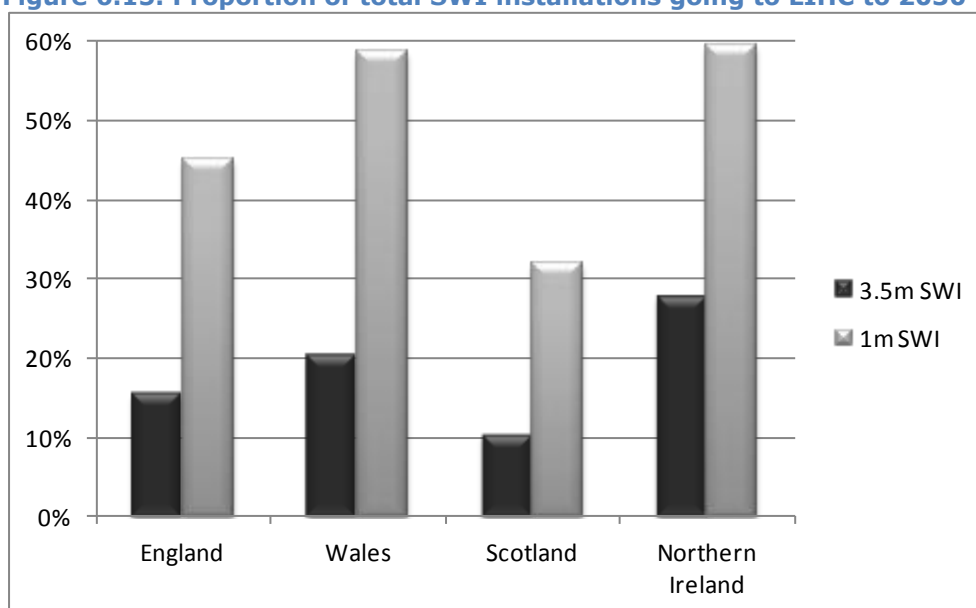


Figure 6.15. Proportion of total SWI installations going to LIHC to 2030



Lowering the number of solid wall insulations by 2.5 million reduces the overall cost of (main) measures deployed in the scenario to 2030 by over £27.2 billion⁴⁰.

	Total main measures (m)	Total measures costs (£m)	Aggregate gap – no costs on bills (Sc.4a) (£m)	Aggregate gap – partial costs on bills (Sc.4c) (£m)
3.5m SWI	58.5	£168,822	£393	£424
1m SWI	56.0	£141,574	£395	£449
<i>Difference</i>	-2.5	-£27,248	£2.0	£25

With fewer solid wall insulations, the emissions savings resulting from the simulation of measures across the UK housing stock in the NHM to 2030 is around 1MtCO₂ less than with the 3.5 million solid wall measures (a total reduction of around 14MtCO₂, 14% reduction on the baseline).

6.5 Summary

The results from the multiple scenarios simulating the deployment of measures across the UK housing stock and projected fuel price rises to 2030 show a range of outcomes for fuel poverty levels. The impact depends on which households get measures and how these measures are paid for.

The results highlight the importance of (a) ensuring effective targeting of measures at fuel poor households to ensure they benefit and are protected from the impact of fuel price rises; and (b) designing domestic energy policy such that any cost pass-through to energy bills is designed to ensure low-income and vulnerable households are not unduly burdened.

⁴⁰ The cost of solid wall insulation is calculated by the model, based on the size of the property that receives the measure. This reduction in cost as a result of lowering the number of SWI's equates to an average cost of solid wall insulation of about £11,000.

7 The wider benefits of warmer homes

7.1 Introduction

This study has presented some detailed statistical analysis and modelling of fuel poverty in the UK, both now and projected to 2030. The results provide an indication of the potential impact of fuel price rises and the installation of measures on fuel poverty in quantified terms (i.e. number of fuel poor households and the fuel poverty gap). This section discusses some of the wider implications of fuel poverty, considering the challenges faced by households living in cold, damp homes and facing unaffordable fuel bills and the potential benefits of implementing policies and programmes to address these.

7.2 Impact of cold homes on health and well-being

The realities of living in fuel poverty can translate into adverse impacts on physical and mental health and social well-being. The effects will vary from one household to the next, depending on (amongst other things) the severity of fuel poverty/cold experienced and the coping strategies adopted by households. For example, a household may opt to ration its fuel use to avoid unaffordable bills or fuel debt, and thus face potential health-related consequences of living in an under-heated home. These health risks principally relate to cardiovascular disease and respiratory illnesses, with the young and elderly particularly susceptible. In addition, long-term exposure to a cold home has been shown to impact on weight gain in young children and babies, increase hospital admission rates for children and increase the severity and frequency of asthmatic symptoms (Marmot Review 2011⁴¹). Children living in cold housing are more than twice as likely to suffer from breathing problems, including asthma and bronchitis and children living in damp and mouldy homes are up to three times more likely to suffer from coughing, wheezing and respiratory illness as their peers who live in dry homes (Marmot Review 2011⁴¹).

Pressures on the household budget due to high energy costs may prompt households to seek financial savings elsewhere, with further implications for health and well-being. For example a household making cut backs on food expenditure (quantity and/or quality) may suffer longer term health impacts associated with a poor diet with low nutritional value.

Mental health problems and stress may occur in any household struggling to live on a constrained income and faced with unaffordable energy bills (Gibbons & Singler, 2008⁴²). A stressful home environment has implications for relationships and general emotional well-being of those subjected to it. A lack of ability to heat the home can affect social relationships external to the household, as households may feel less able to invite people into their home. This can further exacerbate mental health effects (e.g. feelings of social isolation, low self-esteem and depression) (Gibbons & Singler, 2008).

Whilst widely acknowledged, the negative health impacts of living in a cold and/or damp home remain complex, multi-faceted and not fully understood. Excess Winter Deaths (EWD) and Excess Winter Admissions (EWA) are often discussed in the context of fuel poverty and cold homes. In

⁴¹ Marmot Review Team (2011), The health impacts of cold homes and fuel poverty, Friends of the Earth/Marmot Review Team

⁴² Gibbons, D. & Singler, R. (2008) *Cold Comfort: A Review of Coping Strategies Employed by Households in Fuel Poverty*, Available at: http://www.infohub.moneyadvicetrust.org/content_files/files/cesi_cold_comfort_report.pdf.

2008-2009, over 26,000 Excess Winter Deaths were reported in England, with the majority occurring in those older than 65 years (Tod et al., 2012⁴³). Whilst it is difficult to ascertain the extent to which EWDs are due to cold indoor living temperatures, it has been estimated that 30-50% of EWDs can be attributed to cold housing (Braubach et al., 2011⁴⁴). This figure compares unfavourably with other northern European countries, such as Finland, which, despite having a colder climate, experienced half this rate of Excess Winter Deaths (Tod et al., 2012). Better standards of insulation are recognised as a key factor in the observation of fewer excess winter deaths and lower rates of fuel poverty in colder European countries (Liddell & Morris, 2010⁴⁵).

7.3 Health benefits of reducing cold homes

There is an increasing body of literature that explores the impacts and health issues related to cold, damp homes and the associated benefits of improving the thermal efficiency of dwellings. For example, evidence from the Warm Front Health Impact Evaluation⁴⁶ showed that grant recipients reported an increased use of the domestic space used during cold months as a result of improved insulation measures. Improvements to a household's thermal comfort and a reduction in the stress associated with energy debt can also yield significant mental health benefits (Harris et al., 2010⁴⁷). This finding was supported by the Warm Front Study Group, operating from 2001-2006, who revealed that better living conditions and lower energy costs can have a significant impact on mental health.⁴⁸ Higher temperatures, satisfaction with the heating system, greater thermal comfort, reductions in fuel poverty and lower stress were found to be significantly correlated with improved health (Gilbertson et al. 2012⁴⁹). Statistical analysis of the results from a cross-sectional survey of 2,685 low income householders participating in the Warm Front scheme before and after intervention showed self reported mental health to be *directly* associated with the installation of Warm Front measures. In particular, levels of anxiety and depression reduced by almost 50% following Warm Front improvements (Gilbertson et al., 2012).

However, a recent extensive review of literature on the health impacts of cold homes highlights the need to treat such statistics with caution. The findings from the review - which was commissioned by the National Institute of Health and Care Excellence (NICE) in developing its draft guidance on tackling the health impacts of cold homes with a particular focus on the role to be played by the

⁴³ Tod, A.M., Lusambili, A., Homer, C., et al. (2012) Understanding factors influencing vulnerable older people keeping warm and well in winter: a qualitative study using social marketing techniques. *BMJ open*, 2(4), p.e000922-. Available at: <http://bmjopen.bmj.com/content/2/4/e000922.abstract>

⁴⁴ Braubach, M., Jacobs, D.E. and Ormandy, D. (2011). *Environmental burden of disease associated with inadequate housing. Methods for quantifying health impacts of selected housing risks in the WHO European Region*. WHO Regional Office for Europe

⁴⁵ Liddell, C. & Morris, C. (2010) 'Fuel poverty and human health: A review of recent evidence.' *Energy Policy*, 38, pp.2987-2997.

⁴⁶ Green, G. & Gilbertson, J. (2008) *Warm Front Better Health: Health Impact Evaluation of the Warm Front Scheme*. Published by the Centre for Regional, Economic and Social Research, Sheffield Hallam University. <http://www.shu.ac.uk/research/cresr/sites/shu.ac.uk/files/warm-front-health-impact-eval.pdf>

⁴⁷ Harris, J., Hall, J., Jenkins, R., Meltzer, H., McManus, S. & Oreszczyn, T. (2010) *Health, mental health and housing conditions in England*. Research for the eaga Charitable Trust by the National Centre for Social Research

⁴⁸ See reference 30

⁴⁹ Gilbertson, J., Grimsley, M., & Green, G. (2012) 'Psychosocial routes from housing investment to health: Evidence from England's home energy efficiency scheme'. *Energy Policy*, 49, pp.122-133

health and social care sectors⁵⁰ - describe how much of the literature has limitations due some shortcomings in the quality of one or more of baseline data, health assessments or internal temperature logging. This makes it difficult to draw concrete conclusions about the likely impact on particular health conditions (and their associated treatment costs) of specific energy efficiency improvements in any target group of households.

Nevertheless, as concluded by the review for NICE, the available evidence does suggest that energy efficiency improvements to dwellings enables households struggling to keep warm to increase internal temperatures affordably and achieve improvements in health as a result. The draft guidance subsequently includes recommendations for the role of the health service in identifying and referring vulnerable people living in cold homes to insulation schemes.

The analysis for NICE also included an attempt to model certain specific health benefits which may be delivered by a programme of insulating the homes of fuel poor households. This used the HIDEEM model⁵¹ in association with a housing stock model. The analysis is almost identical to that undertaken by the same research team for DECC in 2013 as background to the 'Fuel Poverty Framework for Action in England'.⁵² The HIDEEM model associates increases in internal temperature with improvements in health. It also includes potential negative health impacts of reduced ventilation resulting from retrofit activity. To do so, HIDEEM draws on the same evidence of the relationship between internal temperature increases and improvements in health that the NICE review cautions against (i.e. due to shortcomings in quality of baseline data, health assessments or internal temperature logging). The results of the HIDEEM analysis should therefore be treated with similar caution.

7.4 'Quality Adjusted Life Years'

The analysis undertaken for NICE in developing its guidance on the health impacts of cold homes also expresses the health benefits in Quality Adjusted Life Years (or 'QALYs'). QALYs is a method developed in health economics⁵³ to measure the impact of a particular intervention on a person's health and wellbeing. The QALY technique provides a common currency for comparing the benefits gained from different treatments and interventions on a society-wide (or health and social care service wide) basis. For example, it enables a comparison between the overall impact on the population's health of an intervention which enables a person with restricted mobility to achieve greater mobility with a treatment which reduces another person's depression.

NICE uses this technique to compare the cost-effectiveness (i.e. cost per QALY) of different health treatments and interventions in one field or condition against different treatments or interventions in another. NICE's guidance to the NHS and wider health and social care sector is strongly influenced by these comparisons. The analysis for NICE mentioned above suggested that the cost per QALY of

⁵⁰ London School of Tropical Medicine, Public Health England and University College London (2014) *Evidence Review and Economic Analysis of Excess Winter Deaths for NICE Reviews 1-3*, NICE <https://www.nice.org.uk/guidance/gid-phg70/resources/excess-winter-deaths-and-illnesses-guideline-consultation-supporting-evidence2>

⁵¹ See <http://www.ucl.ac.uk/energy-models/models/hideem>

⁵² See DECC (2013) *Fuel Poverty: a Framework for Future Action - Analytical Annex*, DECC, at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/211137/fuel_poverty_strategy_framework_analytical_annex.pdf

⁵³ For a simple guide to QALYs and how they are derived, see <http://www.medicine.ox.ac.uk/bandolier/painres/download/whatis/QALY.pdf>

(to simplify) an insulation programme targeted at the homes of ill people was too high (at least to justify that activity being funded solely from NHS budgets). The resulting draft NICE guidance therefore reflects this finding (i.e. it does not recommend the NHS pays for such a programme), but it does recommend that the health service takes steps to ensure such programmes take place and assists with targeting, support for referrals etc.

7.5 Simulating warmer homes in the NHM

As the discussion above highlights, the benefits of insulating the homes of fuel poor households may translate into a warmer living environment. This may leave the householder no better off financially (they maintain the same level of spend on fuel but with improved thermal fabric their home now feels warmer). Modelling fuel poverty does not allow for this outcome, due to the methodology and theoretical nature of the fuel poverty metric (i.e. householders required spend on fuel to maintain a specified and assumed level of warmth and heating regime).

Some further modelling was therefore undertaken to explore the implications of fuel poor households taking the benefits of measures as warmth rather than bill savings (and therefore rather than carbon emission reductions). The same scenario of targeting LHC fuel poor households as presented in the previous chapter (scenario 4 – see section 6.2.4, page 64) was simulated, but with the indoor living temperature of dwellings in the housing stock dataset set at a lower starting temperature (19°C, see further discussion below around setting this temperature threshold). The scenario simulates the allocation of measures and fuel prices to 2030 as before. In calculating the new, lower fuel bill after measures have been applied, the model allows fuel poor households to maintain their previous level of spend on fuel and instead take the benefits of any measures as warmth, by increasing their living temperature up to 21°C. The scenario does not allow household fuel spend to exceed the previous level (pre-measures), so households can be no worse off financially. If a household reaches 21 degrees without needing to spend all the financial benefits of any measures received, they will be both warmer and better off financially (with a lower fuel bill). This scenario will have no impact on the number of households being lifted out of fuel poverty (beyond the element of randomness in the model), as this is still calculated as per the methodology (i.e. based on required spend on fuel under the standard assumptions about heating temperatures). This process is illustrated in Figure 7.1 below.

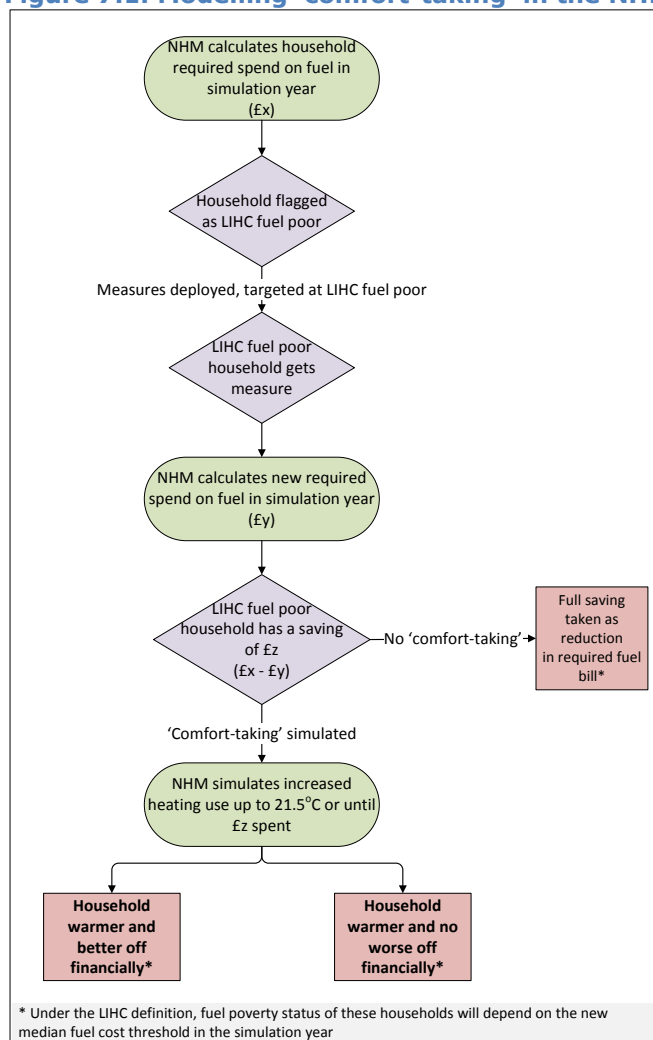
7.5.1 Modelling limitations

The aim of this scenario is to give an indication of the extent to which fuel poor households may be able to increase the temperature in their home as a result of receiving energy efficiency measures. There are however a number of limitations with the approach and the conclusions that can be drawn, not least due to the lack of information on the (starting) temperature of these dwellings (i.e. which households are ‘cold’ and by how much). The English Housing Energy Follow-up Survey (EFUS)⁵⁴ does collect information about the heating regime and internal temperature for a sample of households. The team was however unfortunately unable to gain access to the full EFUS dataset for this project owing to DECC concerns about data protection. This prevented any detailed analysis of the types of households that have lower indoor temperatures, such that we could replicate this in the NHM scenario to more effectively model the potential benefits of making previously cold homes

⁵⁴ <https://www.gov.uk/government/statistics/energy-follow-up-survey-efus-2011>

warmer through the application of measures. As a result, for the purpose of this modelling, the starting indoor living temperature was reduced to 19°C across all households. This was based on analysis of the EFUS by BRE for DECC (in which BRE concluded compared to the sample population as a whole “there are no significant (or very small) differences in mean heating season temperatures [in] households in fuel poverty under the Low Income High Costs (LIHC) indicator” (BRE, 2013⁵⁵).

Figure 7.1. Modelling ‘comfort-taking’ in the NHM



7.5.2 Results from simulating ‘warmer homes’ in the NHM

As described above a scenario was simulated in the NHM to explore the potential for fuel poor households to increase the temperature of the home as a result of receiving an energy efficiency measure. The modelling inputs are the same as for scenario 4c which targets measures at the LIHC fuel poor first in every year of the simulation and the costs of measures are partially passed on to bills. The impact of fuel poverty is broadly the same as under scenario 4c, as fuel poverty is a measure of required spend on fuel, which is unaffected by the ‘comfort-taking’ simulated in this scenario. There is a slight reduction in the emissions savings however, as these are derived from an estimate of actual household energy consumption (a 12% reduction on baseline levels, compared to 14% under scenario 4c).

⁵⁵ Energy Follow-up Survey (2011). *Report 2: Mean household temperatures*. BRE on behalf of DECC. December 2013. <https://www.gov.uk/government/statistics/energy-follow-up-survey-efus-2011>

The results of the comfort-taking element of the scenario show that over the lifetime of the scenario a total of some 3.9 million (LIHC) fuel poor households have increased their indoor living temperature by an average of 2.2°C as a result of benefiting from measures⁵⁶.

