Fuel Poverty Methodology Handbook (Low Income High Costs)

30 April 2020 **Statistical Methodology**

Note – In 2021, fuel poverty in England changed to a new metric of Low Income Low Energy Efficiency but this Low Income High Costs handbook is the latest report setting out how fuel poverty was measured up to 2020.

Contents

1. Introduction

This methodology handbook is a guide for all users of the BEIS fuel poverty statistics. Within it, the user will find descriptions of the methodology used to calculate the 2018 fuel poverty figures for England, and the yearly fuel poverty time series produced back to 2003. Information on the fuel poverty datasets available and where to find them is also included in Section 8.

Users should note that the detailed methodological descriptions found from Chapter 2 onwards relate to the English fuel poverty statistics only (information on the other devolved nations are provided in Section 1.3).

This is the 2020 version of this document, relating to the 2018 fuel poverty figures, and supersedes all earlier methodology documents and updates.

1.1 What is fuel poverty

Fuel poverty in England is measured using the Low Income High Costs (LIHC) indicator. A household is considered to be fuel poor if:

- They have required fuel costs that are above average (the national median level); and

- Were they to spend that amount, they would be left with a residual income below the official poverty line.

The LIHC definition is a relative indicator as it compares households to the national median fuel costs and income – thereby reflecting contemporary trends.

The Low Income High Costs indicator is a *dual* indicator consisting of:

i)   The **number** of households that have both low incomes *and* high fuel costs (shown by the shaded area in the bottom left hand quadrant in Figure 1); and

ii)   The **depth** of fuel poverty among these fuel poor households. This is measured through **a fuel poverty gap** (shown by the vertical arrows in Figure 1), which represents the difference between the required fuel costs for each household and the nearest fuel poverty threshold.

For a detailed explanation of how to calculate the Low Income High Costs indicator, see Chapter 6.

Figure 1: Fuel poverty under the Low Income High Costs indicator
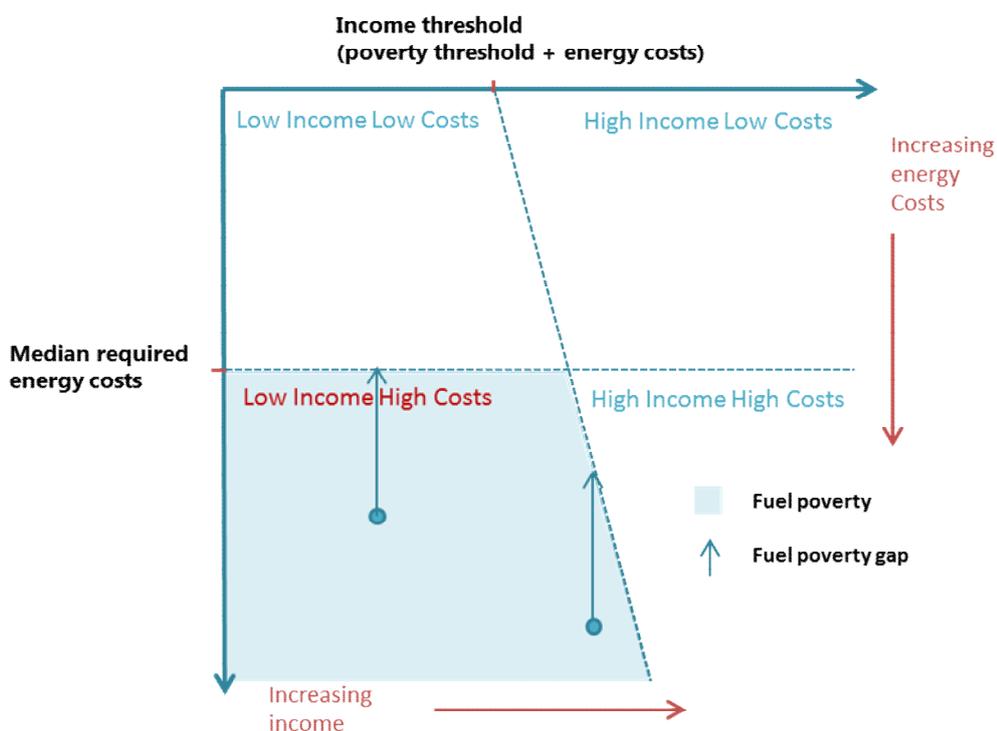
The key elements in determining whether a household is fuel poor under the LIHC indicator are:

- Household income;
- Household energy requirements (dependent on dwelling characteristics and the lifestyle of household occupants); and
- Fuel costs.

The cost of energy is *modelled* rather than being based on *actual* spending. This ensures that we do not overlook those households who have low energy bills simply because they actively limit their use of energy at home, for example, by not heating their home. It is calculated by combining the fuel requirements of the household with corresponding fuel prices. These costs capture four areas of energy requirements:

- Space heating;
- Water heating;
- Lights and appliances; and
- Cooking.

The modelling ensures that the household achieves the adequate level of warmth (as set out in the definition of fuel poverty and explained in more detail in Section 5.6), subject to a range of characteristics concerning the dwelling and its occupants.

The household energy requirements are modelled based on several factors including:

- The size of the property;
- The number of people who live in the dwelling and their occupancy patterns;
- The energy efficiency of the dwelling; and
- The mix of different fuels used by each household.

1.2 What are the uses of fuel poverty statistics?

Fuel poverty data has a wide range of uses both within and outside of Government. As well as being used to track objectives against targets, it is used to help develop, focus and target policies. Whilst it is not possible to use the dataset to identify individual and specific households that are in fuel poverty, within Government it is used to provide an understanding of the demography and geography of the fuel poor, and to indicate which groups are particularly susceptible to fuel poverty.

In addition, the wider English Housing Survey (EHS) dataset can provide detail around the heating and energy requirement of different types of households and homes. This information can be used to form an understanding of the role and impact of energy efficiency measures on fuel poverty and help to target policies to improve the energy efficiency of the housing stock.

Detailed demographic and dwelling-level splits of fuel poverty in England are available for users, published as part of the annual fuel poverty reporting[1]. In addition to the current year figures, a workbook showing long term trends in fuel poverty amongst different types of household is updated and published annually[2]

BEIS also publish the full fuel poverty dataset each year at the household level. This is made available from the UK Data Service[3] after the full EHS datasets are made available. This is helpful for users who want to extend their analysis of fuel poverty.

BEIS continue to endeavour to meet user requirements for sub-regional estimates of fuel poverty. This data is used particularly by local authorities, who combine this data with information they hold themselves to help target schemes at a local level. Annual sub-regional LIHC fuel poverty data are available as Experimental Statistics[4] for 2011 to 2018.

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[1] https://www.gov.uk/government/statistics/fuel-poverty-detailed-tables-2020
[2] https://www.gov.uk/government/statistics/fuel-poverty-trends-2020
[3] https://ukdataservice.ac.uk/
[4] Experimental statistics are defined in the Code of Practice for Official Statistics as "new official statistics undergoing evaluation. They are published in order to involve users and stakeholders in their development and as a means to build in quality at an early stage".

1.3 Why are fuel poverty statistics reported separately for England, Wales, Scotland and Northern Ireland?

Fuel poverty is a devolved matter, with each separate administration having individual policy targets, measurement and outputs. The main reason for the devolution is that the separate administrations have the power to affect certain aspects of fuel poverty policies (such as energy efficiency programs) but not others (such as incomes and market conditions, which impact fuel prices). As a result, different indicators of fuel poverty are used, that are based on different methodological assumptions.

Fuel poverty in Wales, Scotland and Northern Ireland, is currently calculated using a 10% indicator as opposed to the LIHC indicator in England, to determine the proportion of fuel poor in these nations.

Under the 10% indicator, a household is considered to be fuel poor if they are required to spend more than 10% of their income on fuel, so as to maintain an adequate standard of warmth. The fuel poverty ratio, used under this method, is defined as:

$$Fuel\ Poverty\ Ratio = \frac{Modelled\ fuel\ costs\ (i.e.\ modelled\ consumption\ \times price)}{Income}$$

Where this ratio has a value greater than 0.1 (10%), the household is considered to be fuel poor.