Table 7.1. Aggregate number of households increasing indoor living temperature over scenario lifetime

	Total households warmer over scenario lifetime
England	3,257,000
Wales	199,000
Scotland	372,400
Northern Ireland	110,400
UK	3,938,800

7.6 Implications of results

The results presented above quantify the number of fuel poor households that are warmer as a result of measures being deployed to 2030. This is of course a purely theoretical and modelled result. There was insufficient data available for this project to enable identification of households in the NHM dataset who are ‘cold’ to start with. It is therefore not possible to quantify in more realistic terms how many fuel poor households may be made warmer as a result of the installation of measures modelled in this study. It was simply assumed that all fuel poor households would spend any financial gains from measures on increasing the temperature of their home by up to 2.5°C. The results can be considered to provide a very broad indication of the extent to which the provision of energy efficiency measures to fuel poor households may enable them to increase the temperature in their home. Placed in the context of the health benefits of a warmer home discussed previously, this provides further indication of the wider benefits of improving the energy efficiency of fuel poor households.

7.6.1 The cost of cold homes to the health service

Quantifying these benefits in financial terms remains highly elusive however. As mentioned in section 7.3, there are severe limits to the conclusions which can be drawn from the existing, generally low quality evidence linking energy efficiency improvements with increases in internal temperatures and therefore with specific associated improvements in health. Where evidence does exist, it tends to focus on changes to health indices (i.e. improvements in health) and fails to capture any consequent changes to demand for health services (which would potentially deliver cost savings). As a result, based on the available research evidence, it is extremely difficult to draw robust conclusions about the relationship between investment in energy efficiency improvements and reduction in health service costs.

That said, it is not unreasonable to argue that unhealthy internal temperatures caused by fuel poverty exacerbate ill-health and therefore create associated demands on the health service which

⁵⁶ This result is a direct output of the scenario: households are flagged every time they ‘take comfort’ (i.e. receive a measure that enables them to increase the thermostat setting). The model records this action to produce a report on the total number of fuel poor households flagged as ‘taking comfort’ over the lifetime of the scenario.

have a cost. A number of studies have attempted to do just this and quantify the cost in financial terms of fuel poverty to the health service. Age UK calculated that the annual cost to the NHS in England of cold homes is £1.36 billion⁵⁷. This does not include associated costs to social care services, which is likely to be substantial. It can then be inferred, with some logical justification, that addressing fuel poverty and the associated cold homes would therefore save the NHS a significant proportion of this cost.

To put into context, the average cost of measures modelled in this study (simply taking the total capital cost of measures installed divided by the number of unique dwellings receiving measures) is around £7,800 (this is an average across the scenarios). If this sum were to be spent on improving the thermal efficiency of every fuel poor household in the UK in 2013 (under the LIHC definition, some 2.86 million households), the bill would come in at around £22.5 billion in total; to 2030 this represents an annual spend of £1.32bn. The cost of caring for an older person in hospital on the other hand is estimated at £1,750–£2,100 *per week*.

Some efforts have also been made to monetise the value of a QALY⁵⁸ so that it can be included in a cost benefit analysis of programmes such as the one modelled for NICE. Such exercises are fraught with difficulties but the UK Government consensus as reported by the Department of Health has settled around a figure of about £60,000. This is based on ‘willingness to pay’ research done on preventing car accident fatalities for the Department for Transport.⁵⁹ This monetisation was included in the analysis underpinning DECC’s Fuel Poverty Framework for Action mentioned above.

7.6.2 Delivering financial savings to the NHM

The monetisation of QALYs and inclusion in cost benefit analysis can be somewhat deceptive. It suggests that gaining the QALYs somehow makes some money available, generating a financial value stream that could be captured to help fund the insulation programme. This is not the case. There is no financial market for QALYs that pays for them being delivered. Indeed, there is also no acceptance in government budgeting that a QALY, while obviously of benefit to the individual who gains it, and to societal health and wellbeing in general, creates a net cost saving to the Government or ‘UK Plc’.

That said, there is a potential financial value stream of a targeted insulation programme through the avoided costs to the health service as a result of people with improved health making fewer demands upon it (e.g. by needing fewer GP appointments and hospital admissions).

It should be noted that this ‘NHS cost saving’ argument is often countered not by an appeal to evidence (or the lack of it) but to the presumption that demand for NHS services is, in effect, in equilibrium. In other words, under this presumption, if someone’s health improves enough to enable them to avoid visits to their GP, that appointment will be taken up by someone else who would have

⁵⁷ Age UK, 2012. The cost of cold.

⁵⁸ E.g. Glover D and J Henderson (2010) *Quantifying the health impacts of government policies*, Department of Health at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216003/dh_120108.pdf

⁵⁹ As reported in Glover & Henderson (2010) see footnote 58

otherwise have not made an appointment.⁶⁰ The average level of ill-health seen by GPs would reduce (which is societally a good thing), but the financial savings would not materialise because no less work has been done by the health service. There may be some merit in this argument, but it has a ‘reductio ad absurdum’ quality which is unhelpful and suggests that no improvements to the health of the population would save the NHS money.

Whilst the full economic impact of cold homes remains an unquantifiable and contestable figure, making the connection between fuel poverty and poor health presents an opportunity in terms of both reaching those in need and monitoring the impact of improvement measures. Accessing health data to target and track the impacts and benefits of energy efficiency interventions is fiendishly difficult for a third party outside of the health service. However, due to the nature, frequency and potential severity of physical health conditions associated with living in a cold damp home (e.g. asthma attacks), patients suffering these effects are likely to present themselves directly to the NHS. Making the health service a central and integral part of delivering an energy efficiency policy could ensure that, not only are measures delivered to those in need (typically the ‘hard-to-reach’) but also that the benefits could be quantified by any observed reduction in presentations of the recipient patients to the health service. This issue is discussed again in the final chapter of this report.

⁶⁰ This is on the basis that health services are effectively ‘rationed’ by the number of appointments available with GPs (or beds in hospital). As a result, some GP patients will be reacting to a lack of appointment ‘for a few days’ by waiting to see if they get better (which some will). In the event that fewer people need appointments because their homes are warmer, the capacity released will be taken up by those people who would otherwise have ‘waited to see’.

8 Meeting the 4th carbon budget and addressing fuel poverty

8.1 Introduction

The modelling presented in Chapter 6 explored the potential impact on fuel poverty to 2030 of expected fuel price rises and the installation of measures identified by the CCC to deliver emissions reductions in the residential sector to meet the fourth carbon budget. The results from the range of scenarios modelled (summarised again below in Table 8.1) show that the combined impact of expected fuel price rises and measures need not adversely impact on fuel poverty levels. Rather, if measures are targeted specifically at fuel poor households (that is, those identified as fuel poor in every year of the simulation, which takes account of physical changes to the housing stock as a result of simulating the CCC measures and fuel prices over time, but with no assumed change in the characteristics of dwelling occupants) by 2030:

- fuel poverty could be reduced to around half of the estimated number of fuel poor in 2013
- emissions reductions could still be on par with, if not exceed⁶¹, those achieved under a scenario in which fuel poor households are not specifically targeted with measures.

However, this ‘win-win’ situation is highly dependent on (a) finding the fuel poor and ensuring measures are taken up by these households; (b) how the measures are paid for; (c) whether the benefits of measures actually translate into fuel bill savings or benefits are taken as warmth. Each of these issues is discussed further below.

Table 8.1. Summary of results from modelling fuel price rises and measures impacts on fuel poverty to 2030 (UK, LIHC definition)

	Fuel poverty (UK LIHC)		
2013 UK baseline	10.9%		
Fuel prices rise and no measures are installed across UK housing stock	↑ to 11.8%		
Measures cost recovery:	<i>Measures funded through taxation</i>	<i>Measures funded fully through energy bills</i>	<i>Measures funded partially through energy bills</i>
Fuel prices rise and measures installed with policy to ensure fuel poor households get measures (“perfect targeting”)	↓ to 4.5%	↓ to 4.8%	↓ to 4.5%
Fuel prices rise and measures installed randomly across all households	↑ to 11.5%	↑ to 12.0%	↑ to 11.8%
Fuel prices rise and no measures installed in fuel poor households	↑ to 14.0%	↑ to 14.4%	↑ to 14.1%

⁶¹ The differences in emissions reductions achieved relates to the types of households (e.g. size and heating fuel) receiving the measure and inclusion of the heat replacement effect in the modelling, whereby a decrease in electricity use in the home as a result of improvements in appliance efficiency results in an increase in heating.

8.2 Targeting and policy delivery

The scenarios modelled in this study show the potential to alleviate fuel poverty through ‘perfect targeting’ of measures at households classed as fuel poor according to the official definition(s). And, conversely, the implications if no policies or programmes are in place to ensure fuel poor households receive their share of measures (the ‘fuel poor get nothing’ scenarios).

Further analysis of the outputs from one simulation, targeting the LIHC fuel poor with the partial cost of measures passed on to energy bills (scenario 4c) was undertaken to explore:

- (1) the types and proportion of different measures being allocated to the fuel poor; and
- (2) the characteristics of households remaining in fuel poverty in 2030.

The results are useful in showing the extent to which these measures can address the problem and where further measures and/or interventions are needed.

8.2.1 Distribution of measures across the fuel poor population

Table 8.2 shows the proportion of different measures being allocated to LIHC fuel poor households over the lifetime of the scenario. (This scenario simulates the deployment of measures targeted specifically at the LIHC fuel poor to minimise their fuel bills. As households move in and out of fuel poverty overtime, different households will be targeted in each year of the simulation). Over the full simulation to 2030, nearly half of all the cavity wall insulations, some 17% of solid wall insulations and 35% of loft insulation measures are allocated to households defined as LIHC fuel poor at that point in time in the simulation.

Table 8.2. Proportion of measures going to LIHC fuel poor households over the lifetime of the scenario

(Count in thousands)		% of measures to LIHC fuel poor over scenario lifetime				
	<i>Total measures</i>	UK	England	Wales	Scotland	Northern Ireland
CWI (both)	2,289	48%	39%	2.8%	5.2%	1.0%
SWI	3,475	17%	14%	1.3%	0.5%	0.4%
Loft Insulation	5,490	35%	29%	1.6%	3.1%	1.1%
Floor insulation	4,142	58%	49%	2.9%	5.2%	1.3%
Heat pump	3,999	17%	13%	0.9%	2.4%	0.8%
Gas boiler	11,430	21%	18%	1.0%	1.6%	0.0%
Oil boiler	1,270	76%	58%	4.3%	10.2%	3.3%

Table 8.3 shows the proportion of households who are fuel poor in the baseline year (2013) and receive measures over the lifetime of the scenario. Over one third of the 2013 LIHC fuel poor benefit from cavity wall insulation; 16% from solid wall insulation and 60% from loft insulation.

Table 8.3. Proportion of baseline year (2013) LIHC fuel poor households receiving measures over the lifetime of the scenario

	% of baseline LIHC fuel poor receiving measures over scenario lifetime				
	UK	England	Wales	Scotland	Northern Ireland
CWI (both)	34%	33%	38%	43%	28%
SWI	16%	17%	26%	5%	17%
Loft Insulation	60%	60%	55%	58%	75%
Floor insulation	62%	63%	61%	61%	51%
Heat pump	27%	25%	30%	36%	45%
Gas boiler	64%	68%	58%	49%	3%
Oil boiler	25%	23%	31%	34%	51%
Total LIHC fuel poor households in 2013 (m)	2.86	2.38	0.14	0.27	0.07

8.2.2 Who remains fuel poor?

Simulating the deployment of measures targeted at LIHC fuel poor households (with partial costs of measures passed on to energy bills) reduces fuel poverty in 2030 to 4.5% (1.18 million households) under the LIHC definition across the UK as a whole (4.6% (1 million households) in England)⁶². Of these households in fuel poverty in 2030, some 745,000 (63%) were fuel poor in 2013 (Table 8.4). Looking at it another way, the simulation of the CCC's measures targeted at the LIHC fuel poor in every year of the scenario results in some 2.1 million (74%) of the 2013 UK LIHC fuel poor being lifted out of fuel poverty, whilst around one quarter (26%) of the 2013 LIHC fuel poor remain so in 2030 and 439,000 households become fuel poor (Table 8.4). The proportions for England only are very similar, with 27% (634,000) of the 2013 LIHC fuel poor remaining so in 2030, whilst some 372,000 houses previously non-fuel poor in 2013 become so by 2030.

Table 8.4. Count and proportion of LIHC fuel poor households in the baseline year (2013) and scenario end (2030) (UK)

2013:	2030:		
	Non-fuel poor	Fuel poor	Total
Non-fuel poor (row %)	23,024,280 (98%)	439,160 (2%)	23,463,440
Fuel poor (row %)	<u>2,114,160</u> (74%)	744,840 (26%)	2,859,000
Total	25,138,440 (95.5%)	1,184,000 (4.5%)	26,322,440

Non-fuel poor in 2013; become fuel poor by 2030.

Estimated total fuel poor in 2013

Lifted out of fuel poverty.

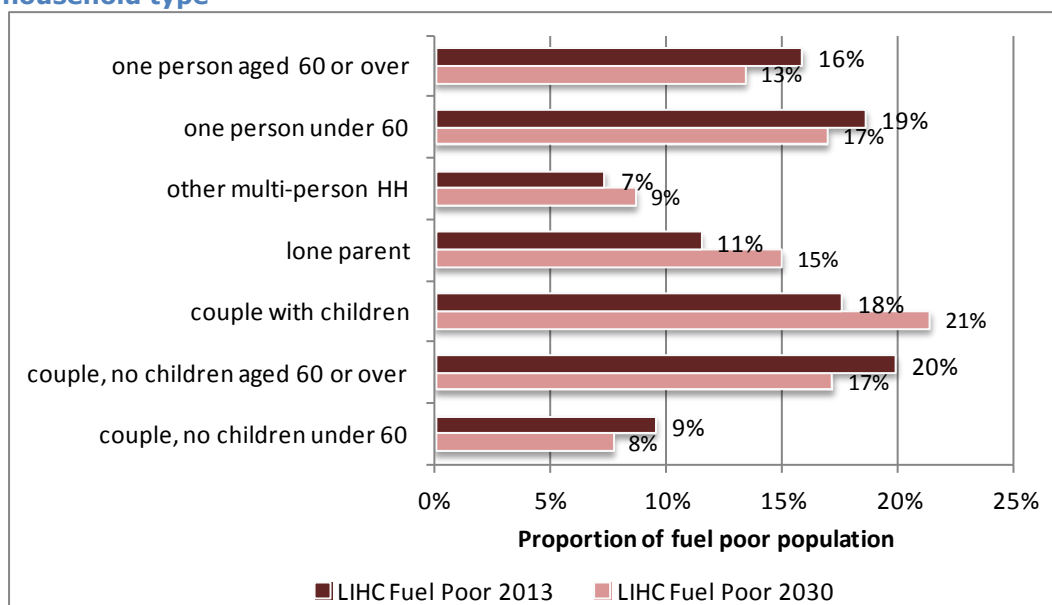
Estimated total fuel poor in 2030.

Fuel poor in 2013 & remaining fuel poor in 2030.

⁶² Note that this scenario recalculates and identifies the (LIHC) fuel poor in every year of the simulation and targets these dwellings with measures. To do this, the median fuel cost threshold is recalculated every year, which takes account of changes in fuel prices and physical property characteristics of the housing stock (i.e. as a result of simulating the deployment of the CCC's measures). It assumes no change to the occupancy characteristics of the dwelling however.

Analysis of the types of households in fuel poverty under the LIHC definition in England in 2030 compared to the 2013 LIHC fuel poor population shows a slight shift towards younger person households, with relatively more couples with children and lone parents and relatively fewer retired households making up the fuel poor population (Figure 8.1). Newer properties, purpose-built flats, and social housing all account for a slightly higher proportion of the 2030 LIHC fuel poor compared to the baseline (see Box 8.1).

Figure 8.1. Distribution of LIHC fuel poor households in England in 2013 and 2030 by household type



Looking only at the ‘newly fuel poor’ (households in England who were not LIHC fuel poor in 2013 but are in 2030) shows these are predominantly in urban areas; working-age households with children; newer properties; medium-sized terraced or semi-detached houses; on mains gas. Whilst private sector housing dominates (45% owner-occupied and 21% private rented) social housing makes up a greater proportion of the ‘newly fuel poor’ compared to the baseline and England as a whole. Just under one third of the newly fuel poor (29%) do not have wall insulation, suggesting these households are missing out on receiving measures in the simulation. Financial options for providing further assistance to households remaining in fuel poverty in 2030 are also considered in the following section.

Box 8.1. Distribution of LIHC fuel poor across different socio-demographic descriptors

	Urban	Town & fringe	Village	Hamlet & isolated dwellings	count
LIHC Fuel Poor 2013	77%	9%	10%	4%	2,378,600
LIHC Fuel Poor 2030	81%	8%	8%	3%	1,006,400
LIHC newly Fuel Poor 2030	87%	8%	4%	1%	372,200
<i>All England</i>	81%	9%	7%	3%	22,022,200

Tenure	Housing Association	Local Authority	Owner Occupied	Private Rented	count
LIHC Fuel Poor 2013	9%	9%	60%	22%	2,378,600
LIHC Fuel Poor 2030	13%	13%	53%	21%	1,006,400
LIHC newly Fuel Poor 2030	18%	16%	45%	21%	372,200
<i>All England</i>	9%	8%	67%	15%	22,022,200

Household composition	couple, no children under 60	couple, no children aged 60 or over	couple with children	lone parent	other multi-person HH	one person under 60	one person aged 60 or over	count
LIHC Fuel Poor 2013	9%	20%	18%	11%	7%	19%	16%	2,378,600
LIHC Fuel Poor 2030	8%	17%	21%	15%	9%	17%	13%	1,006,400
LIHC newly Fuel Poor 2030	7%	14%	29%	22%	11%	10%	7%	372,200
<i>All England</i>	18%	18%	22%	8%	7%	13%	15%	22,022,200

Age of HRP	16 - 24	25 - 34	35 - 44	45 - 54	55 - 64	65 or over	count
LIHC Fuel Poor 2013	5%	9%	17%	21%	18%	29%	2,378,600
LIHC Fuel Poor 2030	6%	11%	21%	21%	17%	25%	1,006,400
LIHC newly Fuel Poor 2030	7%	16%	24%	22%	11%	19%	372,200
<i>All England</i>	3%	14%	20%	20%	17%	25%	22,022,200

Employment status	full time work	part-time work	retired	unemployed	full time education	other inactive	count
LIHC Fuel Poor 2013	26%	11%	33%	11%	3%	16%	2,378,600
LIHC Fuel Poor 2030	30%	11%	29%	11%	3%	17%	1,006,400
LIHC newly Fuel Poor 2030	35%	13%	20%	9%	3%	21%	372,200
<i>All England</i>	51%	8%	27%	4%	1%	9%	22,022,200

	pre-1919	1919 to 1944	1945 to 1964	1965	count
LIHC Fuel Poor 2013	27%	19%	23%	31%	2,378,600
LIHC Fuel Poor 2030	22%	18%	23%	37%	1,006,400
LIHC newly Fuel Poor 2030	16%	18%	25%	41%	372,200
<i>All England</i>	21%	17%	20%	42%	22,022,200

	End terrace	Mid terrace	Semi detached	Detached	Converted flat	Purpose built	count
LIHC Fuel Poor 2013	14%	15%	33%	27%	3%	8%	2,378,600
LIHC Fuel Poor 2030	13%	16%	30%	22%	5%	13%	1,006,400
LIHC newly Fuel Poor 2030	15%	24%	33%	15%	3%	10%	372,200
All England	10%	18%	27%	26%	4%	15%	22,022,200

Dwelling size	less than 50	50 to 69 sqm	70 to 89 sqm	90 to 109	110 sqm or	count
LIHC Fuel Poor 2013	4%	11%	30%	21%	34%	2,378,600
LIHC Fuel Poor 2030	3%	12%	35%	21%	29%	1,006,400
LIHC newly Fuel Poor 2030	2%	17%	47%	21%	12%	372,200
All England	8%	20%	29%	17%	26%	22,022,200

	No insulation	CWI	SWI	count
LIHC Fuel Poor 2013	58%	42%	1%	2,378,600
LIHC Fuel Poor 2030	21%	71%	8%	1,006,400
LIHC newly Fuel Poor 2030	29%	63%	8%	372,200
All England	30%	57%	14%	22,022,200

8.2.2.1 Assisting the remaining fuel poor households

The modelling undertaken for this study applies a trajectory of measures to 2030 as estimated by the CCC as necessary to meet the fourth carbon budget. There are therefore a limited number of measures available in each year of the simulation. This has implications for the fuel poor targeted scenarios, which are designed to select measures that will minimise fuel bills in fuel poor households, but with the selection being limited to a predefined set and count of measures available in each year.

For example, if 100,000 fuel poor households could benefit from cavity wall insulation in one year of the simulation, but there are fewer than this number of CWI measures in the CCC's trajectory of measures for that year, some of the fuel poor will miss out on this measure. The model will instead be forced to select the next best available measure for reducing their energy bills.

The results from the fuel poor targeted scenarios modelled here do not therefore answer the question '*what measures are needed to alleviate fuel poverty?*'; rather it shows how far the measures in the CCC's projections could go to addressing fuel poverty to 2030. The nature of the LIHC definition adds further complexity, as the allocation of measures and changes in fuel prices overtime will result in the thresholds for low income and high costs shifting, and therefore households can move in and out of fuel poverty over the lifetime of the scenario.

The results from simulating the CCC's fourth carbon budget measures (with targeting at the fuel poor) suggest that a number of the 'remaining fuel poor' in 2030 could still benefit from certain energy efficiency measures. Due to the modelling constraints and caveats outlined above in mind, it may be that these households are simply missing out (due to limited number of measures available

each year) and had the model not been constrained in this way, these households would not appear fuel poor in 2030.

However, in some circumstances measures alone will be insufficient to lift a household out of fuel poverty, highlighting the need for additional, ‘financial’ based mechanisms to be implemented in parallel with energy efficiency measures.

These could take the form of energy bill rebates, whereby households receive direct reductions on their fuel bills (similar to the Warm Homes Discount payments); or ‘income maximisation’ through, for example, benefits checks and/or a specific “*fuel poverty benefit*” payment.

The latter is a theoretical concept that would see fuel poor households receive a specific income-based benefit. This is however unlikely to be workable in practice, primarily due the difficulty and additional costs of identifying fuel poor households. This would ultimately never achieve 100% targeting and a significant proportion of the fuel poor homes would not be reached. In addition, a fuel poverty benefit payment (that would target only those who have both low incomes and high fuel costs – i.e. the fuel poor by definition) could be considered to be unfair, as households struggling with low incomes, but not with higher than average fuel costs would be ineligible for such a payment.

Whilst providing financial assistance to the fuel poor makes sense in practice, the benefits to and impact on fuel poverty levels by definition (and therefore for policy purposes) will be complicated by the relative nature of the LIHC indicator. Improving the financial situation or lowering the fuel bills of a proportion of the population will shift the median income and/or fuel bill thresholds. As a result, some households may move into fuel poverty whilst at the same time some of those assisted may remain in fuel poverty (even if now better off financially).

Recognising, and within the context of, the above caveats, some additional analysis was undertaken to explore the cost implications of providing financial assistance to the ‘remaining fuel poor’. This analysis does not recalculate fuel poverty after these payments have been made but does provide some indication of the scale of financial interventions that would be required to assist these households. The results are summarised in Table 8.5 below.

The average fuel bill rebate required for the 1.2 million households remaining in fuel poverty in 2030 (after simulating the CCC’s fuel price and measures projections to 2030, with measures targeted at the LIHC fuel poor in every year of the scenario) is estimated at around £370. This is the average amount needed to reduce their fuel bills below the ‘high cost’ threshold. This amounts to a total national cost of some £434 million. The alternative option of income assistance would require an average income increase of approximately £6,100 to each household (total cost of £7.2 billion) to increase their income above the ‘low income’ thresholds. This is roughly comparable to the total budget for Income Support (£6.9 billion in 2011/12).

An alternative, more cost-effective approach would be to award whichever was the lower of the two values (a fuel bill rebate or income top-up) to move the household out of LIHC fuel poverty. This approach requires an estimated investment of some £350m.

Table 8.5. Required financial assistance for remaining fuel poor households

	Fuel bill rebate	Income increase required (e.g. fuel poverty benefit payment)	Cost effective combination of fuel rebates and income support
Average rebate/payment	£367	£6,135	Fuel rebate: £292 Income support: £337
Number of households receiving rebate/payment	1,184,000	1,184,000	Fuel rebate: 1,079,000 Income support: 105,000
Total UK costs	£434m	£7,262m	Fuel rebate: £315m Income support: £35m Total: £350m

8.2.3 Impact of simulating the deployment of measures on the LIHC fuel poor nodes

Section 5.5 presented the results of CHAID analysis to explore the key defining characteristics of the LIHC fuel poor households in England in the baseline year (2013). Nine distinct groups of households (distinguished based on their estimated fuel poverty gap) were identified by the CHAID model. The nature of these groups was explored in detail to help identify some of the key defining characteristics that could be useful for targeting fuel poor households in a fuel poverty alleviation programme. Additional analysis was undertaken to explore the implications for these groups of the simulation of measures under the LIHC-fuel poor targeting scenario (4c).

Table 8.6, Figure 8.2 and Figure 8.3 show the implications for fuel poverty levels in each node after the simulation of measures to 2030. Overall, some 634,000 (column C) households estimated to be LIHC fuel poor in 2030 are represented by these nodes (representing 63% of the total 1 million estimated to be in fuel poverty in England in 2030 under scenario 4c; column E). Between 23% and 32% of households in each node remain fuel poor in 2030 (column F; i.e. some 68-77% of households each node are no longer defined as fuel poor under the LIHC definition in 2030 following the deployment of measures - Figure 8.3).

Node 2 represents a group of households estimated to be the most severely fuel poor in 2013 (households with the largest estimated average fuel poverty gap, Figure 8.2). Of these 338,000 households (all estimated to be LIHC fuel poor in 2013), 28% remain fuel poor under the LIHC definition in 2030 (column F of Table 8.6) following the simulated targeted deployment of the CCC's measures projections; or rather, 72% of households in this group are no longer fuel poor in 2030 (Figure 8.3). The average fuel poverty gap of the remaining fuel poor in this node is reduced by 41% from over £1,350 in 2013 to around £800 in 2030 (Figure 8.2). Almost half the dwellings in this group benefit from wall insulation in the scenario simulation (35% cavity and 14% solid wall insulation); 69% receive some loft insulation, a third (32%) a heat pump and biomass boiler respectively and 70% some solar PV (Table 8.7).

Node 4 sees the greatest reduction in the average fuel poverty gap from 2013 to 2030, of almost £550. This group is dominated by small, electrically-heated flats, almost half of whom benefit from wall insulation in the modelling scenario (31% cavity and 21% solid wall insulation) and nearly a third (32%) receive heat pumps.

Node 15 sees the greatest reduction in the number of fuel poor households (relative to the baseline (Figure 8.3)). The majority of dwellings in this node were without any wall insulation; the simulation

of measures deployed therefore sees a high proportion benefit from cavity or solid wall insulation (Table 8.7).

Table 8.6. Impact of simulation of measures on the LIHC fuel poor nodes in England

Node description	A Node ID	B Number in node (& therefore LIHC fuel poor in 2013)	C No. LIHC fuel poor in 2030 in node	D % of LIHC Fuel Poor population in 2013	E % of 2030 LIHC fuel poor population in node	F % of node still LIHC fuel poor in 2030
<i>Most severely fuel poor: Rural, off-gas households with older occupants.</i>	2	338,200	95,800	14%	10%	28%
<i>Urban families in larger, detached, solid-wall uninsulated houses</i>	9	229,400	59,800	10%	6%	26%
<i>Small, urban, electrically-heated, rented flats</i>	4	397,400	126,400	17%	13%	32%
<i>Working age families and multi-adult households in larger urban detached and semi's</i>	10	202,800	58,400	9%	6%	29%
<i>Retired couples in newer 3-bed detached houses in urban and fringe areas</i>	8	226,200	55,800	10%	6%	25%
<i>Older private-sector dwellings without wall insulation, under-occupied by single retired</i>	15	300,800	71,400	13%	7%	24%
<i>Under-occupying single adults in 3-bed post-war semi's with insulated cavity walls</i>	16	272,000	67,000	11%	7%	25%
<i>Out-of-work lone parents in rented, older houses without insulated walls</i>	13	205,800	51,600	9%	5%	25%
<i>Working families in inter-war housing without insulation</i>	14	206,000	48,000	9%	5%	23%
Total		2,378,600	634,200	100%	63%	27%

Figure 8.2. Percentage change in average fuel poverty gap by node (2013 to 2030, England)

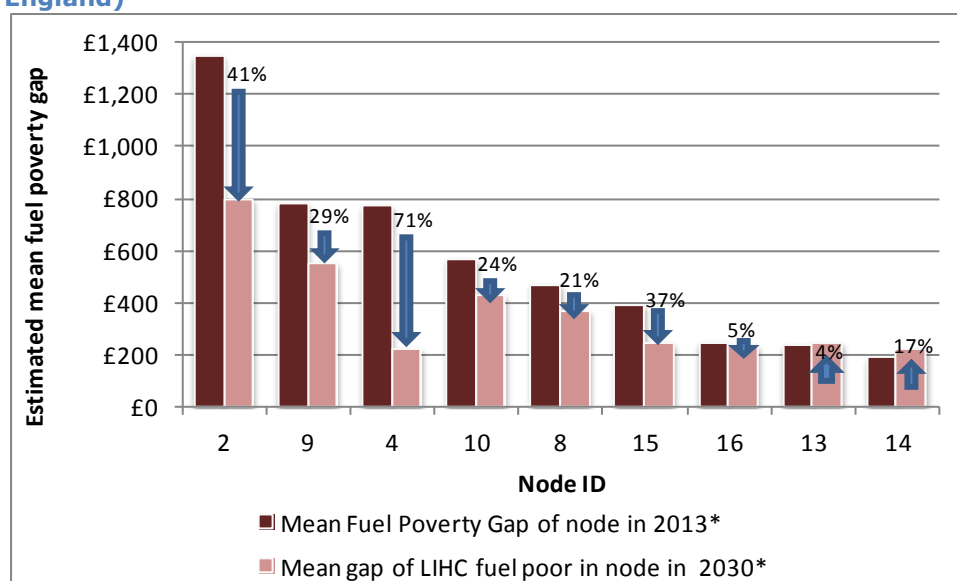
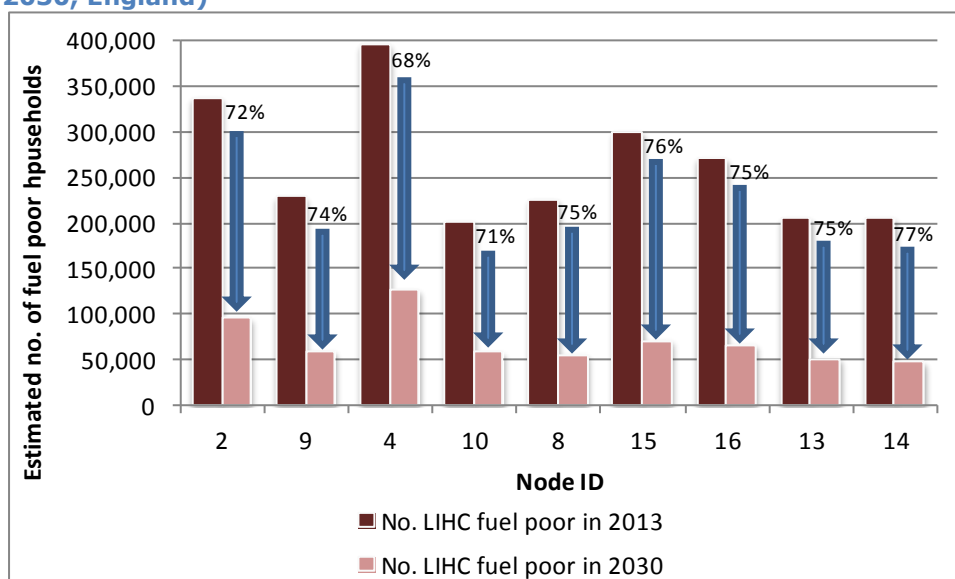


Figure 8.3. Percentage change in number of LIHC fuel poor households by node (2013 to 2030, England)**Table 8.7. Proportion of households in each node receiving measures over the lifetime of the scenario simulation**

Node description	Node ID	Count of households	Cavity wall insulation	SWI	Loft insulation	Heat Pump	Floor insulation	Biomass
Most severely fuel poor: Rural, off-gas households with older occupants.	2	338,200	35%	14%	69%	32%	67%	32%
Urban families in larger, detached, solid-wall uninsulated houses	9	229,400	43%	29%	77%	12%	65%	11%
Small, urban, electrically-heated, rented flats	4	397,400	31%	12%	32%	32%	53%	17%
Working age families and multi-adult households in larger urban detached and semi's	10	202,800	31%	13%	73%	11%	71%	12%
Retired couples in newer 3-bed detached houses in urban and fringe areas	8	226,200	27%	10%	67%	13%	70%	9%
Older private-sector dwellings without wall insulation, under-occupied by single retired	15	300,800	53%	32%	58%	13%	62%	16%
Under-occupying single adults in 3-bed post-war semi's with insulated cavity walls	16	272,000	7%	0%	66%	13%	72%	9%
Out-of-work lone parents in rented, older houses without insulated walls	13	205,800	37%	23%	57%	12%	57%	14%
Working families in inter-war housing without insulation	14	206,000	30%	23%	56%	13%	55%	10%
All 2013 LIHC fuel poor households	Total	2,378,600	33%	17%	60%	19%	63%	15%

8.2.4 Summary: targeting and policy delivery

The results demonstrate the potential for a policy designed to address both emissions and fuel poverty to be complementary rather than conflicting. However, the current paradigm of energy efficiency policy (specifically the ECO) that obligates suppliers to deliver measures typically result in 'least cost' approaches to delivery with focus on those areas where there are more opportunities for cost-effective measures (i.e. not solid walled properties) and where it is easier to deliver (i.e. not in rural areas).

Energy efficiency policy therefore needs to ensure a delivery model that places sufficient impetus on the needs of fuel poor households.

Targeting the fuel poor by definition may in practice be neither feasible nor cost-effective. As the case studies in the previous chapter illustrated, there is little evidence of schemes that have specifically targeted fuel poor households, for those very reasons, instead adopting proxy measures

to identify low-income (e.g. on means-tested benefits) and vulnerable (e.g. elderly or with children) households.

Analysis presented in Chapter 0 of this report explored the key defining characteristics of fuel poor households under both definitions. These results can be used to guide which household types should be prioritised in a fuel poverty alleviation programme. For example, older, private sector housing – and the private rented sector in particular – appears a key feature of the LIHC fuel poor, along with:

- Off-gas, rural, older properties;
- Working-age families in larger, older, solid wall properties in urban areas (on gas);
- Electrically-heated flats.

The physical nature of these household types (solid walls and off-gas) highlights the need for fuel poverty schemes to move beyond the lower cost measures and instead deliver measures that will sufficiently raise the energy efficiency (SAP/ EPC) rating of the dwelling. A minimum standard for energy efficiency provides a more robust buffer protecting low-income households from the impacts of future fuel prices. Other schemes related to income maximisation should be implemented in parallel with a minimum energy efficiency target, such as benefits checks. Past fuel poverty alleviation schemes have shown that the provision of benefits checks can have a greater impact on fuel poverty than measures alone. This offers a potential double advantage of increasing the income of the household and also ensuring it qualifies for any measures available under a programme that has benefits-eligibility criteria.

Identifying low-income/ vulnerable households is notoriously difficult and costly. Targeting based on the Index of Multiple Deprivation Income Domain offers one approach to identifying areas with a high proportion of households in receipt of benefits (therefore likely to be some of the poorest and most deprived areas). Due to the nature of the indicator (being a small-area indicator) this would be best combined with an area-based, local approach to scheme delivery (e.g. with local authorities).

Cross-departmental working and better data sharing are two further key approaches that could help identify low-income households and ensure spending on schemes is cost effective (i.e. reducing some of the costs associated with finding target households). For example, there are potential opportunities not as yet fully exploited in terms of:

- Working with NHS trusts – frontline workers have direct contact with patients in their homes, thus presenting an opportunity to identify cold, damp homes, particularly in the context of the living environment exacerbating a health issue. A potential programme could see health professionals able to “prescribe” energy efficiency to those suffering the effects of cold homes. This also presents an opportunity to make more explicit the link between cold homes and poor health and quantify any benefits resulting from measures as a reductions in the number of patient presentations to the health service⁶³.
- Working with DWP to ensure that further data sharing enables better targeting of those on low incomes that are vulnerable to the rising cost of fuel. The Warm Homes Discount

⁶³ See: <http://www.cse.org.uk/news/view/1854>

appears a particularly progressive policy due to its effective targeting at low income households⁶⁴.

- Working with and through community groups that help people access government schemes through guidance i.e. helping to identify the ‘silent sufferers’ who do not claim benefits to which they are entitled, and that are necessary to qualify for support through an energy efficiency scheme.

8.3 Funding fuel poverty measures

The modelling undertaken as part of this study has shown the implications of different approaches to funding energy efficiency and low carbon measures. Under any scenario where the costs of measures are recovered through energy bills, fuel poverty inevitably appears worse. Any new policy that involves an element of cost pass-through to energy bills should first consider the social distributional implications (‘who benefits, who pays?’) and implement a ‘safeguard’ to ensure at risk groups are sufficiently protected from any policy impacts on bills. The types of households to which this may apply will depend on the policy design (both targeting method and cost recovery). Research has identified the following key groups of consumers as being particularly at risk from adverse impacts of the current set of Government energy and climate change policies:

- Households with electric heating (particularly if living in a purpose built flat and/or a home with at least one pensioner)
- People living in rural areas
- People who are high energy users due to specific needs e.g. long term ill/disabled

As indicated by the modelling results in chapter 0, avoiding any pass-through of the costs of measures to energy bills – i.e. funding the delivery of energy efficiency and low carbon measures through taxation - offers a more progressive means of funding than through an obligation on energy suppliers which ultimately represents a cost to energy consumers.

The modelling undertaken in this study could be further developed to include a scenario whereby measures are paid for by the householder themselves. This could include a finance-based mechanism such as the Green Deal to ensure a less regressive as measures can translate into financial savings thus meaning the beneficiary is no worse off financially. This is not appropriate for low income households however, who are typically less able/ willing to take-up any finance (“debt-averse”) and where the benefits of energy efficiency measures often need to be taken as warmth (and therefore result in no realised reduction in energy bill), as discussed further below.

8.4 Modelling to reality

The results presented in this study are entirely theoretical, being a fuel poverty modelling project and given that the definition itself is based on a modelled based estimate of household energy requirements, rather than actual household energy consumption. Simultaneously modelling the impact of measures on fuel poverty (theoretical energy consumption) and emissions (from actual energy consumption) is a problem. The methods applied in this study have sought to overcome this

⁶⁴ Preston, I., White, V., Thumim, J. & Bridgeman, T. (2013b) Distribution of Carbon Emissions in the UK; Implications for UK energy policy, report for JRF

by calculating and reporting on fuel poverty as per the fuel poverty methodology, thereby maintaining the correct approach to estimating *required* spend on fuel, but reporting on emissions based on an adjusted ('calibrated') level of energy consumption to more closely align with what households actually consume (refer to Box 4.3). Within these methods there (inevitably and necessarily) remain omissions relating to how households respond to improved levels of thermal efficiency and/or new heating systems, which have implications for actual emissions and financial savings realised. Regardless of whether the household has been lifted out of fuel poverty by definition, in practice an improvement to the thermal efficiency of the dwelling will not necessarily result in the household spending less on fuel. Previous research has shown that on average households typically spend only around two thirds of their modelled 'required' spend. This is where consideration of the wider benefits of insulating homes is pertinent. As shown by the case studies, improvement measures that do not translate into actual bills savings for the householder can still be considered a success story if that householder is now living in a warmer home, that has multiple benefits for health, mental and social well-being. The fact that this benefit cannot be quantified in financial terms should not be a barrier.