The 10% definition of fuel poverty was previously used to calculate the fuel poverty statistics in England, from 2001 - 2011. In 2012, an independent review was published by Professor John Hills[5] which recommended a new method to calculate fuel poverty, with separate indicators to calculate both the **extent** and **depth** of fuel poverty. This is known as the Low Income High Costs (LIHC) indicator and has been used since the 2011 fuel poverty statistics (published August 2013) to produce fuel poverty statistics for England. Long term trends tables have been produced from 2003 using the LIHC indicator[6].

The underlying assumptions used in the modelling of fuel poverty statistics varies for each country, as detailed below.

- In England fuel poverty is modelled from the English Housing Survey (EHS) using the LIHC indicator, and this document explains the methodology underpinning the English calculation.

- In Scotland, the most recent statistics use a 10% indicator. The Scottish Housing Survey is used to model fuel poverty. The most recent statistics measure fuel poverty according to the definition of fuel poverty set out in the Scottish Fuel Poverty Statement

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[5] https://www.gov.uk/government/publications/final-report-of-the-fuel-poverty-review
[6] https://www.gov.uk/government/collections/fuel-poverty-statistics

2002 using a 10% indicator. The underlying assumptions to calculate theoretical energy consumption are similar to those used in England. The main differences in the Scottish definition are alternative interpretations of;

- a satisfactory heating regime for pensioners, long-term sick and disabled households, meaning the adequate standard of warmth is achieved at a higher temperature for these groups (23°C compared with English 21°C);
- a different approach to under-occupancy.

- The Fuel Poverty (Targets, Definition and Strategy) (Scotland) Bill[7] was introduced to the Scottish Parliament on 26 June 2018 and the Fuel Poverty (Targets, Definition and Strategy) (Scotland) Act 2019[8] received Royal Assent on 18th July 2019. This includes a new definition of fuel poverty in Scotland based on advice from an independent panel of experts and further scrutiny and amendment by the Scottish Parliament. Please see Annex C in the main fuel poverty report[9] for further detail on the new definition.

- The Welsh Housing Conditions Survey is used to estimate fuel poverty in Wales under a 10% measure. Figures for Wales are also updated less frequently, as the fuel poverty module of questions are not asked every year. The most recent estimates of fuel poverty in Wales are measured using the Welsh Housing Conditions Survey 2017-18.

- The last Housing Condition Survey for Northern Ireland was run in 2016. Fuel poverty statistics produced using both a 10% and LIHC definition were published in 2018. It should be noted that Northern Ireland has no statutory requirement relating to fuel poverty.

As a result of both definition and methodological differences in fuel poverty for each devolved nation, the figures are non-additive (i.e. cannot be combined) in relation to a UK total. The latest fuel poverty figures for each of the devolved nations can be found at Annex C in the annual fuel poverty report[10]. More details of the devolved surveys and fuel poverty in each of the nations, can be found at the links below:

Scotland:

https://www.gov.scot/publications/scottish-house-condition-survey-2017-key-findings/
http://www.gov.scot/Topics/Statistics/SHCS

Wales:

https://gov.wales/fuel-poverty-estimates-wales

Northern Ireland:

https://www.nihe.gov.uk/Working-With-Us/Research/House-Condition-Survey

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[7] https://www.parliament.scot/parliamentarybusiness/Bills/108916.aspx
[8] http://www.legislation.gov.uk/asp/2019/10/contents/enacted
[9] https://www.gov.uk/government/statistics/annual-fuel-poverty-statistics-report-2020
[10] https://www.gov.uk/government/statistics/annual-fuel-poverty-statistics-report-2020

2. What are the key data sources for modelling fuel poverty?

2.1 The English Housing Survey

The source of data for housing and the household members, essential for estimating fuel poverty figures under LIHC, is the English Housing Survey (EHS). The EHS is currently an annual survey, commissioned by the Ministry of Housing, Communities and Local Government (MHCLG). For the purposes of producing the fuel poverty statistics, two years of the survey are combined. The EHS data collected April 2017 to March 2018 (17-18 single year dataset) is combined with the data collected April 2018 to March 2019 (18-19 single year dataset) in order to produce the fuel poverty dataset used to estimate 2018 fuel poverty figures.

The EHS covers all tenures and includes a household interview and a physical inspection of properties by a surveyor. The information obtained through the survey provides an accurate picture of the type and condition of housing in England, the people living there, and their views on housing and their neighbourhoods. The survey is a random sample of housing and householders in England. The sample is clustered, with half of England being sampled each survey year, meaning that two consecutive years of the survey provide a national sample, which is what is used to derive the fuel poverty statistics.

The two key components of the EHS used in the estimation of fuel poverty are:

- Interview Survey: An interview is conducted with the householder. The interview covers a wide range of topics that include: household characteristics, satisfaction with the home and the area, disability and adaptations to the home, and income details;
- Physical Survey: The interview is followed by a visual inspection of the property, both internally and externally, by a surveyor. Data collected includes the number and type of rooms and facilities contained in the property, the condition of a wide range of aspects of the physical structure, details of the heating systems, approximate age of the property, and assessment of neighbourhood quality.

Currently, each year around 13,300 interviews are conducted with householders, and around 6,200 dwellings (approximately 6,000 households and 200 vacant properties) have a follow-up physical survey of their dwelling.

Further information for users of the English Housing Survey datasets include: technical advice notes for the EHS[11], the EHS headline reports and survey forms[12], and the different levels of access for the EHS datasets that are available from the UK Data Service[13]. Analysts who use the EHS data are recommended to use derived files where required variables exist, as these data are validated and reconciled with other data across the survey and are without missing values.

Calculating the main components of fuel poverty

Most of the information used to calculate the main components of fuel poverty (income, energy prices and energy requirements) can be obtained from the interview and physical EHS surveys:

Income
- The EHS interview survey collects detailed information about the income of the Household Reference Person (HRP) [14] and any partner from different sources (wages, pensions, benefits, savings and investments and other sources, e.g. rent from property).
- Less detailed income information is collected of other household members aged over 16 (who are not the HRP or partner).
- The EHS interview survey also collects information on housing benefit and Council Tax support, Support for Mortgage Interest (SMI), Mortgage Payment Protection Insurance (MPPI) and housing costs (rent and mortgage payments).

Energy prices
The EHS interview survey collects information on the method of payment of gas and electricity, and the household's location in the country. This can be used to determine which average regional fuel prices to use in order to estimate the energy bills for each household.

Energy requirements
Data on the occupancy characteristics, and region, is provided by the interview survey. The physical survey then provides information about the physical characteristics of the home, which are used to inform the modelling of household energy use for fuel poverty, including:

- Detailed information about the dimensions
- Dwelling type and age
- Heating and hot water systems
- Dwelling fabric and exposure/shading

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[11] https://www.gov.uk/government/collections/english-housing-survey-technical-advice
[12] https://www.gov.uk/government/collections/english-housing-survey
[13] https://www.gov.uk/guidance/english-housing-survey-datasets-and-bespoke-analysis
[14] The Household Reference Person (HRP) is the person in whose name the dwelling is owned or rented or who is otherwise responsible for the accommodation. In the case of joint owners or tenants, the person with the highest income is taken as the HRP. Where incomes are equal, the older occupant is taken as the HRP.

- Energy efficiency measures

Further information required for the modelling of fuel poverty is obtained from other data sources. These are detailed in section 2.2 below, and within the chapters for each component of fuel poverty.

2.2 Energy price information

Fuel prices used in the modelling of fuel poverty are produced using information gathered from a variety of external sources, as the EHS does not collect detailed information on energy suppliers and tariffs. Details of these sources are given below:

- The Quarterly Energy Prices publication[15] is used to provide the average annual fuel prices for mains gas and electricity. Specifically, the prices are published within the following BEIS published tables:

  Average variable unit costs and fixed costs for electricity for UK regions (QEP 2.2.4); and,
  Average variable unit cost and fixed cost for gas for regions in Great Britain (QEP 2.3.4).

  The quarterly survey used to produce the tables for this official statistical[16] publication covers around 90 per cent of the energy suppliers and records specific details of the price of each tariff, and the number of customers on each tariff in each region of the UK, splitting this by payment type. BEIS then make assumptions for the proportion of the market that is not surveyed in order to produce an estimate of the entire energy market. Prices take the form of unit costs, fixed costs and any discounts that are given (e.g. discount for paperless billing).
- The Consumer Price Index (CPI)[17], published by the ONS, is used to obtain fuel prices for coal, heating oil and smokeless fuels. The prices are collected monthly and split regionally.
- The Sutherland Tables[18] provide fuel price data for Liquefied Petroleum Gas (LPG) and bottled gas. Fuel prices from the Sutherland Tables are available quarterly and are split regionally to show comparative heating costs across the UK.
- Finally, SAP 2012 fuel prices[19] (from the Government's Standard Assessment Procedure for the energy rating of dwellings) are used for other fuels and tariffs (where their use is relatively minor), including biofuels, communal heating, and economy 10

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[15] https://www.gov.uk/government/collections/quarterly-energy-prices
[16] See Chapter 10
[17] https://www.ons.gov.uk/economy/inflationandpriceindices
[18] http://www.sutherlandtables.co.uk/
[19] https://www.bre.co.uk/sap2012/

and 24 electricity tariffs. These prices are then inflated to the survey year using the CPI.

3. How is household income modelled?

This chapter details the income methodology, including the calculation of the final fuel poverty income variables, validation of income and changes in the income methodology. A list of the acronyms used in the description of the income methodology can be found in Chapter 11.

3.1 Overview

The equivalised after housing costs (AHC) income is used to define the number of households living in fuel poverty under the LIHC indicator and calculate the fuel poverty gap. It is produced by:

- Adding the personal incomes of every member of the household together plus any benefit payments that the household receives (from private sources, state benefits, and savings) to provide the Primary Benefit Unit (PBU) income. Income from other benefit units and the Winter Fuel Payment (WFP), if applicable, is then added to give the 'Basic household income'.
- Addition of income related directly to housing, including: housing related benefits (HB), Mortgage Payment Protection Insurance (MPPI), Council Tax Support (CTS), and the deduction of Council Tax payable. This is the 'Full household income'.
- Deduction of housing costs (total mortgage repayments and net rent payments).
- The division by the relevant income equivalisation factor (see Table 11) to reflect the fact that different households have different spending requirements. This creates the final 'Equivalised AHC income'.

The income is calculated as the sum of the income of the Household Reference Person (HRP) and any partner, known as the Primary Benefit Unit (PBU), plus any other adult members of the household, known as Other Benefit Units (OBU). The EHS interview survey collects detailed information about income sources for the PBU, and less detailed income information for the OBU. Figure 2 outlines the main steps involved in this process and the sections to follow, detail the procedures involved in each step.

Figure 2: The main steps in calculating equivalised AHC income

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┌─────────────────────────┐    ┌─────────────────────────┐         ┌─────────────────────────┐
│ Income from private     │    │ Add income from housing │────────▶│ Add income from MPPI    │
│ sources                 │    │ related benefits that   │         │                         │
└───────────┬─────────────┘    │ help pay towards rent   │         └───────────┬─────────────┘
            │                  └─────────────────────────┘                     │
            ▼                               ▲                                  ▼
┌─────────────────────────┐    ┌─────────────────────────┐         ┌─────────────────────────┐
│ Add income from         │    │                         │         │ Add income from council │
│ benefits & tax credits  │    │     Basic Income        │         │ tax support             │
└───────────┬─────────────┘    │                         │         └───────────┬─────────────┘
            │                  │    (For each household) │                     │
            ▼                  └─────────────────────────┘                     ▼
┌─────────────────────────┐                 ▲                      ┌─────────────────────────┐
│ Convert private income  │                 │                      │ Deduct council tax from │
│ sources provided as net │                 │                      │ all households          │
│ to gross income         │                 │                      └───────────┬─────────────┘
└───────────┬─────────────┘    ┌─────────────────────────┐                     │
            │                  │ Add Winter Fuel         │                     ▼
            ▼                  │ Payments to those       │         ┌─────────────────────────┐
┌─────────────────────────┐    │ eligible                │         │      Full Income        │
│ Deduct income tax and   │    └─────────────────────────┘         │                         │
│ national insurance      │                 ▲                      │   (For each household)  │
│ payable                 │                 │                      └───────────┬─────────────┘
└───────────┬─────────────┘                 │                                  │
            │                  ┌─────────────────────────┐                     ▼
            ▼                  │ Add on income from      │         ┌─────────────────────────┐
┌─────────────────────────┐    │ other benefit units     │         │ Deduct housing costs    │
│ Add net income from     │    └─────────────────────────┘         └───────────┬─────────────┘
│ savings/investments     │                 ▲                                  │
└───────────┬─────────────┘                 │                                  ▼
            │                  ┌─────────────────────────┐         ┌─────────────────────────┐
            ▼                  │      PBU Income         │         │ Apply equivalisation    │
┌─────────────────────────┐    │                         │         │ factor                  │
│ Bring lone parents and  │    │  (Of HRP and any        │         └───────────┬─────────────┘
│ pensioners up to at     │    │  partner for each       │                     │
│ least basic Income      │    │  household)             │                     ▼
│ Support/Pension Credit  │    └─────────────────────────┘         ┌─────────────────────────┐
└───────────┬─────────────┘                 ▲                      │   Equivalised AHC       │
            │                               │                      │   Income                │
            ▼                               │                      │                         │
┌─────────────────────────┐                 │                      │   (For each household)  │
│ Impute missing values   │─────────────────┘                      └─────────────────────────┘
└─────────────────────────┘
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3.2 Missing data

The Computer Assisted Personal Interviewing (CAPI) used to conduct the EHS interview survey contains many 'soft checks' to clarify values with the householder where extreme amounts were initially provided, particularly around state benefits/allowances and tax credits. Thus, the EHS income calculation method assumes that the details given by the respondent are correct unless there is a strong reason to suggest otherwise. These are assessed on a case by case basis. A method of imputation is required for these cases, and (more commonly) for cases where information on income sources/amounts is either refused or unknown. Within the 2018 combined year fuel poverty dataset, just under two-thirds of the cases had no imputations for the Primary Benefit Unit (PBU) income data. Of the remaining 34.9 per cent of cases with imputations, some cases had private sources (15.5 per cent) or benefits (7.7 per cent) imputed where the information was missing, refused or unknown. An additional 4.8 per cent of cases had some private sources and

some benefits imputed or changed. The remainder of cases had imputations such as, household income imputed using group median (1.9 per cent), pension imputed to basic state pension where below basic state pension (1.7 per cent), pension imputed using group median where above basic state pension (1.9 per cent) and basic income imputed where below basic income support (1.4 per cent). Table 1 summarises the type and method of imputations carried out.

Table 1: Imputation procedures

Type of income	Type of missing data	Method of imputation
Private incomes	Sources of private income are refused or unknown	Sample median imputed at a later stage
Self-employed	Amounts missing	Uses data from the Annual Survey of Hours and Earnings (ASHE) based on age, gender, part-time/full-time, social economic group and from 2010 data, also geographical location
Regular employment	Amounts missing	
Occupational pension	Amounts missing	Sample median based on gender and social economic group
Private pension	Amounts missing	
Other sources	Amounts missing	Sample median based on working status
State benefits	Benefits received are refused or unknown	Sample median imputed at a later stage
- Universal Credit - Income support - Job Seekers Allowance - Pension credit - State pension - Incapacity benefit - Employment and support allowance - Child benefit - Working tax credit* - Child tax credit - Maternity allowance - Widows pension - War disablement pension - Severe disability allowance - Industrial injuries disablement benefit - Attendance allowance - Carers allowance - DLA (mobility component) - DLA (care component) - PIP (mobility component) - PIP (daily living component) - Statutory sick pay	Benefit amount is refused or unknown	Where the rates vary greatly depending on the situation of the HRP and any partner (notably means tested benefits) individual benefit assessments are carried out. More general methods are used for benefits where fewer rates apply.
Other disability benefit	Benefit amount is refused or unknown	Theoretical amount of DLA (mobility) modelled
Savings	Amount of savings refused or unknown	Imputed using CHAID analysis using various household and dwelling characteristics
Primary Benefit Unit (PBU) income	Overall net household income missing or in households with a partner, HRP only missing/partner only missing	Median sample income imputed based on the HRP and any partner using the variables working status and social economic group or using HRP/partner information only
Other Benefit Units (OBU)	Income amount missing for additional adults (on an individual basis)	Hot-decking (see section 3.4 for more information) based on gender, age, social economic group, working status, (from 2010 data) grouped geographical location for additional adults in work and (from 2015 data) presence of an income source.
Winter Fuel Payment (WFP)	No information collected on whether household receives WFP	Modelled based upon eligibility of all household members. The amount depends upon the age profile of the household members.
Housing related benefits that help pay towards rent	Amounts missing	Full housing benefit – set as the net rent amount

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		Partial housing benefit, don't know if full or partial or in receipt of the housing element of Universal Credit – individual housing benefit assessment carried out
MPPI	No information given as to amount (applies to all MPPI cases)	Imputed using mortgage information
Council Tax Support (CTS)	No information given as to the actual amount (applies to all CTS cases)	Full CTS – set as the council tax due Partial CTS/don't know if full or partial – individual CTS assessment carried out

* The childcare element is not modelled for Working Tax Credit.