Box 8.2. Realising the impacts of improvement measures on fuel poor households

Householder A: fuel poor to non-fuel poor; warmer but no better off financially and no emissions reductions

An individual household benefitting from an energy efficiency measure may choose to take the full benefit as warmth. In doing so, they maintain the same level of heating as before, but now feel the benefit with a more comfortable living environment. The householder is therefore no better off financially in reality (assuming no fuel or tariff switching – i.e. same level of fuel consumed at the same unit cost as prior to the measures) and no emissions savings will result (unless fuel switching is involved). So whilst in theory the installation of this measure may show a householder lifted out of fuel poverty and a reduction in emissions, it is only the theoretical fuel poverty statistic that holds true.

Householder B: fuel poor to non-fuel poor; still cold but better off financially and emissions reductions achieved

An alternative scenario may see a fuel poor household receive an energy efficiency measure that prompts them to reduce their heating use. The improved thermal efficiency of the dwelling may be such that the householder has been able to reduce their heating and maintain an adequate level of warmth, thus being better off financially and delivering some emissions savings. However, if the householder was under-heating prior to the measure (i.e. cold) and maintains this existence, they may now be non-fuel poor in theory (reduced required expenditure on fuel) but still living in an inadequately heated dwelling.

9 Case studies

Introduction

The results presented so far in this report have been derived from detailed modelling of the impacts of energy efficiency and low carbon measures on fuel poverty. The previous chapter discussed some of the realities and challenges faced by those living in cold homes, facing unaffordable energy bills. This chapter builds on the modelling results and narrative to present five case studies of ‘real life’ examples of low income households receiving solid wall insulation⁶⁵. The aim was to collate examples of households in fuel poverty by definition, who have benefitted from this measure. However, our research found very few schemes that have specifically targeted fuel poor households (by definition) and/or collated sufficient data to present an interesting case study. The former highlights the complexity of targeting households on this basis; typically schemes adopt proxy measures to identify vulnerable (e.g. elderly or children in the household) and low-income (e.g. in receipt of certain means-tested benefits) households as determining a household's fuel poverty status requires detailed data about the property (in order to quantify required household spend on fuel) and actual household income (sensitive data).

Three of the case studies presented here are therefore taken from a small pilot solid wall insulation scheme in the South West of England that did specifically set out to target fuel poor households⁶⁶. Applicants to the scheme underwent a full SAP assessment and completed a short questionnaire to establish fuel poverty status. This scheme also involved a detailed evaluation of the impacts of the measure on both household SAP rating and required energy spend (i.e. fuel poverty status) and more qualitatively, in terms of the experience of householders receiving the measure and wider, non-financial impacts observed.

Case study 1

Summary

Location	Rural village, North East Somerset
Occupancy	Single, female, retired
Tenure	Owner occupied
Building type	1900s, 4-bed mid-terrace, solid stone, house with single storey extension to rear.
Prior renovation	Double glazing. Converted loft with insulation
Heating	Mains gas central heating. 2 year old gas condensing combi boiler. Secondary gas fire
Insulation installed	External render system with 110 mm mineral wool slab to rear of property only
Total cost of work	£13,631
£ spent per tCO₂ lifetime saved	£543

⁶⁵ Solid wall insulation was chosen as this is typically one of the more expensive measures, with a long payback time and relatively ‘immature’ measure in terms of policy support and supply chain)

⁶⁶ ‘Freedom from Fuel Poverty’ scheme. See: <http://www.cse.org.uk/projects/view/1142>

About the property

A retired single woman applied to a fuel poverty alleviation programme funded by Bath and North East Somerset Council in 2009-10 for solid wall insulation. Her home is a two story mid-terraced solid stone house with four bedrooms and a rear ground floor extension.

Work details

The householder was concerned about altering the external appearance of her property and the need for planning permission to this, but she did also not want the disruption of having internal wall insulation. It was therefore decided to externally insulate the rear of the property only. An insulation treatment consisting of a 110mm mineral wool slab, base coat, mesh, primer and top coat were applied. In order to accommodate the new insulation the roof fascia had to be adapted and many detailing elements amended.



Fuel poverty assessment	Before works	After works	Difference (value)	Difference (%)
SAP estimated fuel bills (£/year)	£2,052	£1,779	-£273	13%
SAP estimated CO ₂ emissions (kg/year)	7,088	6,083	-1,005	14%
SAP rating	36	44	+8	
Fuel poverty ratio (%)	14.5%	12.6%	-1.9%	

Impact on fuel poverty status

The added insulation resulted in the SAP rating for the property increasing from 36 to 44. This corresponds to a reduction in the required household energy bill of £273 down to £1,779. The householder's fuel poverty index has subsequently reduced from 14.5% to 12.6%.

Other impacts

"I don't think I've saved anything. I don't think I've saved any money, but I've been, I've been warmer for the money that I've spent"

At the time of evaluation, the customer had not noticed any actual energy bill savings as a result of the works – i.e. she had not reduced her use of the heating. Instead, she maintained her existing heating regime and enjoyed a warmer home, taking the benefits as thermal comfort rather than as financial

savings. She also noted the improvement in visual appearance of the property.

"I am, very pleased [with how it looks]. Like I say, I think I was quite bowled over by it really, because I didn't expect it."

Case study 2

Summary

Location	Rural village, Somerset
Occupancy	Single, female, retired
Tenure	Owner occupied
Building type	1933 semi detached home with a brick cavity that is too narrow to insulate, ground floor extension
Prior renovation	Loft insulation, double glazed windows
Heating	Calor gas, back boiler central heating system with a secondary gas fire.
Insulation installed	Proprietary external render system with 110mm render cladding the entire property.
Total cost of work	£20,096
£ spent per tCO₂ lifetime saved	£503

About the property

A retired single woman applied to a fuel poverty alleviation programme funded by Bath and North East Somerset Council in 2009-10 for solid wall insulation. Her home is a semi-detached house built in 1933. It has cavity walls but these are too narrow to insulate.

Work details

A proprietary external render system was used to apply 110mm of external wall insulation to insulate the property. The thickness of the insulation meant that a lot of detailing elements had to be considered and ultimately amended. There were delays in the project due to inclement weather as the render requires fair weather to dry and the works coincided with a particularly bad spell of weather over the winter.

Impact on fuel poverty status

The added insulation resulted in the SAP rating for the property increasing from 44 to 57. This corresponds to a reduction in the estimated bill of £275 down to £1,219. The householder's fuel poverty index was subsequently reduced from 10.7% to 8.7% lifting the household from fuel poverty.

Fuel poverty assessment	Before works	After works	Difference (value)	Difference (%)
SAP estimated fuel bills (£/year)	£1,494	£1,219	-£273	18%
SAP estimated CO₂ emissions (kg/year)	6,524	4,925	-1,599	26%
SAP rating	44	57	+13	
Fuel poverty ratio (%)	10.7%	8.7%	-2%	

Other impacts

Although very difficult to measure, analysis of the householder's actual spend on fuel (LPG) suggested a potential saving of 30-40% on what she was spending prior to the works. The householder has also noted several positive side effects of the insulation, including reduced condensation, reduced external noise, improvement in the external appearance of the property and cooler internal temperature in the summer.

"In the back bedroom I think it was; condensation, because it's above the kitchen. And that definitely seemed better."



Case study 3

Summary

Location	Rural village, North East Somerset
Occupancy	Young family
Tenure	Owner occupied
Building type	1700's 3 bed end terrace with solid stone walls
Prior renovation	Loft insulation, dormer bedroom
Heating	Mains gas central heating. 2 year old gas condensing combi boiler. Secondary gas fire
Insulation installed	External render system with 110 mm mineral wool slab to rear of property only
Total cost of work	£6,215
£ spent per tCO₂ lifetime saved	£165

About the property

A young family applied to a fuel poverty alleviation programme funded by Bath and North East Somerset Council in 2009-10 for solid wall insulation. Their home is a 3 bedroom mid terraced house built of Mendip stone dating back to the 16th century.

Work details

This property required a mix of internal and external solid wall insulation, due to a need to maintain the external appearance at the front of the dwelling. The majority of the home (59.57 m²) was internally insulated, with a small amount (3.4 m²) being externally insulated at the rear of the property. The external insulation covered the outside of the kitchen, which eliminated the need for relocating electrics, plumbing and kitchen units. The household also had solar photovoltaic panels installed at the same time as the insulation as part of the scheme (and now benefits from the feed-in tariff). (Figures quoted here apply to the effect of the insulation only, unless otherwise specified).



External insulation on the rear of the property



Internal wall insulation

Impact on fuel poverty status

The added insulation resulted in the SAP rating of the property increasing from 44 to 55. This corresponds to a reduction in the estimated bill of £349 down to £1,703. The householder's fuel poverty index has subsequently reduced from 7.1% to 5.9%.

Fuel poverty assessment	Before works	After works	Difference (value)	Difference (%)
SAP estimated fuel bills (£/year)	£2,052	£1,703	-£349	17%
SAP estimated CO ₂ emissions (kg/year)	8,121	6,617	-1,504	19%
SAP rating	44	55*	+11*	
Fuel poverty ratio (%)	7.1	5.9	-1.2	

* Also accounts for addition of solar photovoltaics

Other impacts

The impact on both comfort and actual expenditure on fuel for this household has been significant. Prior to the insulation, they experienced incredibly high and unmanageable fuel bills (oil heating). They were forced to limit their use of the heating and even when they did

use it they felt little benefits in warmth. They experienced negative health effects from living in a cold home and facing the stressful existence of unaffordable living costs. Following the installation of the solid wall insulation, they experienced significant improvements in the thermal comfort – now when they did

"We were depressed. I mean it's a lovely spot but it was so depressing because you didn't want to come home. [...] Now we're just feeling a lot more comfortable in here... the children haven't been so ill."

use their heating, they felt the benefit; and as the house held the heat for longer, they were able to use their

"Before, even when we had the heating on, we needed the blanket as well, because it was still too cold. But now if we have the heating on we're finding it actually got very, very warm in here."

heating less. Additional benefits included a noticeable decrease in cold related illnesses and greater enjoyment of their home. Despite having internal wall insulation, they did not feel any noticeable loss of indoor living space; rather the fresh coat of paint enhanced the appearance of their home.

Case study 4

Summary

Location	Urban area
Occupancy	Single mother and child
Tenure	Social housing
Building type	Pre 1900 2 bedroom mid terrace
Prior renovation	Loft insulation, double glazing
Heating	Mains gas central heating. gas combi boiler.
Insulation installed	External wall insulation
Total cost of work	£15,000*
£ spent per tCO₂ lifetime saved	£373

* Estimated

About the property

A single mother of one received solid wall insulation through the E.ON 'Challenge 100' scheme. Her home is a 2 bedroom mid terraced council house built pre 1900.

Work details

The system used involved the addition of external wall insulation which was then covered by a render, both external walls were covered.



Impact on fuel poverty status

The added insulation resulted in the SAP rating for the property increasing from 50 to 69. This corresponds to a reduction in the estimated bill of £417 down to £683. The householder's fuel poverty index has subsequently reduced from 26.1% to 16.2%.

Fuel poverty assessment	Before works	After works	Difference (value)	Difference (%)
SAP estimated fuel bills (£/year)	£1,100	£683	-£417	38%
SAP estimated CO ₂ emissions (kg/year)*	4,246	2,636	-1,610	38%
SAP rating	50	69	+19	
Fuel poverty ratio (%)	26.1%	16.2%	-9.9%	

* Estimated

Case study 5

Summary

Location	Urban area
Occupancy	Family of four
Tenure	Privately renting
Building type	Pre 1900 2 bedroom mid terrace
Prior renovation	Loft insulation, double glazing
Heating	Mains gas central heating, gas combi boiler.
Insulation installed	External wall insulation
Total cost of work	£15,000*
£ spent per tCO ₂ lifetime saved	£371

* Estimated

About the property

A family of four received solid wall insulation through the E.ON 'Challenge 100' scheme. Their home is a 2 bedroom mid terraced council house built pre 1900.

Work details

The system used involved the addition of insulation which was then covered by a render, both external walls were covered.

Impact on fuel poverty status

The added insulation resulted in the SAP rating for the property increasing from 50 to 69. This corresponds to a reduction in the estimated bill of £419 down to £721. The householder's fuel poverty index has subsequently reduced from 13.5% to 8.5% bringing the family out of fuel poverty.



Fuel poverty assessment	Before works	After works	Difference (value)	Difference (%)
SAP estimated fuel bills (£/year)	£1,140	£721	-£419	38%
SAP estimated CO ₂ emissions (kg/year)*	4,400	2,783	-1,617	38%
SAP rating	50	69	+19	
Fuel poverty ratio (%)	13.5%	8.5%	-5%	

* Estimated

Annex I: Methodological differences between the NHM and DECC/DA fuel poverty models

The key differences in the approach used by CSE (using the NHM), DECC (for England) and each of the Devolved Administrations in modelling fuel poverty relate to: housing stock data (sources and survey year); adjustments made to the energy efficiency of the stock (to allow for measures installed since the surveys were undertaken); fuel prices (source, years and level of granularity); incomes (year and approach to uprating); and methodological assumptions around heating regimes and under-occupancy.

Housing stock data:

- CSE uses the **UK-representative** NHM housing stock data, derived from the English Housing Survey 2010/11; Scottish House Condition Survey 2007-09; Northern Ireland House Condition Survey 2009. Wales is represented in the NHM stock through a reweighting of EHS data
- DECC's latest fuel poverty estimates for **England** use the English Housing Survey **2012**.
- The Welsh Government's **2012** fuel poverty estimates for **Wales** were modelled by BRE using the Living in Wales Survey 2008 and its own Excel-based fuel poverty modelling tool.
- The Scottish Government's **2012** fuel poverty estimates for **Scotland** use the Scottish House Condition Survey 2012.
- The Northern Ireland Housing Executive's latest fuel poverty estimates for **Northern Ireland** are for 2011, using the Northern Ireland House Condition Survey **2011**.

Housing stock energy efficiency

- **CSE:** NHM input housing stock data updated to 2013 baseline to reflect measures installed as a result of Government policies since the surveys were undertaken. Policy and programme annual reports, HEED and latest Government installation figures provided estimates of number of measures. Measures are then deployed across the NHM housing stock by region where this information was available, and targeted at specific household types where applicable (e.g. CERT Priority Groups) (NB only measures known to have been installed under Government programmes were simulated; some upgrades will have happened outside of these programmes thus we may be underestimating the energy efficiency of the UK in 2013). Full details on the data applied in updating the NHM stock to 2013 will be provided in the annex of the report to CCC).
- **DECC England:** uses EHS 2012 survey data on physical property characteristics.
- **Wales, BRE:** Living in Wales 2008 survey used as a starting point and updated to a 2012 baseline to reflect energy efficiency measures installed since then under Government schemes. Data on installations collated from HEED; projections using data from EHCS/EHS and LiW surveys (for boilers and double-glazing) and the Feed-in Tariff Installation Report. Energy efficiency upgrades are applied evenly to the stock and are not targeted at any particular group. Installation of PV panel simply reduces electricity use by 800kWh per year.
- **Scotland:** Data on physical property characteristics collected as part of the 2012 SHCS.
- **Northern Ireland:** NIHCS 2011 physical property characteristics data collected as part of the survey.

Fuel prices:

- **CSE** uses 2013 fuel prices supplied by the CCC, supplemented with additional sources to provide a breakdown by all fuel types, method of payment, tariff and region/country (see Annex Table 1).
- **DECC England:** Fuel prices are applied from DECC quarterly energy price statistics for metered fuels by region and method of payment and the fuel price component of the Consumer Prices Index for non-metered fuels.
- **Welsh Government/ BRE, Wales:** Fuel prices are applied for Gas, Electricity, Oil (which includes LPG and bottled gas) and Solid fuel (which includes coal, anthracite, wood and smokeless fuel) only. No breakdown by method of payment or other fuels (including off-peak electricity). Fuel price changes are taken from the monthly RPI tables; percentage increases in fuel prices from 2008 to 2012 are derived from the RPI and applied to the LiW 2008 dataset.
- **Scottish Government, Scotland:** 2012 DECC Quarterly Energy Prices for mains gas, electricity, heating oil, plus information on mid-year consumer fuel prices independently collected from suppliers.
- **Northern Ireland:** Uses NIHCS 2011 method of payment data; DECC electricity and gas prices; Sutherland tables average fuel prices for non-metered fuels.

Incomes:

- **CSE** uprates income from the NHM housing stock input data survey years to 2013 using the Annual Survey of Hours and Earnings (ASHE), 2013 benefit data and RPI statistics (see Annex Figure 1).
- **DECC England** fuel poverty statistics for 2012 use actual EHS survey income data for 2012.
- **Wales, BRE:** Living in Wales 2008 survey was used as a base; changes in income from 2008 to 2012 (which is split into two components: Earned and Other) are derived from the Average Weekly Earnings data⁶⁷ and CPI⁶⁸
- **Scotland:** Household income data collected as part of the 2012 SHCS.
- **Northern Ireland:** NIHCS 2011 income data collected as part of the survey.

Methodological differences: occupancy and heating regimes

- **Under occupancy:** DECC's official approach to modelling fuel poverty applies a reduced heating regime for households identified as 'under-occupied'. This approach halves the total area of the house heated (both the main living area which is assumed to be heated to 21°C and the remaining area assumed to be heated to 18°C). It was not possible to fully replicate this approach in the NHM. Instead only the main living area (the area assumed to be heated to 21°C) is halved in under-occupied dwellings; the full remaining area of the dwelling is

⁶⁷ (<http://www.ons.gov.uk/ons/taxonomy/index.html?nscl=Earnings> Data Section: EARN01: Average Weekly Earnings: AWE Regular Pay tab. Table KAI9.)

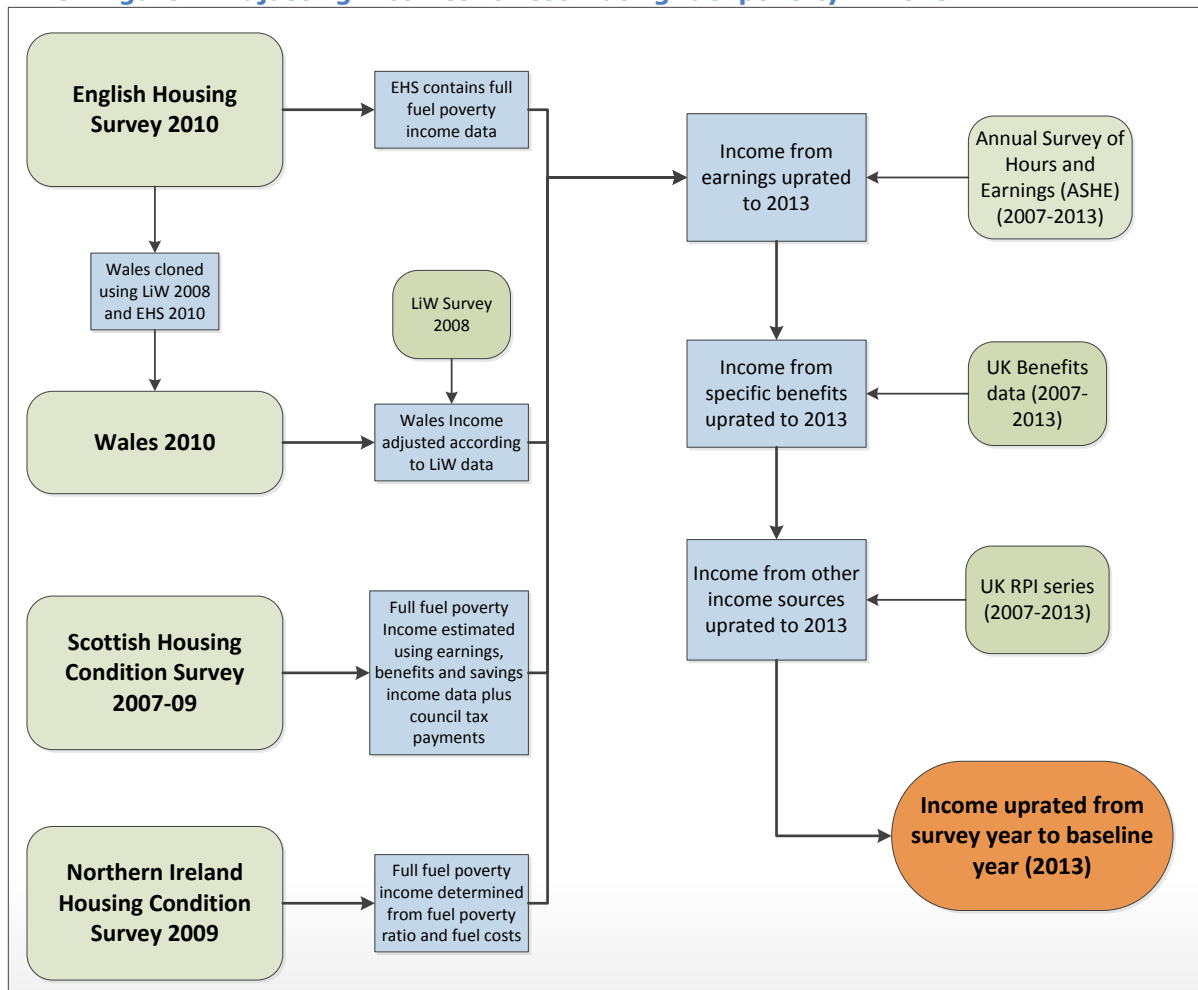
⁶⁸ <http://www.ons.gov.uk/ons/taxonomy/index.html?nscl=Consumer+Price+Indices> Data Section: CPI and RPI Reference Tables. Table 21.

assumed to be heated to 18°C. This means CSE will have a higher estimated energy demand in under-occupied houses compared to DECC.

- **Heating regimes: Scotland** applies a different approach to the other countries and assumes that households identified as being vulnerable are heated to 23°C. CSE has not replicated this approach in modelling fuel poverty across the UK in the NHM. The same heating regime assumptions are applied in all countries, consistent with the Government's fuel poverty methodology (i.e. 21°C in living areas, 18°C elsewhere). This means that CSE's estimates of household energy demand for Scotland will be lower than the Scottish Governments figures.

Annex Table 1. 2013 Unit fuel prices applied in modelling fuel poverty in the NHM for all English regions, Wales, Scotland and Northern Ireland

Fuel	Tariff	MOP
Mains Gas	Dual fuel	DD
		SC
		PPM
	Non-Dual fuel	DD
		SC
		PPM
Standard Electricity	Dual fuel	DD
		SC
		PPM
	Non-Dual fuel	DD
		SC
		PPM
Off-Peak Electricity	E7	DD
		SC
		PPM
Oil	Non-Dual fuel	Non-metered
Coal	Non-Dual fuel	Non-metered
Bulk LPG	Non-Dual fuel	Non-metered
Bottled LPG	Non-Dual fuel	Non-metered
Biomass	Non-Dual fuel	Non-metered

Annex Figure 1. Adjusting incomes for estimating fuel poverty in 2013

Annex II. Summary of fuel prices

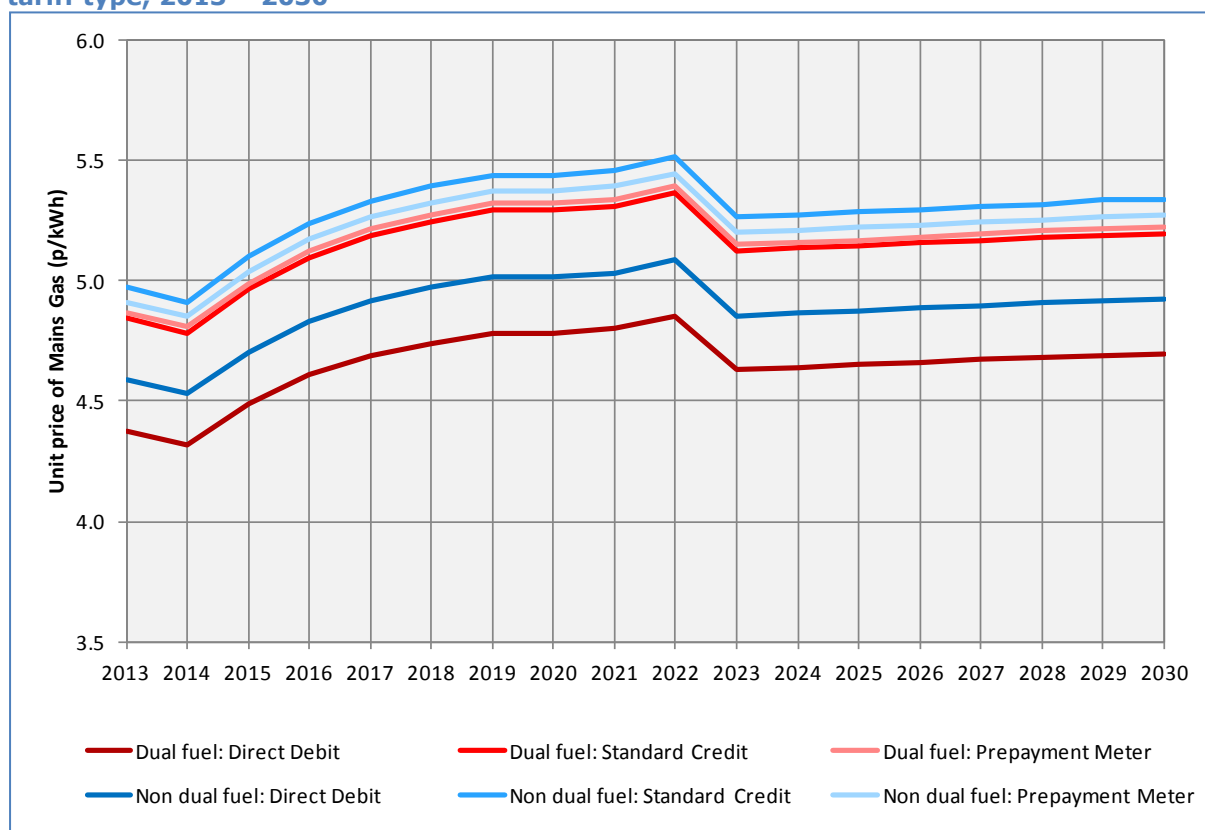
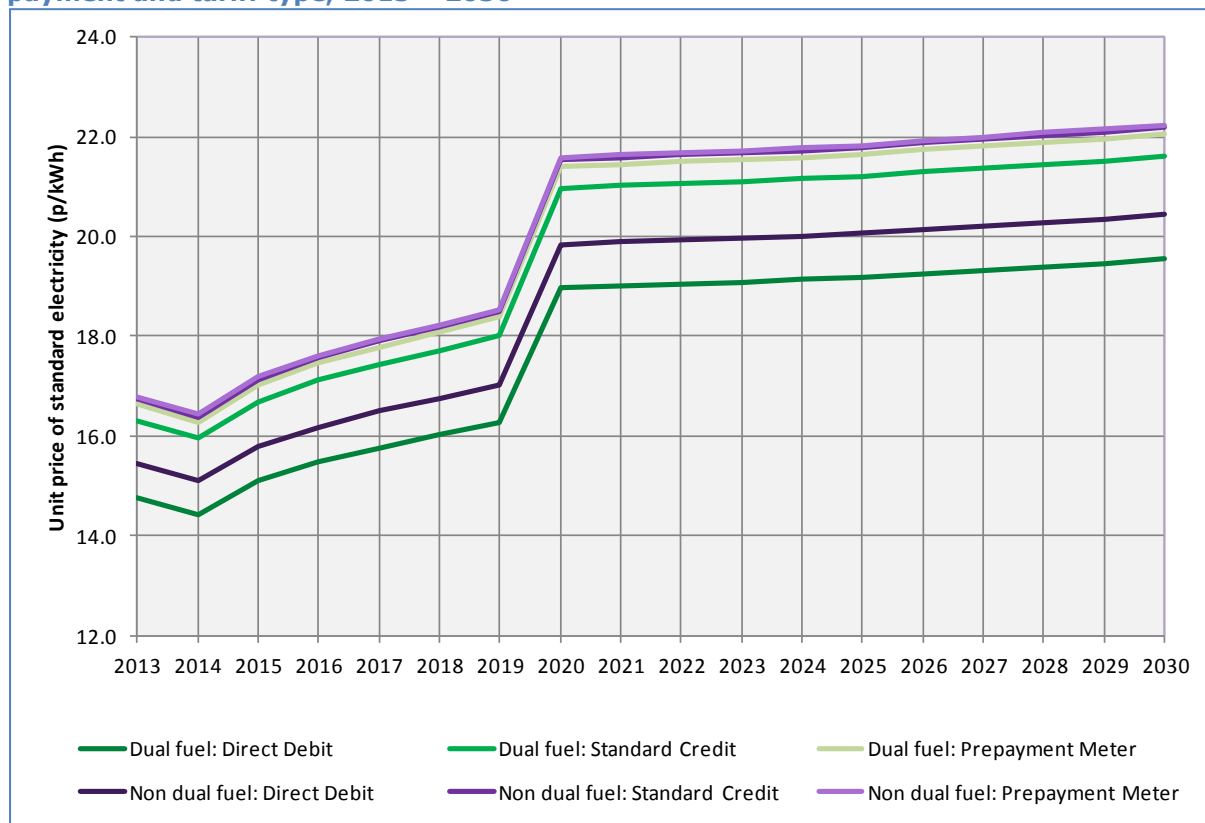
The figures below show a high level summary of the unit prices of fuel, by method of payment and tariff type, applied in the modelling in this study. The prices shown here are the (weighted) average for the UK. Prices were actually applied on a regional basis. The full breakdown of unit prices for every fuel, payment method, tariff and region from 2013 to 2030 have been provided to the CCC separately in an Excel file.

Annex Table 2. Average UK unit fuel prices for metered fuels (mains gas, standard electricity and Economy 7 electricity), 2013 – 2030

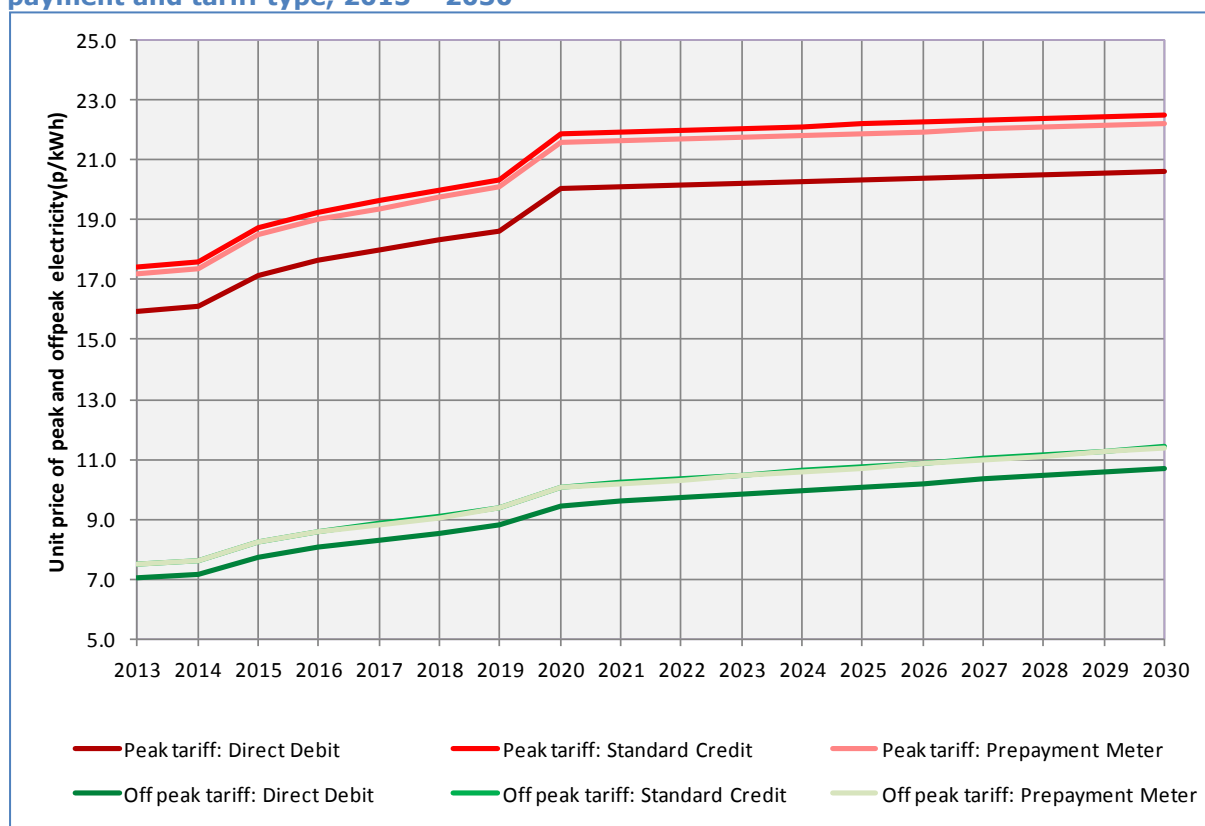
FUEL	Payment method	Tariff type	Unit price of fuel (p/kWh)				
			2013	2015	2020	2025	2030
MAINS GAS	Direct Debit	Dual fuel	4.37	4.49	4.78	4.65	4.69
	Standard Credit	Dual fuel	4.84	4.96	5.30	5.15	5.20
	Prepayment Meter	Dual fuel	4.87	4.99	5.32	5.17	5.22
	Direct Debit	Non dual fuel	4.59	4.70	5.02	4.87	4.92
	Standard Credit	Non dual fuel	4.97	5.10	5.44	5.29	5.34
	Prepayment Meter	Non dual fuel	4.91	5.04	5.37	5.22	5.27
STANDARD ELECTRICITY	Direct Debit	Dual fuel	14.76	15.09	18.97	19.18	19.55
	Standard Credit	Dual fuel	16.32	16.69	20.97	21.20	21.61
	Prepayment Meter	Dual fuel	16.66	17.04	21.40	21.64	22.06
	Direct Debit	Non dual fuel	15.43	15.79	19.84	20.05	20.44
	Standard Credit	Non dual fuel	16.76	17.14	21.54	21.77	22.19
	Prepayment Meter	Non dual fuel	16.80	17.18	21.59	21.82	22.25
ECONOMY 7 ELECTRICITY	Direct Debit	Peak tariff	15.96	17.15	20.02	20.31	20.60
	Standard Credit	Peak tariff	17.44	18.73	21.88	22.19	22.51
	Prepayment Meter	Peak tariff	17.21	18.48	21.58	21.90	22.21
	Direct Debit	Off peak tariff	7.05	7.73	9.46	10.08	10.70
	Standard Credit	Off peak tariff	7.51	8.24	10.08	10.75	11.41
	Prepayment Meter	Off peak tariff	7.49	8.21	10.04	10.70	11.36

Annex Table 3. Average UK unit fuel prices for unmetered fuels, 2013 – 2030

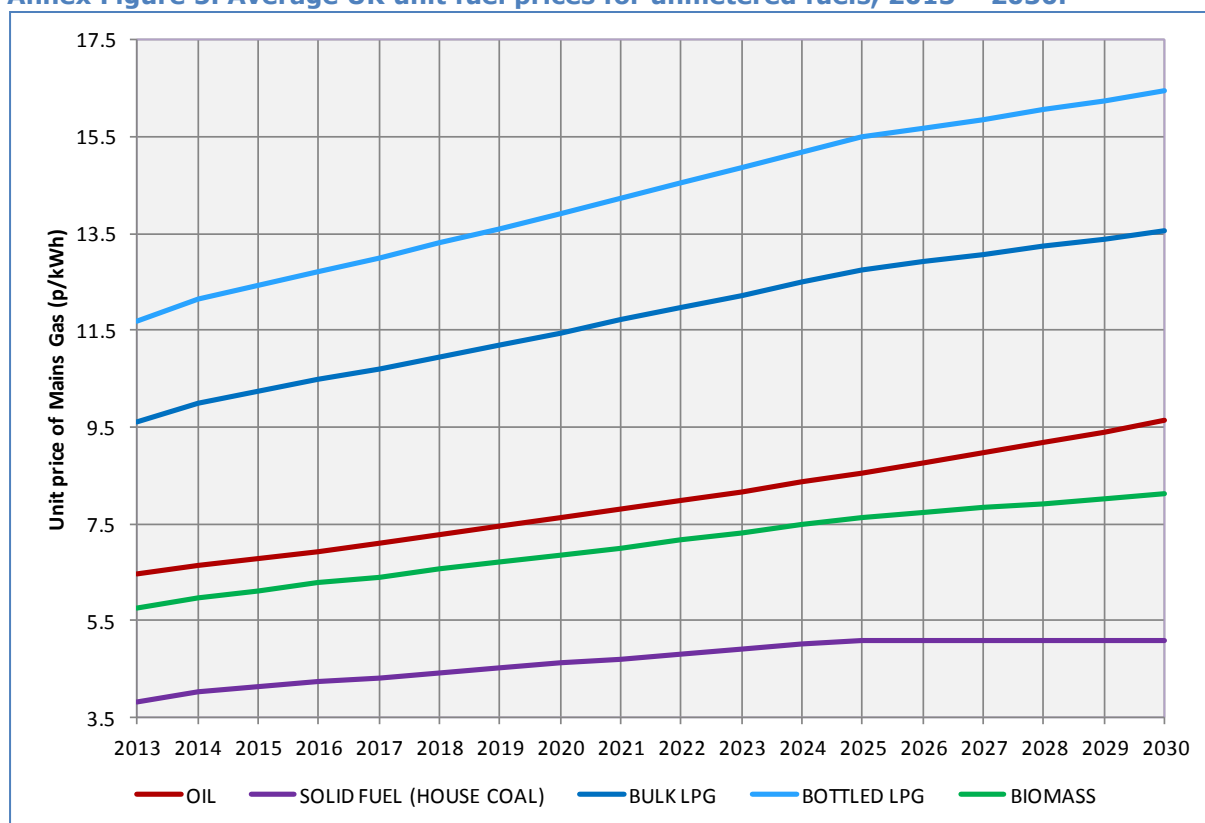
FUEL	Unit price of fuel (p/kWh)				
	2013	2015	2020	2025	2030
OIL	6.48	6.78	7.61	8.55	9.63
SOLID FUEL (HOUSE COAL)	3.83	4.13	4.61	5.10	5.10
BULK LPG	9.62	10.23	11.45	12.76	13.55
BOTTLED LPG	11.68	12.42	13.90	15.50	16.45
BIOMASS	5.76	6.12	6.86	7.64	8.11

Annex Figure 2. Average UK unit fuel prices for Mains Gas by method of payment and tariff type, 2013 – 2030**Annex Figure 3. Average UK unit fuel prices for Standard Electricity by method of payment and tariff type, 2013 – 2030**

Annex Figure 4. Average UK unit fuel prices for Economy 7 Electricity by method of payment and tariff type, 2013 – 2030



Annex Figure 5. Average UK unit fuel prices for unmetered fuels, 2013 – 2030.