3.3 EHS Primary Benefit Unit (PBU) income methodology

Initial checks on the interview survey input data are carried out to ensure the dataset is as clean as possible in preparation for the calculations. This involves checking household characteristic data to identify any implausible values and editing (e.g. replacing with modelled values) where necessary.

After the initial checks, a series of key indicators about the household are created at the person and household level (for example, age/gender of the HRP and any partner, working status of HRP and any partner and the presence and number of dependent children etc.), which are subsequently checked for completeness/plausibility. These indicators are used to compute theoretical entitlement to benefits and are used in the process of imputing missing values and validation.

Income from private sources

Separate calculations are made for the annual income for the HRP and any partner from regular employment (including income from Government training schemes), self-employment, occupational pensions, private pensions and other private sources. For each private income source selected the respondent is asked to provide a banded gross/net amount. If provided, the income is then set at the mid-point of the band.

Where respondents state receipt of private income sources (e.g. employment, self-employment income), or select working in terms of their employment status (the latter combined with also selecting currently in paid work), but are unable/refuse to specify an amount; then an estimated amount is assigned according to the methods outlined in Table 1.

The same amounts are used to impute regular and self-employed income. For these two private income sources, the amount of income assigned depends upon the number of hours worked. The Annual Survey of Hours and Employment (ASHE) data that is used for imputation is presented on the basis of full-time employment. Therefore, if the hours worked are less than or equal to 15 per week, the amount imputed is one-third of the full-time income amount. Part-time work greater than 15 hours per week is set to two-thirds of the full-time income amount.

Where the HRP/partner selected working in terms of their employment status, stated as being in receipt of paid work, but did not select any employment or self-employment income under their income sources (nor responded refused to their income sources) and is not in receipt of any 'other' private income, then the HRP/partner is assigned an employment income and an employment income amount is imputed based upon the method outlined in Table 1. In this situation it is assumed that the HRP/partner unintentionally omitted employment income as an income source in the EHS interview survey.

For student households, if the HRP/partner is in full-time education (and not studying for A-Levels), with no reported income sources, modelled to be living in a university household, then the HRP/partner income is set to in receipt of 'other income', rather than 'no income' and an estimated amount is assigned according to the methods outlined in Table 1. Also, each year, there are a few private income sources coded as £0 in the EHS interview survey. These cases are individually assessed and where deemed implausible; an amount is estimated using the standard imputation routines.

Respondents predominantly provide gross private income amounts. However, where net amounts are given for income from private sources, the gross amount for that source is approximated. The net amount is increased by 47 per cent if the individual is under pension age and in receipt of earnings/self-employment income (to replicate tax and National Insurance). Otherwise, 25 per cent is applied (to replicate tax only), unless the combined private net and gross income is less than the tax threshold, in which case it is assumed that no tax is paid, and the net amount is set to the gross amount. The total gross private income for the HRP and any partner for all sources is calculated. This is required to enable the total tax amount to be deducted. It is not possible to simply calculate the tax on the gross part and then add the gross-taxed to the net, as the rate of tax is dependent on income thresholds. Where imputation has taken place, this is recorded against the data. On-going validation of the amounts of income from private sources is carried out throughout the calculation.

Income from state benefits[20]
The EHS interview survey asks about benefits received by the HRP and any partner (combined as a benefit unit) and the amounts and time periods of the payments. It is unknown whether it is the HRP and/partner who are in receipt of the selected benefit where a partner of the HRP is present in the household, with the exception of state pension, child benefit, income support, pension credit and universal credit where the individual recipient (whether HRP and/or partner) is known. As this information is required for the purpose of tax deduction, it is estimated based on the eligibility criteria of each person in the couple. Using this information, benefit amounts for the HRP and any partner are calculated.

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[20] See section 3.8 for changes to Universal Credit

Missing benefit amounts are imputed for cases where the respondent has answered 'yes' to receiving a particular benefit but did not provide the amount received. For means tested benefits, such as income support, the rate varies greatly depending on the circumstances of the HRP and any partner and for these benefits individual benefit assessments are carried out. For other benefits based on rates, such as Disability Living Allowance, the prescribed rates are imputed.

Questions were introduced into the EHS 2010 interview survey to ascertain whether the missing benefit amounts were due to the inclusion of the missing amounts with other specified benefits. From 2010 modelling onwards, use of this data has been incorporated into the assessment of missing benefit incomes to avoid double counting of benefit income where it is deemed that the missing benefit income has already been accounted for.

The total benefit income is derived for the HRP and any partner separately, split between taxable and non-taxable benefit income.

Income deductions

The final income variables are presented in terms of net income, which is the income net of tax and National Insurance. At this stage in the income calculation process, the private income is presented in terms of gross income and the benefit income is presented in terms of gross and/or net income depending on the selected benefit receipt.

The private income and taxable benefit income are added together separately for the HRP and any partner. This information is used in conjunction with the rates and allowances for income tax, including applicable tax relief from property rental, to derive the income tax payable for the HRP and partner. Based on the rates and allowances for National Insurance[21] , Class 1, 2 and 4 contributions are calculated. The total net income for HRP and partner are computed separately by the following formula:

$$Net\ income = Non\ taxable\ income + Taxable\ income - (National\ Insurance\ payable + Income\ tax\ payable)$$

Income from savings and investment

The EHS interview survey asks the HRP and any partner their combined total amount of savings and any income they have invested, which is provided as banded amounts. The mid-point of the reported band is taken as their savings amount.

Where the amount of savings/investment has not been provided, a method based on Chi squared Automatic Interaction Detection (CHAID) analysis is used to estimate the combined savings/investment of the HRP and any partner. The banded savings question from the interview survey is used as the dependent variable in the analysis and a variety of household and dwelling characteristics such as tenure and age/gender of HRP are used

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[21] National insurance contributions (NICs) fall into a number of classes, the class you pay depends on your employment status and how much you earn. See https://www.gov.uk/national-insurance/national-insurance-classes.

as the predictor variables for estimating the savings amount. Once all the cases have a savings amount, income received from these savings is then calculated using a gross interest rate of 3.75%. Income from savings is modelled as a gross amount and converted (if applicable) to a net amount using an interest rate of 3 per cent net of tax[22]. As well as the personal tax allowance, the personal savings allowance is also incorporated into the gross to net conversion of savings income. The net savings amount is added onto the net private and benefit income.

Low incomes

The next stage in the income calculation is the imputation of low incomes. This is where the PBU net private and benefit income, including income from savings, is assessed for certain groups to ascertain if it is below a theoretical minimum amount.

In 2007/2008 this area was the focus for development and was reviewed by the Fuel Poverty Methodology Group (FPMG) who recommended some improvements to imputing low incomes in 2008. Analysis showed that two household groups are more likely to under-report their income: lone parents; and pensioners (although the reasons for this were not investigated at this time). For these two groups, if their income is less than a minimum amount, their income is imputed, using a different method for each group.

For lone parents, if their net income is below their theoretical income support entitlement then their income is uplifted to their theoretical income support level (Figure 3a). Where the HRP or any partner are over pension age, if their income is lower than state pension, their income is imputed up to state pension (Figure 3b). If their income is greater than state pension but lower than their pension credit entitlement their income is set to missing and later in the calculation procedure it is imputed to the group median based on working status and social economic group. A flag is created to identify cases which are changed in the low income imputation routine and the original values are kept for later checking.