Annex III. CHAID models: 10% definition

Summary of percent correctly predicted in the CHAID models of fuel poverty under the 10% definition in England and the Devolved nations, with further breakdown by each nation for the latter.

England – 10% CHAID model			
Observed	Predicted		
	Non-fuel poor	Fuel poor	Percent Correct
Non-fuel poor	6,848,200	1,255,000	84.5%
Fuel poor	2,284,600	1,903,600	45.5%
Overall Percentage	74.3%	25.7%	71.2%

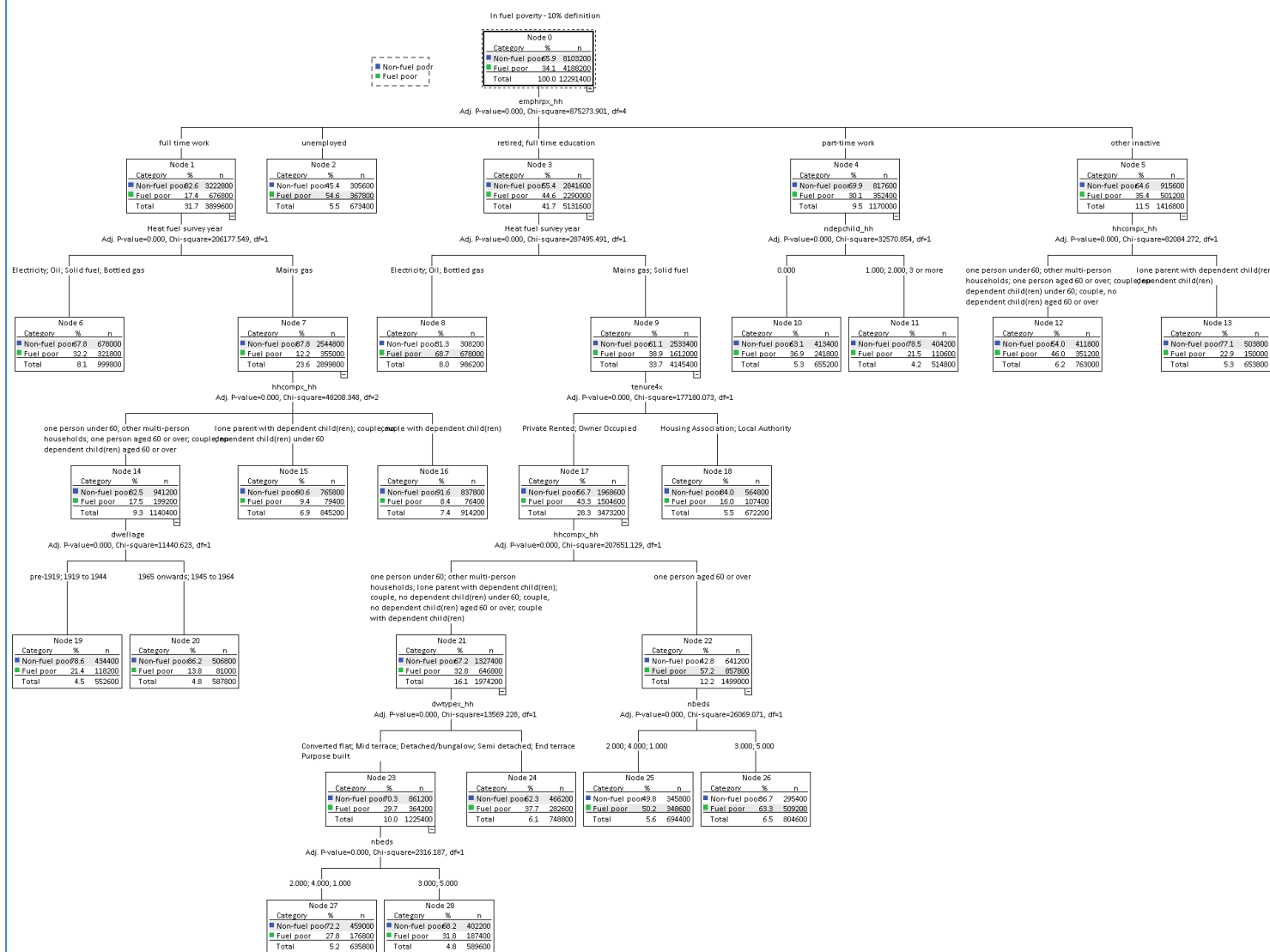
Devolved Nations – 10% CHAID model			
Observed	Predicted		
	Non-fuel poor	Fuel poor	Percent Correct
Non-fuel poor	1,268,520	413,840	75.4%
Fuel poor	596,320	791,400	57.0%
Overall Percentage	60.7%	39.3%	67.1%

Wales – 10% CHAID model			
Observed	Predicted		
	Non-fuel poor	Fuel poor	Percent Correct
Non-fuel poor	680,280	144,240	78.6%
Fuel poor	185,520	256,400	64.0%
Overall Percentage	68.4%	31.6%	74.0%

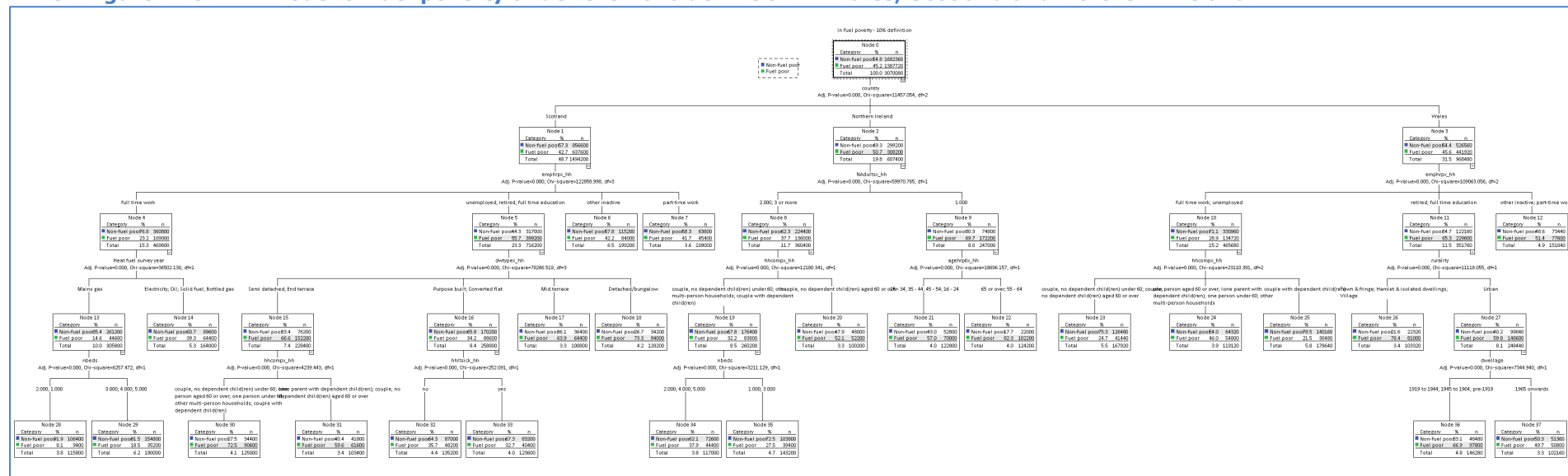
Scotland – 10% CHAID model			
Observed	Predicted		
	Non-fuel poor	Fuel poor	Percent Correct
Non-fuel poor	1,373,800	327,000	80.8%
Fuel poor	327,000	310,600	48.7%
Overall Percentage	72.7%	27.3%	72.0%

Northern Ireland – 10% CHAID model			
Observed	Predicted		
	Non-fuel poor	Fuel poor	Percent Correct
Non-fuel poor	264,400	122,800	75.9%
Fuel poor	83,800	224,400	64.6%
Overall Percentage	50.1%	49.9%	70.3%

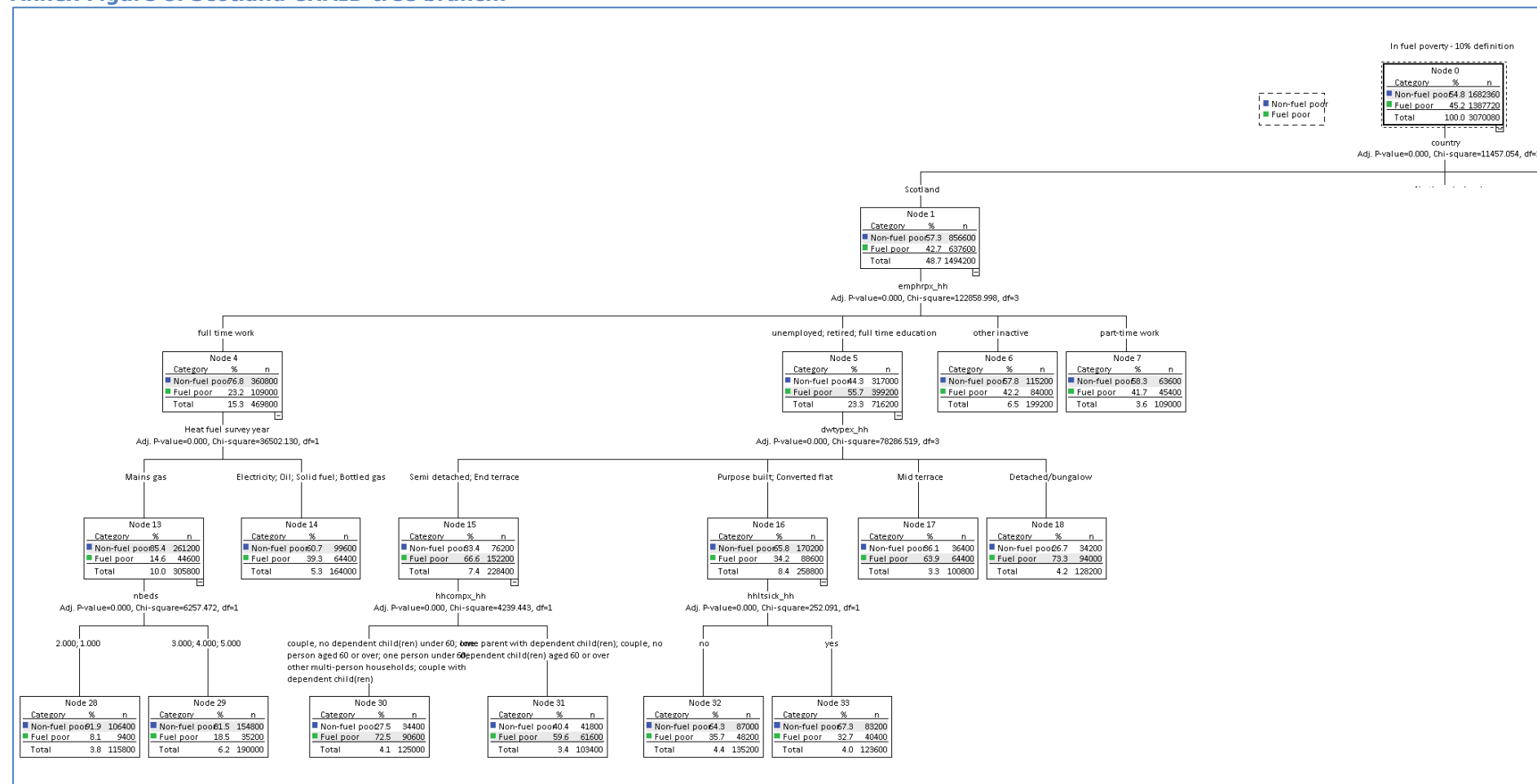
Annex Figure 6. CHAID Model of fuel poverty under the 10% definition in England



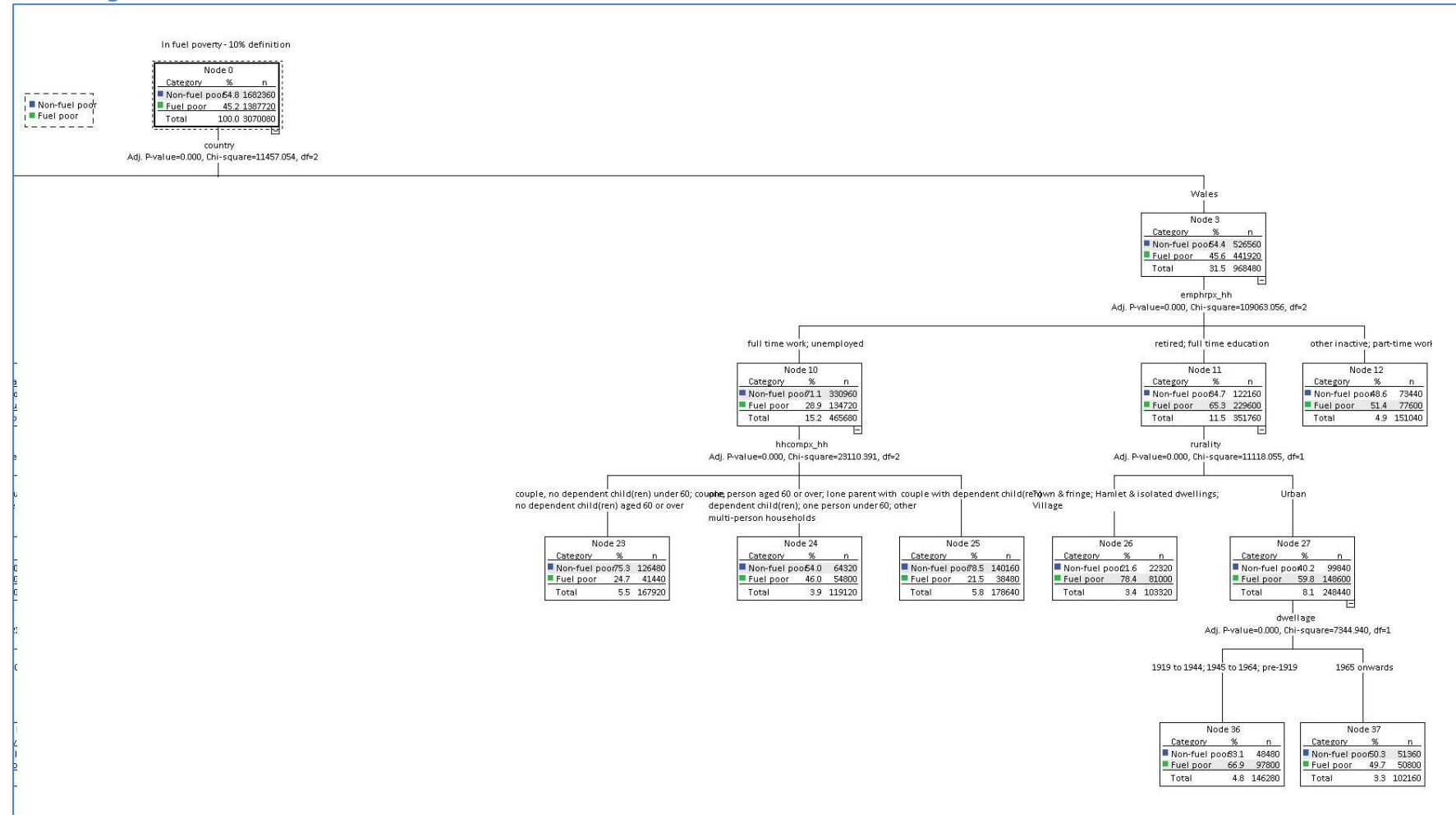
Annex Figure 7. CHAID Model of fuel poverty under the 10% definition in Wales, Scotland and Northern Ireland



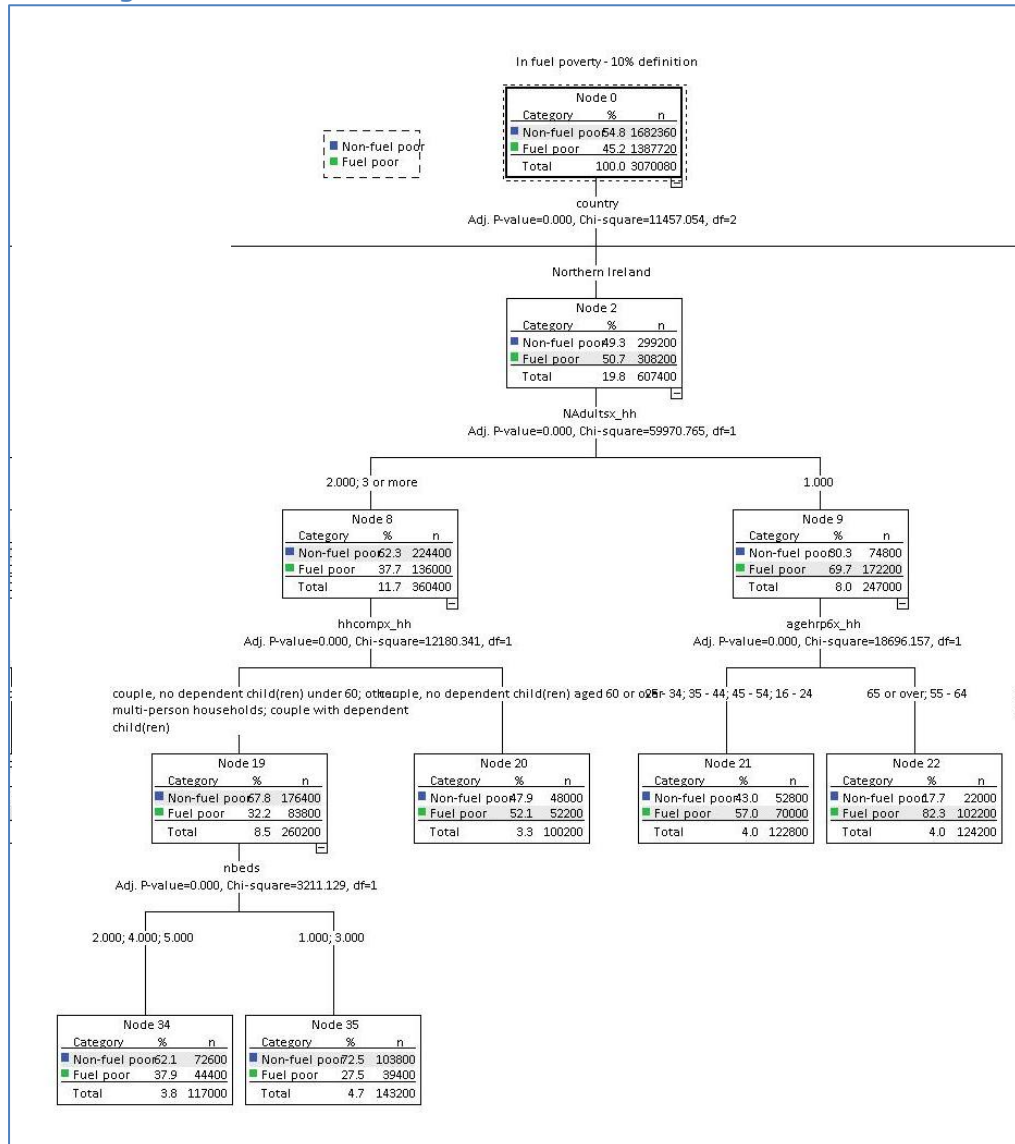
Annex Figure 8. Scotland CHAID tree branch:



Annex Figure 9. Wales CHAID tree branch:



Annex Figure 10. Northern Ireland CHAID tree branch:



Annex IV. Modelling the 4th Carbon Budget and fuel poverty to 2030: inputs and assumptions

Annex Table 4. Measures simulated across the UK housing stock to 2030 in the NHM
CCC measures needed in the residential sector to meet the 4th carbon budget

Insulation and heating measures	Target count (m. households)
External Wall Insulation	2.31
Internal wall insulation	1.17
CWI - Easy to treat	0.89
CWI - Hard to treat	2.83
Loft insulation 50-125mm	3.48
Loft insulation 125-200mm	2.01
Double-glazing	1.30
Suspended timber floor	1.20
Solid floor	2.94
Heating controls - Full	0.96
Heating controls - timer + TRV	1.04
Heating controls - TRV only	4.52
Low energy lighting (cfls & leds)	15.55
ASHP	3.03
Biomass boilers	0.91
GSHP	0.90
Solar Thermal	0.98
Behavioural “measure”¹	
1 deg. C decrease	9.70
Electrical appliances²	
fridges and freezers	24.87
turn off lights	7.03
washing machines	12.45
tumble dryers	7.15
dishwasher	5.83
electric ovens	15.63
TVs	23.70
Reduced flow showers	4.16
Additional measures: not included in CCC time series, but assumed to be happening in ‘baseline’	
Gas condensing boilers	11.43
Oil condensing boilers	1.27
Solar PV	2.13

Notes:

1. This is simulated in the NHM by reducing the thermostat setting (indoor heating temperature) by 1°C
2. Electrical appliances are modelled in NHM by calibrating energy use to reflect the saving on electricity and increase in heating requirement assumed by the CCC

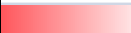
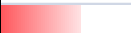
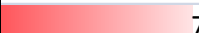
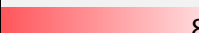
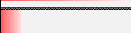
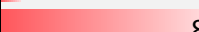
Annex Table 5. Measures costs in the NHM

Technology	Mean	Min	Max	Source of cost data and comments
ASHP	£6,666	£3,826	£11,608	equation applied in NHM using sizing function
Double glazing	£8,712	£8,712	£8,712	fixed cost applied
External wall insulation	£11,163	£2,854	£43,195	equation applied in NHM using sizing function with 50% lower cost for social housing (assumed economies of scale, based on recent figures from LA scheme compared to costs NHM was generating)
Cavity wall insulation	£430	£430	£430	fixed cost applied
Floor insulation	£966	£644	£1,287	fixed cost (this is solid and suspended shown as one measure here)
GSHP	£22,997	£10,833	£63,978	equation applied in NHM using sizing function
Internal wall insulation	£10,783	£3,492	£34,596	equation applied in NHM using sizing function with 50% lower cost for social housing (assumed economies of scale, based on recent figures from LA scheme compared to costs NHM was generating)
Loft insulation	£300	£300	£300	fixed cost applied
Low energy lighting	£77	£77	£77	fixed cost applied (NB this
Programmer	£500	£500	£500	fixed cost applied
Solar Photovoltaic	£9,000	£9,000	£9,000	fixed cost applied
Standard biomass pellet boiler	£7,149	£4,060	£23,557	equation applied in NHM using sizing function
Standard mains gas boiler	£3,000	£3,000	£3,000	fixed cost applied
Standard oil boiler	£4,000	£4,000	£4,000	fixed cost applied
Thermostatic Radiator Valve	£350	£350	£350	fixed cost applied
Time Temperature Zone Control	£689	£689	£689	fixed cost applied

Fixed costs represent an average derived from internal CSE data.

Annex V. Results tables from scenario modelling

Annex Table 6. Impact on fuel poverty levels in 2030 under the 10% definition for the UK

Scenario		10% definition	
		In fuel poverty (m)	% fuel poor
2013 base	2013 baseline	 5.59	21%
Sc.1	2030 counterfactual: no policy costs, no measures	 6.30	24%
Sc.2	2030 counterfactual: policy costs, no measures	 8.01	31%
Sc.3a	Random allocation, with no cost recovery	 5.88	22%
Sc.3b	Random allocation, with full cost recovery	 8.64	33%
Sc. 3c	Random allocation, with partial cost recovery	 7.31	28%
Sc.4a	Target LIHC fuel poor; remaining at random; with no cost recovery	 4.89	19%
Sc.4b	Target LIHC fuel poor; remaining at random; with full cost recovery	 7.87	30%
Sc.4c	Target LIHC fuel poor; remaining at random; with partial cost recovery	 6.36	24%
Sc.5a	Target 10%; remaining measures at random; with no cost recovery	 3.29	13%
Sc.5b	Target 10%; remaining measures at random; with full cost recovery	 6.32	24%
Sc.5c	Target 10%; remaining measures at random; with partial cost recovery	 4.84	18%
Sc.6a	Target LIHC; secondary targeting to minimise emissions; no cost recovery	 4.89	19%
Sc.6b	Target LIHC; secondary targeting to minimise emissions; with full cost recovery	 7.92	30%
Sc.6c	Target LIHC; secondary targeting to minimise emissions; with partial cost recovery	 6.46	25%
Sc. 7a	LIHC FP get nothing; no cost recovery	 5.40	21%
Sc. 7b	LIHC FP get nothing; full cost recovery	 8.10	31%
Sc. 7c	LIHC FP get nothing; partial cost recovery	 6.79	26%
Sc. 8a	LIHC FP get no major measures (some apps & lighting); no cost recovery	 5.31	20%
Sc. 8b	LIHC FP get no major measures (some apps & lighting); full cost recovery	 8.13	31%
Sc. 8c	LIHC FP get no major measures (some apps & lighting); partial cost recovery	 6.76	26%

Annex Table 7. Impact on fuel poverty levels in 2030 under the 10% definition by country

Scenario		10% definition			
		England	Wales	Scotland	Northern Ireland
Baseline	2013 baseline	 19%	 35%	 27%	 44%
Sc.1	2030 counterfactual: no policy costs, no measures	 21%	 38%	 30%	 63%
Sc.2	2030 counterfactual: policy costs, no measures	 28%	 50%	 38%	 67%
Sc.3a	Random allocation, with no cost recovery	 20%	 35%	 27%	 53%
Sc.3b	Random allocation, with full cost recovery	 30%	 48%	 38%	 62%
Sc. 3c	Random allocation, with partial cost recovery	 25%	 42%	 34%	 58%
Sc.4a	Target LIHC fuel poor; remaining at random; with no cost recovery	 16%	 33%	 23%	 52%
Sc.4b	Target LIHC fuel poor; remaining at random; with full cost recovery	 28%	 45%	 35%	 62%
Sc.4c	Target LIHC fuel poor; remaining at random; with partial cost recovery	 22%	 39%	 29%	 57%
Sc.5a	Target 10%; remaining measures at random; with no cost recovery	 11%	 21%	 16%	 30%
Sc.5b	Target 10%; remaining measures at random; with full cost recovery	 22%	 35%	 29%	 47%
Sc.5c	Target 10%; remaining measures at random; with partial cost recovery	 17%	 29%	 22%	 39%
Sc.6a	Target LIHC; secondary targeting to minimise emissions; no cost recovery	 16%	 32%	 23%	 52%
Sc.6b	Target LIHC; secondary targeting to minimise emissions; with full cost recovery	 28%	 45%	 34%	 61%
Sc.6c	Target LIHC; secondary targeting to minimise emissions; with partial cost recovery	 22%	 40%	 29%	 56%
Sc. 7a	LIHC FP get nothing; no cost recovery	 19%	 37%	 25%	 44%
Sc. 7b	LIHC FP get nothing; full cost recovery	 29%	 49%	 36%	 56%
Sc. 7c	LIHC FP get nothing; partial cost recovery	 24%	 43%	 30%	 52%
Sc. 8a	LIHC FP get no major measures (some apps & lighting); no cost recovery	 18%	 37%	 24%	 45%
Sc. 8b	LIHC FP get no major measures (some apps & lighting); full cost recovery	 29%	 51%	 36%	 57%
Sc. 8c	LIHC FP get no major measures (some apps & lighting); partial cost recovery	 24%	 43%	 30%	 52%

Annex Table 8. Impact on fuel poverty levels in 2030 under the LIHC definition for the UK

Scenario		LIHC definition			
		In fuel poverty (m)	% fuel poor	Mean fuel poverty gap	Aggregate fuel poverty gap (£bn)
baseline	2013 baseline	2.86	11%	£639	£1.82
Sc.1	2030 counterfactual: no policy costs, no measures	2.95	11%	£774	£2.28
Sc.2	2030 counterfactual: policy costs, no measures	3.10	12%	£873	£2.71
Sc.3a	Random allocation, with no cost recovery	3.04	11.5%	£713	£2.17
Sc.3b	Random allocation, with full cost recovery	3.15	12.0%	£786	£2.47
Sc. 3c	Random allocation, with partial cost recovery	3.10	11.8%	£747	£2.32
Sc.4a	Target LIHC fuel poor; remaining at random; with no cost recovery	1.19	4.5%	£330	£0.39
Sc.4b	Target LIHC fuel poor; remaining at random; with full cost recovery	1.27	4.8%	£371	£0.47
Sc.4c	Target LIHC fuel poor; remaining at random; with partial cost recovery	1.19	4.5%	£355	£0.42
Sc.5a	Target 10%; remaining measures at random; with no cost recovery	2.17	8.2%	£428	£0.93
Sc.5b	Target 10%; remaining measures at random; with full cost recovery	2.26	8.6%	£558	£1.26
Sc.5c	Target 10%; remaining measures at random; with partial cost recovery	2.19	8.3%	£488	£1.07
Sc.6a	Target LIHC; secondary targeting to minimise emissions; no cost recovery	1.17	4.5%	£334	£0.39
Sc.6b	Target LIHC; secondary targeting to minimise emissions; with full cost recovery	1.24	4.7%	£372	£0.46
Sc.6c	Target LIHC; secondary targeting to minimise emissions; with partial cost recovery	1.17	4.5%	£358	£0.42
Sc. 7a	LIHC FP get nothing; no cost recovery	3.66	14.0%	£1,014	£3.71
Sc. 7b	LIHC FP get nothing; full cost recovery	3.76	14.4%	£1,178	£4.43
Sc. 7c	LIHC FP get nothing; partial cost recovery	3.68	14.1%	£1,102	£4.06
Sc. 8a	LIHC FP get no major measures (some apps & lighting); no cost recovery	3.62	13.8%	£887	£3.21
Sc. 8b	LIHC FP get no major measures (some apps & lighting); full cost recovery	3.74	14.3%	£1,000	£3.74
Sc. 8c	LIHC FP get no major measures (some apps & lighting); partial cost recovery	3.68	14.0%	£940	£3.45

Annex Table 9. Impact on fuel poverty levels in 2030 under the LIHC definition by country

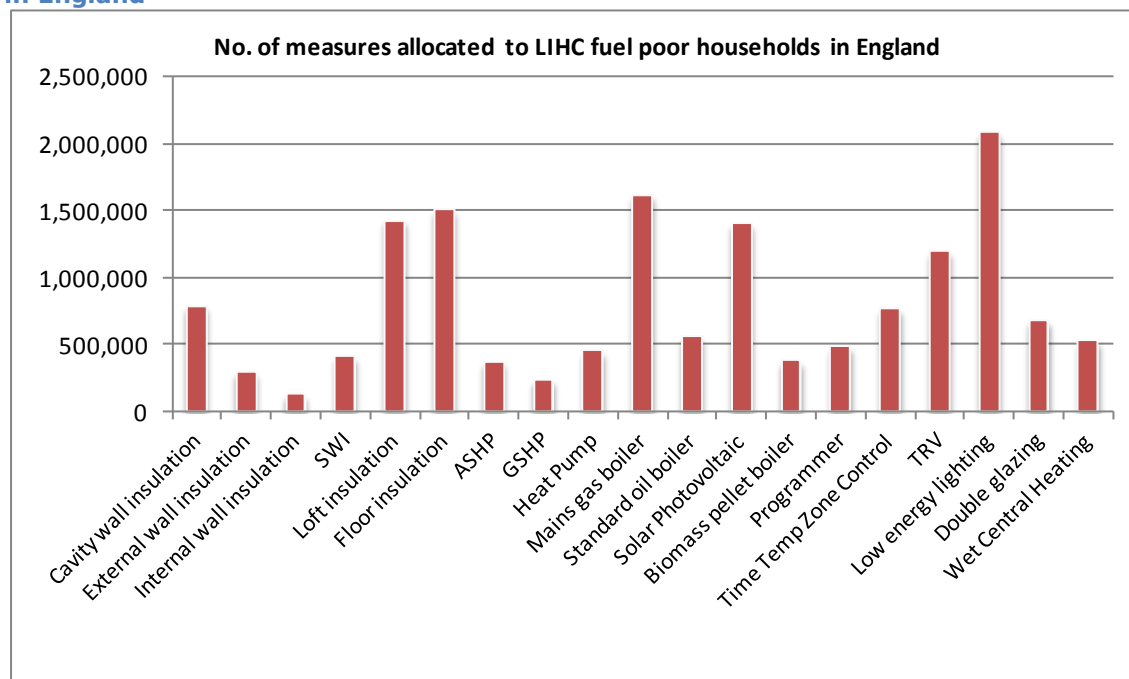
Scenario		LIHC definition			
		England	Wales	Scotland	Northern Ireland
Baseline	2013 baseline	10.8%	11.1%	11.4%	10.4%
Sc.1	2030 counterfactual: no policy costs, no measures	11.0%	11.5%	11.8%	13.7%
Sc.2	2030 counterfactual: policy costs, no measures	11.6%	14.0%	12.8%	14.2%
Sc.3a	Random allocation, with no cost recovery	11.5%	11.6%	12.0%	12.2%
Sc.3b	Random allocation, with full cost recovery	11.8%	12.4%	12.8%	12.7%
Sc. 3c	Random allocation, with partial cost recovery	11.7%	12.3%	12.3%	12.6%
Sc.4a	Target LIHC fuel poor; remaining at random; with no cost recovery	4.6%	4.5%	4.3%	2.9%
Sc.4b	Target LIHC fuel poor; remaining at random; with full cost recovery	4.9%	4.6%	4.6%	3.6%
Sc.4c	Target LIHC fuel poor; remaining at random; with partial cost recovery	4.6%	4.5%	4.5%	3.1%
Sc.5a	Target 10%; remaining measures at random; with no cost recovery	8.3%	8.2%	8.0%	5.9%
Sc.5b	Target 10%; remaining measures at random; with full cost recovery	8.6%	8.9%	8.7%	8.4%
Sc.5c	Target 10%; remaining measures at random; with partial cost recovery	8.4%	8.9%	8.2%	6.9%
Sc.6a	Target LIHC; secondary targeting to minimise emissions; no cost recovery	4.5%	4.5%	4.2%	2.8%
Sc.6b	Target LIHC; secondary targeting to minimise emissions; with full cost recovery	4.8%	4.3%	4.6%	3.0%
Sc.6c	Target LIHC; secondary targeting to minimise emissions; with partial cost recovery	4.5%	4.3%	4.4%	2.8%
Sc. 7a	LIHC FP get nothing; no cost recovery	13.8%	15.8%	14.5%	14.0%
Sc. 7b	LIHC FP get nothing; full cost recovery	14.2%	16.2%	15.0%	14.4%
Sc. 7c	LIHC FP get nothing; partial cost recovery	13.9%	15.8%	14.8%	14.1%
Sc. 8a	LIHC FP get no major measures (some apps & lighting); no cost recovery	13.7%	15.5%	14.2%	13.8%
Sc. 8b	LIHC FP get no major measures (some apps & lighting); full cost recovery	14.1%	16.5%	15.0%	14.3%
Sc. 8c	LIHC FP get no major measures (some apps & lighting); partial cost recovery	13.9%	15.8%	14.1%	14.0%

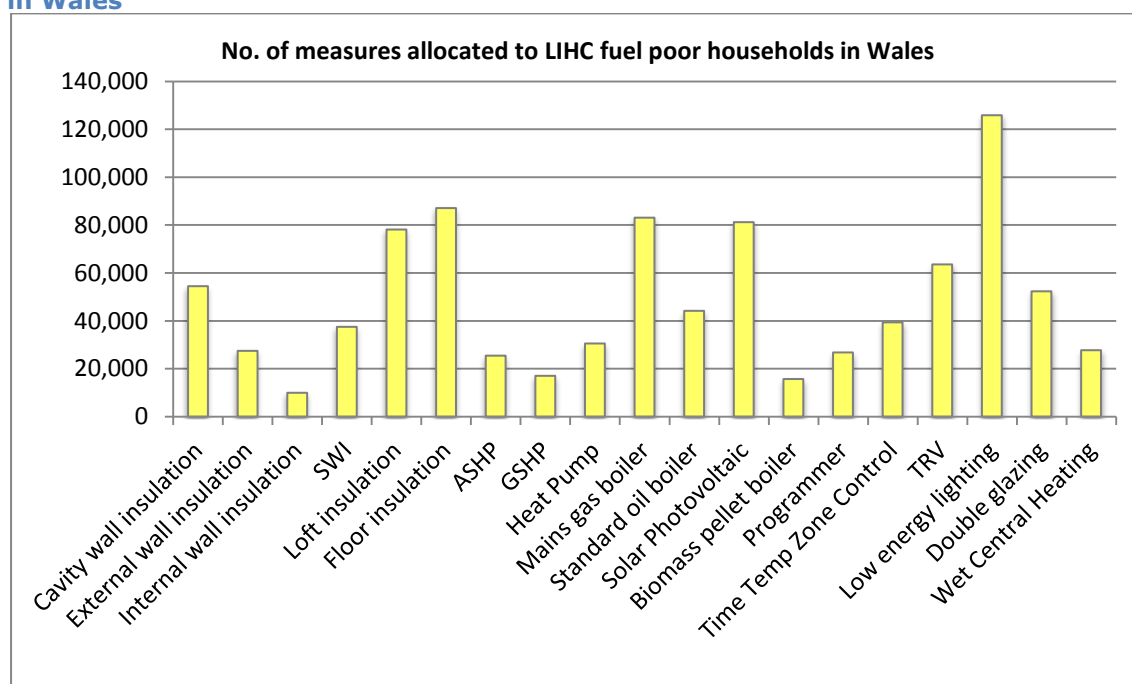
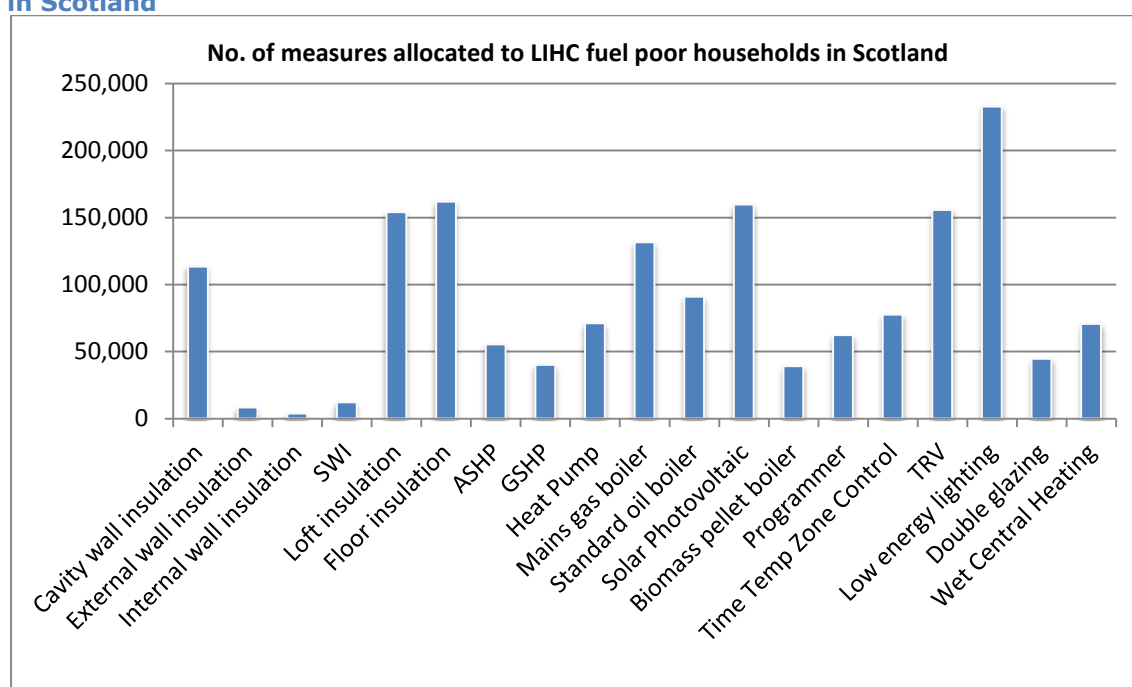
Annex VI. Targeting the LIHC fuel poor: analysis of measures allocation