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[22] No information is collected on the type of savings account, the term of the account or the rate of interest. A net rate of 3% (3.75% gross) is fixed for all householders and has been used for all years of the fuel poverty calculation regardless of whether interest rates are higher or lower than this.

Figure 3: Imputation of low incomes
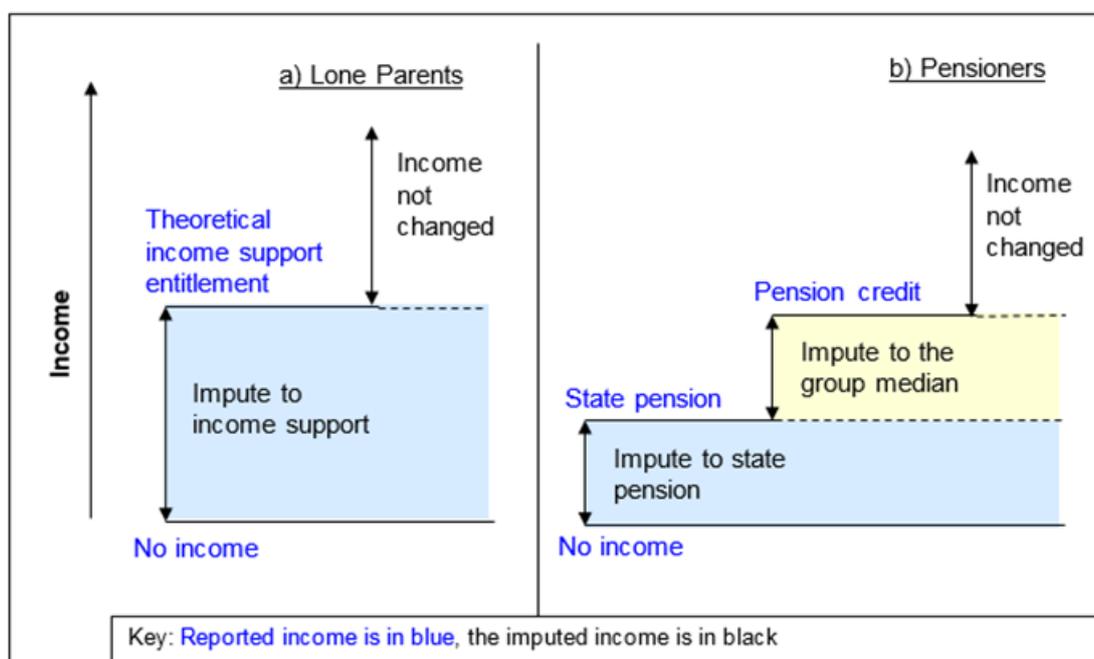
Imputing missing income data

At this stage there are three scenarios in which the total PBU income could still be missing:

    i)   If the respondent answered 'don't know' or 'refused' at the beginning of the income section for the HRP and any partner;

    ii)   If the benefits received are reported as unknown or refused; or

    iii)   If, in the case of pensioners, their income is greater than state pension but lower than their pension credit entitlement, their income is set to missing in the low income imputation routine.

Where the HRP has a partner, it is possible that only one of the incomes is unknown or refused. In this situation, or if there is no partner of the HRP, the income of the individual with the missing amount is imputed to the group median based on their working status and socio-economic group. Where the income of both the HRP and partner are missing, their income is imputed to the group median based on a combined employment status and socio-economic group for both HRP and partner.

Output

Each PBU in the dataset has a net private and benefit income, including income from savings/investments.

$$PBU\ income = Net\ private\ income + Net\ benefit\ income$$
$$+ Net\ Savings\ and\ investment\ income$$

$$(all\ based\ on\ the\ HRP\ and\ any\ partner)$$

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3.4 Fuel poverty basic income methodology

The fuel poverty basic income is the household net income, including winter fuel payment for those eligible. The annual basic household income is then capped at £100,000[23] to maintain the confidentiality of respondents with an income above this level and to comply with the data disclosure control guidance issued by the Government Statistical Service.

Other Benefit Units (OBU)

The PBU is made up of the HRP, their partner (if applicable) and any dependent children. Other Benefit Units (OBU) are made up of other household members that are not part of the PBU, e.g. a grown-up child living with their parents or two or more people sharing a house. Each OBU can include up to two adults, but only if they are a couple, otherwise each adult makes up its own OBU. For the fuel poverty calculations, the income of these additional adult household members is considered as part of the household income[24].

Data on the income of other household members aged over 16 (who are not the HRP or partner) are collected at the person level. Household members aged 16 or over that are not in the same benefit unit as the HRP are considered as additional adults and form the OBU (if the household member is a child of the HRP/partner, aged between 16 and 18 and in further education then they will be included in the same benefit unit as the HRP and therefore not considered as an additional adult).

If a gross income is provided for the additional adult then this value is used for the income of the household member. If no income sources are selected, apart from a particular group of student cases (see below), the income of the additional adult is assigned as £0. If the additional adult has selected income sources but has not provided an amount for their income, then an income value is imputed based on a 'hot-decking approach'.

If an additional adult is a full-time student, with no reported income sources, living in a house where the HRP is also a full-time student in further education, then the additional adult income is set to missing as opposed to no income (as it is highly likely that they have misreported presence of an income source), and an income amount is imputed for the individual based upon the hot-decking approach as described below.

The process of hot-decking involves finding cases in the dataset that provided an income amount, which are similar in other parts of their responses to the cases with the missing value. For imputing missing additional adult income values, a specification to find similar cases is created for each case based on age (banded), gender, working status, socioeconomic group (where applicable), grouped geographical location for those in work

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[23] The Government Statistical Service recommends that an appropriate level of top-coding should be applied to high incomes to make data non-disclosive. https://gss.civilservice.gov.uk/wp-content/uploads/2014/11/Guidance-for-microdata-produced-from-social-surveys.pdf

[24] Additional adult household members reported during the EHS interview survey to be living in Halls of Residence are excluded from the analysis and their income is not considered to be part of the household income.

and presence of an income source. The case with the missing value has a precise specification and it is matched at random to a case with an income value with the same specification, this income value is then used for the missing case. If the additional adult selected receipt of an income source, with a missing income value, then it is only hot-decked against cases with an income greater than zero.

There are two situations where not all missing cases are matched:

i)   If a case with a missing value has a specification which is not matched by a case with a non-missing value; or

ii)   When there are more cases with missing values than with non-missing values of the same specification.

Missing cases that are not matched during the hot-decking process are imputed to a sample median based on working status, and for some working status categories with large samples, age (banded) and gender.

Once all the additional adults have a gross income assigned, it is converted to a net amount by deducting the applicable income tax and National Insurance. The net income of the additional adults is aggregated up to the household level to provide the total net income from Other Benefit Units (OBU) in the household.

Winter Fuel Payments

Winter Fuel Payments (WFP), introduced in 1998, are a payment given once a year to help older people with their cost of heating. They are available to households with at least one resident aged over the female state pension age[25] and are paid automatically to eligible persons who have either received the payment before or who are in receipt of state benefits (other than those that only receive either housing benefit, Universal Credit, council tax support or child benefit). Those who do not automatically receive the WFP have to claim the payment. No question is asked in the EHS survey as to whether anyone in a household receives WFP. The applicable amount of WFP for the household is modelled using the age profile of household members and the specified rates and assigned to the household income. Additional one-off payments[26] for household members aged over female state retirement age are sometimes provided alongside WFP. For example, in 2009/2010, in addition to the WFP payment there was an additional one-off payment of £100 for households over 80 or £50 for those age 60 – 79. If applicable for the year of the dataset, these payments will also be included in the WFP amount.

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[25] A male can claim a Winter Fuel Payment when they reach the state pension age of a woman with the same date of birth.
[26] See page 26 of following document for more examples of additional payments made: Winter Fuel Payments update, Briefing Paper Number 06019, 24th March 2016
http://researchbriefings.files.parliament.uk/documents/SN06019/SN06019.pdf

Output

The Fuel Poverty Basic Income variable (fpbasinc)[27] is created by adding the income from the OBU in the household and the WFP to the PBU income variable.

$$Fuel\ poverty\ basic\ income\ (fpbasinc) = PBU\ income + OBU\ income + WFP$$

There are a small proportion of cases with a fuel poverty basic income of zero. This occurs where:

i)   the HRP and any partner select that they have no sources of income, with no savings/investments;

ii)   there is no income from any other additional adult household members; and

iii)   where there are no household members over female state pension age and therefore not in receipt of WFP.

At this stage of the modelling, for these cases the income is left unchanged.

3.5 Fuel poverty full income methodology

The Fuel Poverty Full Income variable is created by adding the income received related to housing costs, notably housing related benefits (HB), Mortgage Payment Protection Insurance (MPPI) and council tax support, to the uncapped basic income variable, and by subtracting the annual approximate Council Tax bill for the household. Income/outgoings relating to housing costs are dealt with in this final step, and the annual full household income is then capped at £100,000.

Income from Housing Related Benefits that help pay towards rent

Housing benefit, Local Housing Allowance (LHA) and the housing element of Universal Credit apply only to low income households that rent their home or are in a shared ownership scheme, designed to help people on a low income pay their rent. Housing benefit is derived from the householder's response to the questions in the rent and housing benefit module in the EHS interview survey questionnaire.

Where households state that they receive a housing related benefit that helps pay towards rent but do not provide an amount, the amount is imputed in one of the following ways:

i)   If the household states that they are in receipt of full housing benefit/LHA then the weekly housing benefit is set to their theoretical guide rent amount (net of services included in the rent such as heating, meals, water rates etc.) based on their tenure, number of bedrooms and the English Region in which they live.

ii)   If the household states that they are in receipt of partial housing benefit/LHA, receipt of the housing element of Universal Credit or if they do not know if their

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[27] https://www.ukdataservice.ac.uk/get-data

housing benefit/LHA covers all or some of their rent, then an amount of housing related benefit is imputed based on their total net rent payable and their theoretical entitlement to housing benefit. For a selected number of Universal Credit cases, the weekly housing related benefit amount received by the household is calculated earlier in the income model process, and then brought into the rent and housing benefit model to calculate the final amounts. From the 2013 modelling of EHS data onwards, the theoretical entitlement to partial housing related benefits includes the modelling of the under-occupation charge for working-age social tenants as introduced by Government in April 2013.

Income from Mortgage Payment Protection Insurance

Mortgage Payment Protection Insurance (MPPI) promises to make repayments on a householder's mortgage in the event of accident, sickness or unemployment. In the EHS interview survey, applicable households are asked if they are in receipt of contributions towards their mortgage payment under a MPPI policy and, if so, whether it covers full/partial payments. No information is collected on the amount of MPPI. For cases in receipt of MPPI, an amount for MPPI is set equal to their mortgage payment amount.

Income from Council Tax Support

Low income households may be eligible for Council Tax Support (CTS) from April 2013 (also known as Council Tax Reduction). The EHS interview survey asks the HRP and any partner liable for paying Council Tax whether they are in receipt of CTS and, if so, whether it covers full/partial payments. For households in receipt of full CTS payments, their CTS is set to the full amount of Council Tax payable for their property. For households in receipt of partial CTS or households that do not know if they are in receipt of CTS, a CTS amount is assigned based on the Council Tax payable for the property and on their theoretical eligibility.

Council Tax Deduction

The Council Tax band for each dwelling is collected via a data matching exercise undertaken by the Valuation Office Agency[28]. The approximate amount of Council Tax paid by the household is modelled using the Council Tax band of the dwelling and information about charges in the relevant local authority area and is adjusted (using a smoothing methodology) to minimise the identification of lower geographical areas. Single person discount is applied where appropriate based on household size and whether the respondent reported receipt of a discount on their Council Tax.

Output

The Fuel Poverty Full Income variable (fpfullinc)[29] is created by adding the income related to housing costs; i.e. housing related benefits that help pay towards rent, MPPI and

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[28] This is achieved by matching postcodes to Council Tax band information in order to feed into modelling undertaken by the survey contractors for the production of statistics only. Raw council tax data is deleted at the end of the process in line with data sharing agreements.
[29] https://www.ukdataservice.ac.uk/get-data

Council Tax Support, to the uncapped basic income variable (fpbasinc) and subtracting the approximate Council Tax payable.

$$Fuel\ poverty\ full\ income\ (fpfullinc) \\ = fpbasinc + HB\ /\ LHA + MPPI + CTS - council\ tax\ payable$$

As mentioned in Section 3.4, there are a small proportion of cases with a Fuel Poverty Basic Income of zero. These incomes are retained, as recommended by the 2005 Sefton and Chesshire[30] Peer Review of the Fuel Poverty Methodology, in line with the treatment of zero incomes in the Households Below Average Incomes statistics (HBAI)[31] which are based on data from the Family Resources Survey.

In these situations, and also for cases with a low basic income, this can lead to a negative Fuel Poverty Full Income if the household does not report that they are in receipt of any housing related payments and where they are liable for Council Tax for which a deduction is made from their zero/low incomes.

3.6 Fuel poverty equivalised <u>after</u> housing costs methodology

The fuel poverty equivalised AHC income, as used in the calculation of the official fuel poverty statistics, is an extension of the fuel poverty full income variable. Housing costs (as published in the EHS derived interview file) are deducted from the uncapped full income of the household, and the household income is equivalised to reflect the fact that different households have different spending requirements. The final equivalised after housing costs income variable is then capped at £100,000 before the calculation of fuel poverty variables. Any negative AHC equivalised incomes are set to £0. The methodology is detailed in Chapter 6.

3.7 Validation of income data

The validation of the input data into the income calculations, through to validation of the final output fuel poverty income variables, is an important process to ensure data quality. This process is outlined below.

Checking of the income data collected begins at the interview stage. The EHS interview survey is collected using a technique called Computer Assisted Personal Interviewing (CAPI) where the interviewer enters the information collected from the respondent directly into a laptop computer. The EHS CAPI has in-built checks to ensure that the respondent's answers are as accurate as possible. For certain benefits, if an amount is entered outside a valid range then a check will appear on the computer screen. The CAPI system has

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[30] Peer Review of the Methodology for Calculating the Number of Households in Fuel Poverty in England. Final Report to DTI and Defra, by Tom Sefton and John Chesshire. April 2005.
[31] https://www.gov.uk/government/collections/households-below-average-income-hbai--2

cross checks between variables e.g. if housing benefit receipt is selected but not Council Tax benefit. The checks in the CAPI system are routinely reviewed bi-annually and updated as appropriate.

Once in receipt of the interview survey files, before beginning the income calculations, initial checks on the interview survey input data are carried out to ensure they are as clean and complete as possible. This involves checking household characteristic data, which is later used for imputing missing values and validation. Implausible and missing values are identified, and editing/imputation takes place where necessary.

Checks are made at each stage of the calculation process to ensure as far as possible that the data are reasonable, and that missing data have been imputed correctly. Implausible values are interrogated and only when we can be as certain as possible that the information is incorrect is an imputation or change made. Any changes made are always noted alongside the data to indicate the nature and extent of any imputation. At the end of each stage additional checks are made to ensure that there are no missing values in the final variables.

Certain parameters are evaluated at the end of each stage of the calculation process and compared to previous English House Conditions Survey (EHCS)/EHS data. For example, once the benefit section of the calculation process is complete, the take-up proportion of imputed data and average values for each benefit are assessed.

Oddities in the results for the components of the fuel poverty income variables are investigated in detail, concentrating on the difference in the data between the two specific years until the change can be explained. This involves putting the data in context by comparing the components of the fuel poverty income to external administrative sources e.g. DWP/HMRC benefit statistics and data from other surveys e.g. the Annual Survey of Hours and Earnings (ASHE) and the Living Cost and Food Survey (LCFS). From this process it may be deemed that the results are in line with other external sources or the difference attributed to the underlying EHS data or changes to the EHS interview survey. The main external validation techniques applied to the fuel poverty income measures are trend analysis over time and comparison with specific year income data from other surveys, notably the LCFS and the Family Resources Survey (FRS).

The internal validation also occurs on the final fuel poverty income variables, comparing the total income measures to data from previous years, looking at the distribution of income across the population and the average income of certain household groups.

Income data from the LCFS Family Spending publication was used until 2014 to compare the LCFS disposable household income to the fuel poverty basic income. Due to a change in the data provided in the Family Spending publication however, from 2015 onwards the LCFS 2015 disposable income from the Household Disposable Income and Inequality (HDII) report is now compared to the fuel poverty full income (as the two income measures

are fairly closely aligned in their definition) by overall households, tenure and income quintiles. Any unexpected divergence in the results between the two income measures is investigated.