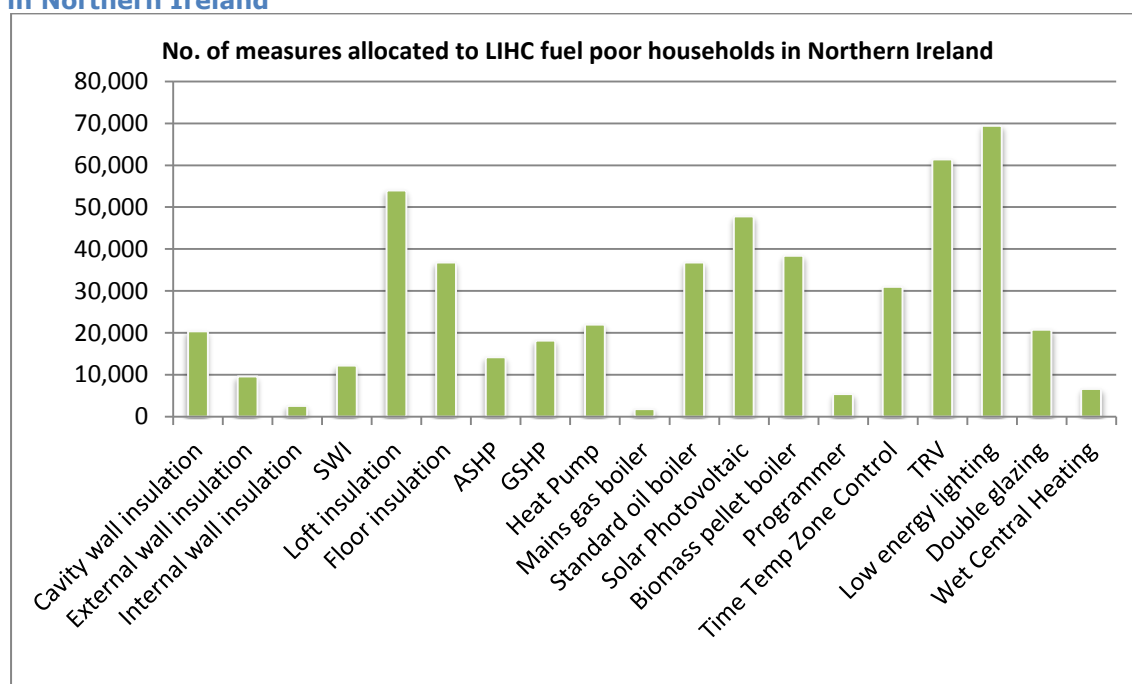
Annex Figure 11 to Annex Figure 14 show the results from modelling in the NHM to simulate the deployment of the CCC's trajectory of measures to meet the fourth carbon budget across the UK stock to 2030, with targeting at the LIHC fuel poor.

The figures show the number of different measures being allocated to fuel poor households, as defined under the Low Income, High Cost definition in 2013. These results are from one scenario simulation (scenario 4c), in which LIHC fuel poor households are always targeted with measures first, and measures are selected to minimise their fuel costs. The total number of measures is over the lifetime of the scenario (to 2030). As households move in and out of fuel poverty over time, this represents a snapshot of the 2013 LIHC fuel poor who receive measures.

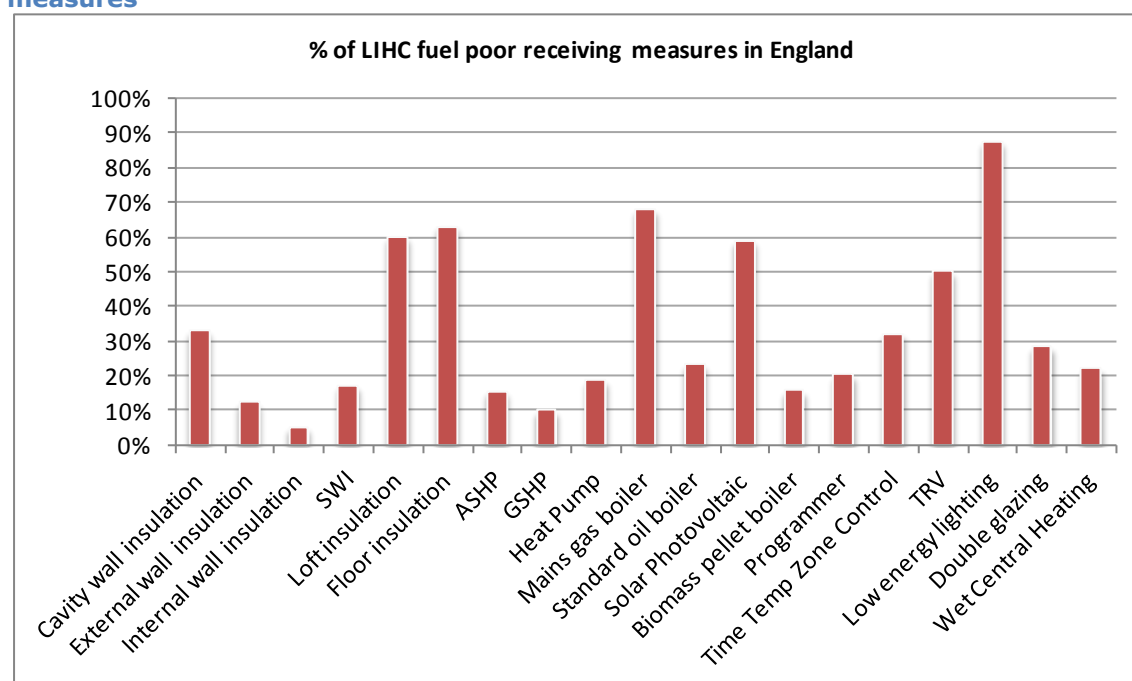
Annex Figure 11. Number of measures allocated to the 2013 LIHC fuel poor households in England

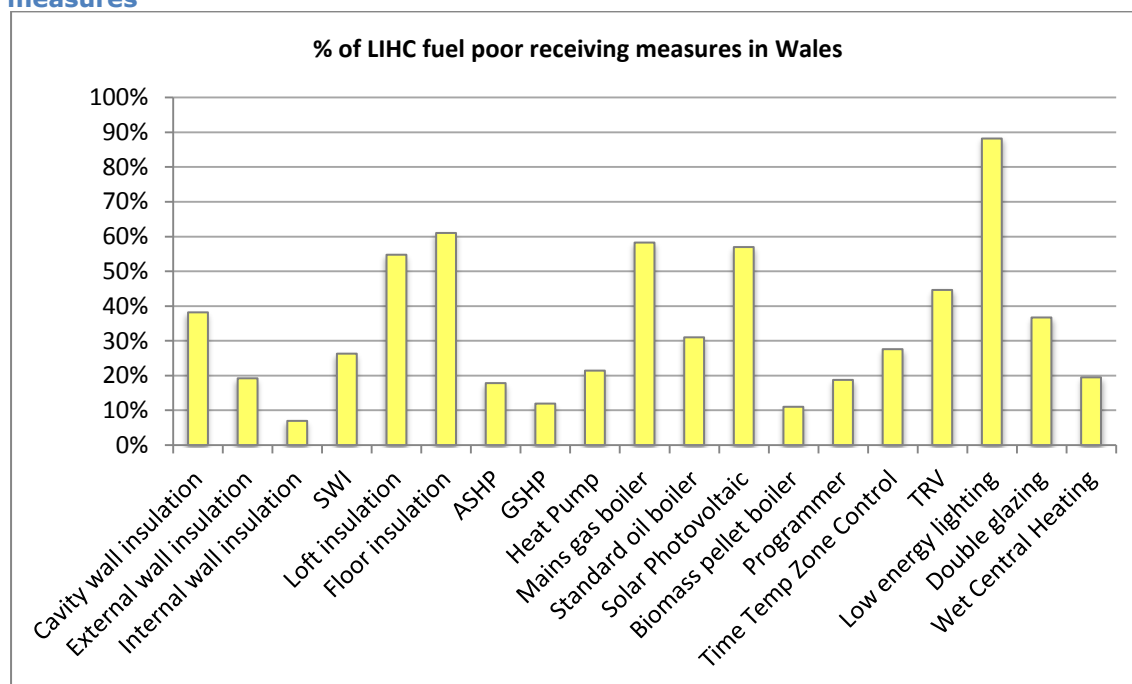
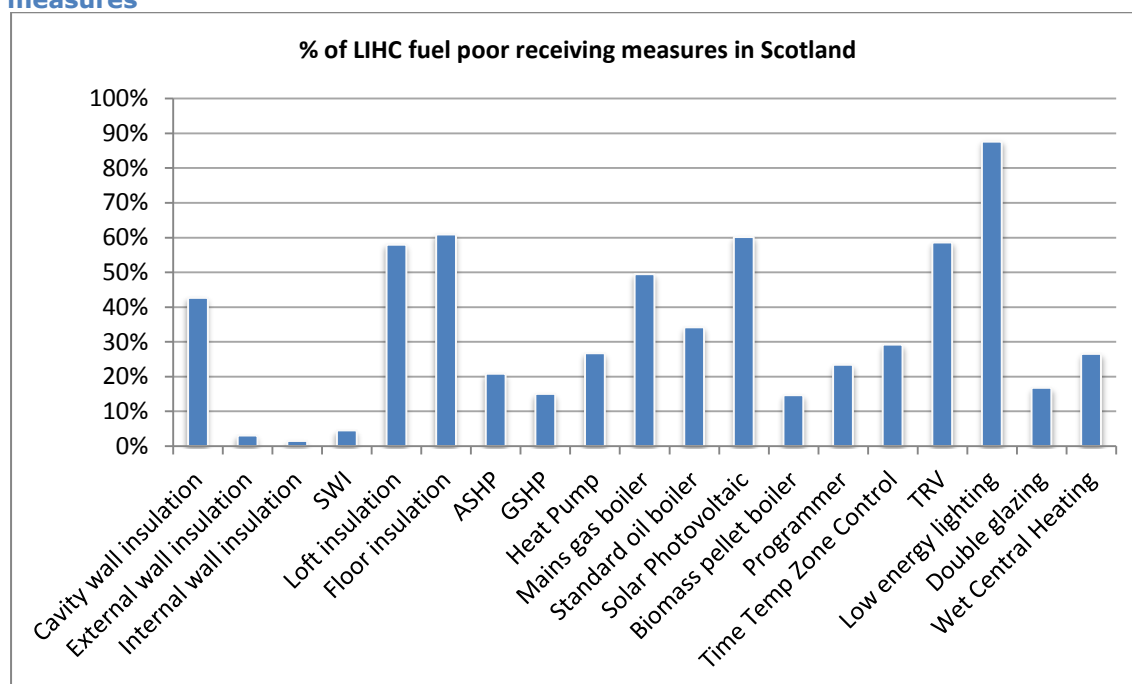


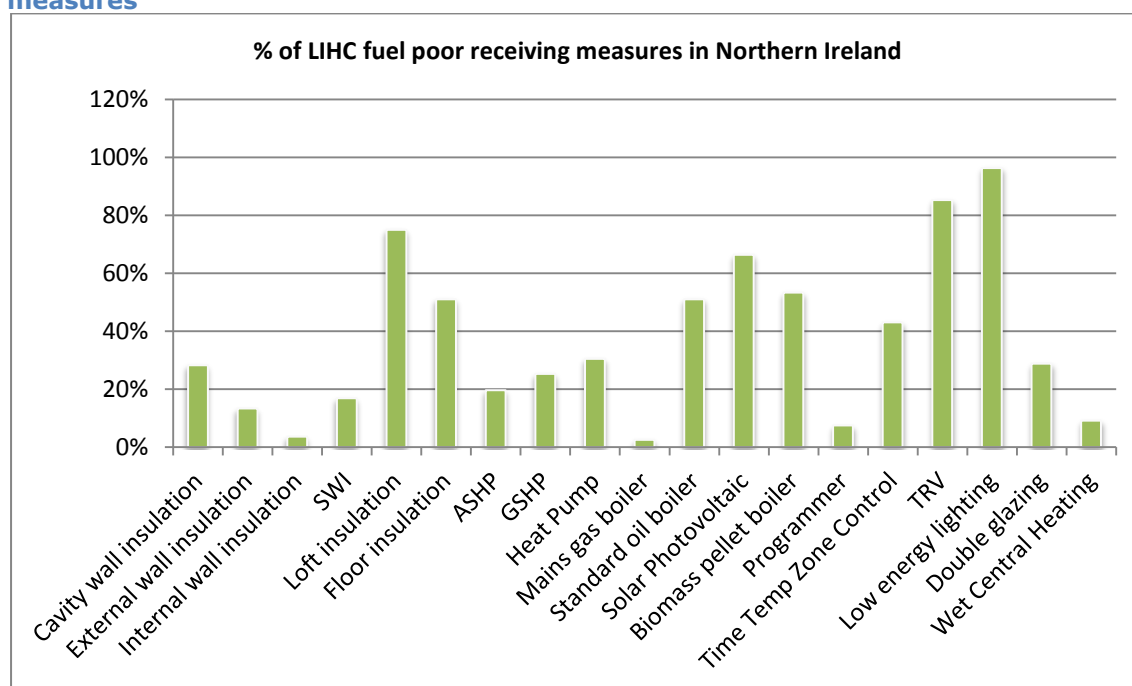
Annex Figure 12. Number of measures allocated to the 2013 LIHC fuel poor households in Wales**Annex Figure 13. Number of measures allocated to the 2013 LIHC fuel poor households in Scotland**

Annex Figure 14. Number of measures allocated to the 2013 LIHC fuel poor households in Northern Ireland

Annex Figure 15 to Annex Figure 18 show the proportion of baseline (2013) LIHC fuel poor households receiving measures over the lifetime of the scenario.

Annex Figure 15. Proportion of the 2013 LIHC fuel poor households in England receiving measures

Annex Figure 16. Proportion of the 2013 LIHC fuel poor households in England receiving measures**Annex Figure 17. Proportion of the 2013 LIHC fuel poor households in England receiving measures**

Annex Figure 18. Proportion of the 2013 LIHC fuel poor households in England receiving measures

Annex VII. Analysis of the Energy Follow-Up Survey

Annex Box 1 summarises some of the key findings from BRE's analysis of indoor living temperatures, using the 2011 Energy Follow-Up Survey.

Annex Box 1. Summary of analysis of mean indoor living temperatures from the Energy Follow-Up Survey (2011) dataset

Source: Report 2: Mean household temperatures. BRE on behalf of DECC. December 2013

<https://www.gov.uk/government/statistics/energy-follow-up-survey-efus-2011>

Analysis of mean living indoor temperatures showed significant differences in the following:

- dwellings built **pre-1919 having lower mean** heating season temperatures in both zones than dwellings built between 1945 and 1990;
- dwellings with a floor area <50m² having higher mean heating season temperatures in both zones than the **largest dwellings with floor areas >140m²**;
- **owner-occupied dwellings** having lower living room and zone 2 mean heating season temperatures than local authority or RSL dwellings;
- dwellings in which the HRP is older than 75 years having higher living room and zone 2 mean heating season temperatures than dwellings with the **HRP aged between 45-64 years**.
- flats are seen to have higher mean heating season living room temperatures than **detached or semi-detached dwellings** but no difference is seen between dwelling types in the zone 2 mean heating season temperatures.
- Dwellings with **no insulation measures** have lower living room mean heating season temperatures than dwellings with at least one or more insulation measures, but no differences are seen in the zone 2 mean heating season temperatures for this characteristic.
- In terms of household characteristics, households with a pensioner living in the dwelling typically have higher living room mean heating season temperatures than households **without a pensioner** present;
- similarly households with one or more persons retired have higher living room mean heating season temperatures than households **with one or more persons working full time**.

There were some groups for which **there are no significant (or very small) differences in mean heating season temperatures**:

- centrally heated versus non-centrally heated dwellings,
- dwellings using different fuels for their main heating;
- cavity insulated walls versus non-insulated walls,
- differing levels of loft insulation,
- households of differing sizes,
- households with and without children present,
- households in all income quintiles
- **households in fuel poverty under the Low Income High Costs (LIHC) indicator**

(BRE, 2013)

Analysis of the distribution of indoor living temperatures over winter months

Access to the household socio-demographic data associated with the EFUS indoor temperature data is restricted. Our analysis was therefore limited in depth for the purpose of this study. The table below (Annex Table 10) shows the distribution of indoor temperatures over winter months across all households in the EFUS (2011) temperature dataset. Without access to the adjoining socio-demographic data however, we are unable to comment on the types of households associated with different indoor temperatures. This does show however, that there is a wide distribution, with some households recording an average indoor temperature as low as 9°C in winter months. For context, the World Health Organisation advises that there is a risk of hypothermia at temperatures of less than 9°C (Annex Box 2). Taking the average temperature across the winter months suggests that some 2.3 million households may be living at temperatures of 16°C or less – the temperature at which WHO guidelines suggest there is a risk of respiratory disease. This analysis should be treated with some caution however due to the relatively small sample of households in this group.

Annex Box 2. World Health Organisation guidelines on indoor living temperatures

18-21°C: comfortable temperature
 9-12 or 24+°C: Risk of stroke and heart attack
 21-24°C or 16-18°C: some discomfort
 12-16°C: risk of respiratory disease
 Less than 9°C: risk of hypothermia

Annex Table 10. Descriptive statistics of mean living room temperatures over the winter months (Source: EFUS, 2011)

Mean temperature for all days in the Living room	Mean	Median	Minimum	Maximum	Percentile 05	Percentile 95	Unweighted Count	Count
Jan 2011	18.6	18.7	9.2	26.9	13.7	22.8	823	21,893,980
Feb 2011	19.0	19.1	9.7	27.1	14.8	22.8	823	21,893,980
Mar 2011	19.0	19.1	11.1	27.0	14.7	22.8	823	21,893,980
Nov 2011	19.3	19.5	12.9	27.7	15.6	22.6	823	21,893,980
Dec 2011	18.5	18.8	9.9	27.5	14.1	22.3	823	21,893,980
Jan 2012	18.7	18.9	9.6	27.5	14.0	22.6	823	21,893,980

Annex Table 11. Banding of mean temperatures in the living room for all days in the winter months (Source: EFUS, 2011)

	Sample Count	Count	Min.	Max.	Mean	Median
9-12: Risk of stroke and heart attack	4	108,495	11.21	11.97	11.63	11.58
12-16°C: risk of respiratory disease	78	2,306,552	12.26	16.00	14.89	15.22
16-18°C: some discomfort	149	4,307,743	16.01	18.00	16.96	16.99
18-21°C: comfortable temperature	422	11,119,152	18.01	20.99	19.44	19.40
21-24°C: some discomfort	132	3,179,988	21.03	23.96	21.93	21.82
24°C+: Risk of stroke and heart attack	13	309,608	24.01	27.35	25.11	24.56