The FRS is considered to be the most comprehensive and accurate income survey conducted in this country, and one that is dedicated to measuring incomes. The FRS income data for the comparable year to the fuel poverty full income is not published until after the publication of the fuel poverty statistics. However, the FRS provides the best external income data source for comparison and it is therefore important to compare a variant of the fuel poverty full income to the equivalent FRS income variable on publication of the FRS data, focusing on the comparability of the distribution of incomes in both surveys and the characteristics of households with the lowest incomes.

The FRS data are also the underlying source behind the AHC equivalised income figures presented in the Households Below Average Income (HBAI) series, published by DWP. Again, the comparable year of the HBAI is not published until after the publication of the fuel poverty statistics but time series charts are produced on availability of the data to compare the HBAI equivalised AHC income to the fuel poverty AHC equivalised income by overall households and income deciles.

Outliers

Outlying cases are identified in the data and validated to ensure that the data modelling processes are being performed correctly. In rare cases where the data are deemed to require modification due to implausible outcomes, modifications to data imputation regimes may be made as appropriate. In the 2014 and 2015 dataset, an alternative income procedure was employed for one case, due to missing responses to their earnings from amounts. In response to this outlying case and to minimise occurrences of outliers that specifically affect fuel poverty, extra checks have now been incorporated into the income modelling procedure, at an earlier stage. In particular, checks are carried out on employment income values below minimum wage and in the top quintile for property value/rent (i.e. those more likely to have low AHC incomes). Cases are now flagged and investigated further if their only private income source is investment income, and the amount for this income source is missing. Issues raised by the unusual circumstances of specific outlier cases are fed back into future validation routines, where checks and processes are added to help deal with similar issues in the future.

3.8 Changes in income methodology

Each year, minor modifications may be made to the fuel poverty income calculation methodology as a result of improvements in the treatment of missing data, changes in the benefit and tax system and minor alterations to the EHCS/EHS interview survey. Selected years have also undergone larger methodology changes to the income calculation

assumptions which is the focus of this section. For the 2018 statistics there were relatively minor changes to the methodology used for the calculation of household income.

Fuel poverty incomes were originally calculated for the 1996 statistics and a very similar methodology was followed for the 2001 statistics. Ahead of the production of the 2003 figures, the Department of Trade and Industry (responsible at the time for publishing fuel poverty statistics) commissioned a consultation to discuss proposed changes to the fuel poverty income methodology. This resulted in three initial changes to the calculation of household incomes, all of which came about due to additional information being collected in the EHCS interview survey. This updated method was first used to calculate the 2003 fuel poverty figures. Headline figures for 1996, 1998 and 2001 were also revised to adopt the new methodology. Further changes have taken place as a result of continual review of improvements towards data quality and substantial changes to the interview survey as discussed in more detail below.

Other Benefit Unit (OBU) income (2003 dataset)

Prior to the work on the 2003 EHCS data, incomes from other benefit units (i.e. other adult household members who were not part of the same benefit unit as the HRP) were modelled using a correction factor based on the Expenditure and Food Survey (EFS – now the Living Costs and Food Survey). For the 2003 dataset a new method of computing the income of other benefit units was introduced that used data collected in the EHCS interview survey. Questions were asked of the respondent about any state benefits or income received by each of the additional adult household members and these were used to derive the income of the OBU.

Council Tax Deduction and Council Tax Benefit (2003 dataset)

Net Council Tax liability was not included in the fuel poverty Full Income definition prior to the 2003 EHCS data. From 2003, Council Tax payments (net of Council Tax benefit) were deducted from the fuel poverty Full Income. This was in order to be consistent with the Government's official Households Below Average Income (HBAI) measure and to ensure consistency within the income definitions (i.e. for full income, including both the payment of Council Tax, and the benefit received to help pay it; for basic income excluding both the payment and the benefit).

Low Income Imputation (2006 dataset)

In 2004, alongside and in support of the fuel poverty consultation, an independent review[32] of the fuel poverty methodology took place. In the peer review it was recommended that the treatment of very low household incomes on the EHCS should be investigated with the view to possibly amending the methodology to match more closely that of the Family Resources Survey (FRS), a dedicated income survey. The FRS does not impute very low incomes but leaves them on the dataset, including negative income amounts (e.g. a self-

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[32] Sefton, T and Cheshire, J. Peer Review of the methodology for calculating the number of households in fuel poverty in England. http://webarchive.nationalarchives.gov.uk/20070603164510/http://www.dti.gov.uk/files/file16566.pdf

employed person who has made a loss in the year concerned), whereas the EHCS (at the time of the review) uplifted all households that were on a low income up to at least their basic income support entitlement.

Following an extensive income review by BRE and the Fuel Poverty Methodology Group (FPMG) a new low income method was decided upon and endorsed by the FPMG. The new method was first adopted for the 2006 fuel poverty calculations, whereby only the household composition categories adults over pension age and lone parents are subject to the low income imputation (see details in Section 3.3).

Housing Benefit (2007 dataset)
In the 2007 EHCS interview survey, the Rent and Housing benefit module of the interview survey was extensively revised leading to a more comprehensive set of questions on rent and housing benefit. The 2007 fuel poverty calculations were adjusted to incorporate these interview survey changes. As a result, the housing benefit amount assigned to applicable households changed from being based on theoretical entitlement to the amount provided by the occupant (where available).

Council Tax Benefit (2007 dataset)
In the 2007 EHCS, the method used for calculating levels of Council Tax benefit was improved due to increased data quality in this area. Prior to 2007, the level of Council Tax benefit assigned to a household was based on theoretical entitlement to this benefit. In 2007, the methodology was improved to allow use of the reported receipt of Council Tax benefit receipt where provided.

Savings/Investment Income (2007 dataset)
In the 2007 EHCS interview survey, the questions asked about savings/investment were adjusted to include more detail about savings/investment above £50,000. Questions on the savings of the HRP and partner were asked in banded savings amounts. Prior to 2007, the top savings band was £50,000 or over. For the purposes of fuel poverty income calculations, it was assumed that this represented a level of savings of £55,000. In the 2007 EHCS interview survey, the following additional bands were added: a) £50,000-£99,999; b) £100,000-£149,999; and c) £150,000 or over. For the purposes of fuel poverty, the income methodology assumes levels of savings of a) £75,000, b) £125,000 and c) £175,000 respectively.

Other Benefit Unit (OBU) income (2008 dataset)
In April 2008, the English House Condition Survey (EHCS) merged with the Survey of English Housing (SEH) to create the English Housing Survey (EHS) leading to further changes in the 2008 interview survey. The main change relevant to the fuel poverty income due to the move to the EHS was the way income information is collected for additional adult household members.

Prior to the 2008 survey, there was an income module in the interview survey on the OBU that collected income and benefit information at the Benefit Unit level on other adult members living within the household (who were not part of the same benefit unit as the HRP). This information was used to compute the income of Other Benefit Units and missing values were imputed via two different methods based on working status. If an adult member of the OBU was working, then income data from ASHE was used to impute an income value based on full-time/part-time, age and sex. If no additional adults in the OBU were working, then the income of the OBU was imputed to their theoretical income support entitlement.

In 2008, the OBU income section was removed from the EHS interview survey. The required information was collected differently via questions asked of all household members aged 16 or over. Additional adult incomes can be extracted from these data and the 2008 fuel poverty income methodology was revised to incorporate the additional adult income survey changes. The method of imputing missing values also changed to hot-decking (for more detail see Section 3.4) to capture the variability found in actual income data on additional adults.

Savings Routine (2008 dataset)

Prior to 2008, the addition of income from savings/investment was the last step in calculating the Primary Benefit Unit income (that of the HRP and Partner). This changed in 2008 and the routine is now performed before the low income imputation so that the amount of income from savings/investment can be added onto the net private and benefit income of the HRP and any partner before the low income assessment. This change was added as an improvement to the income methodology to ensure that the income of lone parents and pensioners are not imputed in the low income imputation routine if they have sufficient savings/investment to put them above the low income threshold.

Earnings from other work (2008 dataset)

Prior to 2008, in the EHCS interview survey there were two income categories. In addition to the income category 'Earnings from main job' there was also an income category called 'Earnings from other work'. From the 2008 survey year onwards, the EHCS category 'Earnings from other work' was removed from the survey and the employment income category broadened from applying to the main job only (under the EHCS) to a general 'Earnings from employment' category under the EHS. From 2008 onwards earnings from other work is likely to be recorded under the category 'Earnings from employment' or the category 'Other sources'.

Housing Benefit (2013 dataset)

For the 2013 modelling of EHS data, the theoretical entitlement to partial housing related benefits includes the modelling of the under occupation charge for working-age social tenants (Removal of Spare Room Subsidy) as introduced by Government in April 2013.

Council Tax Support (2013 dataset)

In April 2013 Council Tax Support (CTS) replaced Council Tax Benefit (CTB). Across all Local Authorities (LA), support for pensioners remained the same as under the old CTB scheme. Therefore, no changes have been made to the calculation of theoretical partial CTS for pensioners in 2013. Different LA's adopted different approaches to the CTS scheme, but it is not feasible to model each scheme on the EHS data. Generally, across the majority of Local Authorities, the support for working age claimants was cut compared to the old CTB scheme. For 2013 and subsequent modelling, a blanket factor is applied to reduce the theoretical partial CTS entitlement for working age claimants for all Local Authorities. This factor is derived each year by simulating theoretical CTS entitlement on EHS data and matching it to research undertaken on CTS reductions by the JRF[33] (Joseph Rowntree Foundation) and varies very slightly around the 0.85 mark for each survey year.

Council tax payable (2015 dataset)

From 2015, a smoothing methodology has been applied in the derivation of council tax to minimise identification of lower geographical details. Rather than using the exact council tax due for each Local Authority as previously used in modelling, an average council tax due is calculated based on several similar local authorities, resulting in very small differences to the amounts assigned.

Universal Credit (2016 dataset)

Universal Credit is a benefit that was introduced in April 2013 and is gradually replacing the following means-tested benefits: income-based Job Seekers Allowance, income-based Employment and Support Allowance, Income Support, Child Tax Credit, Working Tax Credit and Housing Benefit. Due to an increasing number of households in receipt of this benefit, changes to the way Universal Credit is modelled were introduced in 2016, to better match how universal credit is paid to households in receipt of this benefit. This resulted in a more accurate representation of how the benefit is split up into the main element (modelled as the Universal Credit benefit) and the housing element (modelled as housing benefit).

Personal Savings Allowance (2016 dataset)

From April 2016, changes were made to the way income from savings is taxed. The personal savings allowance exempts basic rate taxpayers from tax on the first £1000 of savings income, while higher rate taxpayers are exempt from tax on the first £500 of savings income. Additional rate taxpayers have no personal savings allowance. The personal savings allowance has been incorporated into the calculation of income from savings.

Student households (2017 dataset)

Student households in the EHS have previously been flagged as a group where it is believed that their total household income is typically underreported. Several measures

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[33] https://www.jrf.org.uk/report/how-have-low-income-families-been-affected-changes-council-tax-support

were put in place to better represent student income from loans and family allowances. In the EHS 2017/18, a reminder was added to interview survey to prompt interviewers to include student loans and family allowances as income. Also, minor changes surrounding the income of student households were incorporated into the 2017 modelling; 1. If an additional adult is a full-time student, with no reported income, living in a house where the HRP is a full-time student in further education, then the additional adult income is set to missing (as it is likely that they have misreported presence of an income source) and an income amount is imputed. 2. If the HRP/partner is in full-time education (and not studying for A-Levels), with no reported income, modelled to be living in a university household, then the HRP/partner income is set to in receipt of 'other income', rather than 'no income' and an income amount is imputed.

Rental Income (2017 dataset)

From April 2017, a property trading scheme was introduced whereby an individual can benefit up to £1,000 in tax-free allowance for property income. For the 2017 fuel poverty modelling, the property trading scheme allowance has been incorporated into the derivation of the personal tax allowance, as well as incorporating the pre-existing rent a room scheme that allows an individual to earn up to a threshold of £7,500 per year tax-free from letting out furnished accommodation in their home. If the HRP/partner selects receipt of income from rent, the fuel poverty income modelling assumes that the HRP/partner benefits in tax relief from either the £1,000 property trading allowance scheme or, if a lodger is present, the rent a room relief legislation. You cannot get both rental allowances; therefore, the greatest applicable tax allowance figure is derived based on the HRP/partner modelled rental income and their circumstances, and assigned to the individual.

Negative AHC equivalised incomes (2017 dataset)

From 2017 modelling, any negative AHC equivalised incomes are set to zero. This is done to take account of the inappropriate action of equivalisation factors on negative incomes, which will act in the opposite direction to that which is intended. Setting to zero is based upon the recommendation of the Canberra Group Handbook on Household Income Statistics[34]. In addition to this, the fuel poverty income modelling and EHS rent/mortgage modelling (the latter from which the derived housing cost variables are sourced) are very separate models with little integration between the two. Due to this, there can be some cases every year that have extreme negative AHC incomes values which are highly implausible. Setting the AHC income values to £0 mitigates these extreme implausible situations. This has no effect on the fuel poverty status, or fuel poverty gap, for these households.

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[34] http://www.unece.org/index.php?id=28894

Support for Mortgage Interest (2018 dataset)

Homeowners on certain benefits may be eligible to get help towards mortgage interest payments called Support for Mortgage Interest (SMI). However, from April 2018, SMI no longer exists as a benefit for new or existing claimant's, instead it is now paid as a loan which is repaid with interest upon the sale of the claimant's home, or on a claimant's return to work if the borrower can afford it. As SMI has switched from a benefit to a loan, from 2018 modelling, SMI is no longer included as a component of fuel poverty household income.

Universal Credit (2018 dataset)

Since its introduction in April 2013, attention is paid to cases where the HRP or partner selects receipt of Universal Credit in the benefit module of the EHS interview survey. To better capture the data on Universal Credit amounts, questions regarding Universal Credit were altered in the EHS 2018 interview survey. The modelling of Universal Credit has been updated to reflect the EHS interview survey revisions. Universal Credit covers an 'income' component and (if applicable) a 'housing' component. To ensure that Universal Credit receipt is not double counted under both the income component (income based benefits) and the housing component (housing related benefits), cases where the HRP/partner selects Universal Credit in the detailed income benefits section of the interview survey, are assigned a Universal Credit Scenario between 1 and 20 in the benefit modelling. The scenario assigned depends upon how the suite of EHS Universal Credit/housing related benefit interview survey questions were answered in combination with theoretical modelled universal credit 'income only' amounts. Depending on the scenario assigned, the Universal Credit amount collected in the benefit section of the EHS interview survey is either treated as the total Universal Credit amount that includes help towards housing costs i.e. an 'income' element and a 'housing' element combined, or as an 'income' only amount i.e. an amount that excludes the housing element. In the former situation, the income only amount is derived by deducting the housing element (as collected in the housing benefit module of the EHS interview survey) from the total combined amount. The housing element of Universal Credit is not incorporated as income in the Primary Benefit Unit (PBU) income variable, but the housing element of Universal Credit is included as income in the fuel poverty full income variable (an extension of the PBU income variable). The combination of the EHS interview survey revisions regarding Universal Credit and the revisions to the Universal Credit methodology, reduces the risk of double counting Universal Credit in the income modelling.

# 4. How are energy prices calculated?

4.1 Overview

The fuel price element of the fuel poverty calculation produces fuel prices which can readily be combined with household energy requirement outputs to produce fuel costs (see Section 5.10). The price that each household pays for its fuel depends on four main factors:

- The household's location within the country (as fuel prices vary regionally);
- The choice of supplier;
- The choice of tariff;
- The method of payment where relevant, i.e. payment by direct debit, standard credit or prepayment meter (PPM).

Information on the exact tariff, or the supplier, is not collected in the EHS. The survey does however collect information on the geographical location of each case and on the method of payment for metered fuels (i.e. gas and electricity). Therefore, this allows the application of an average fuel price for each combination of region and method of payment, leading to the calculation of fuel prices specific to each household.

The process involved is shown as a flowchart in Figure 4.

Figure 4: Process of calculating energy prices
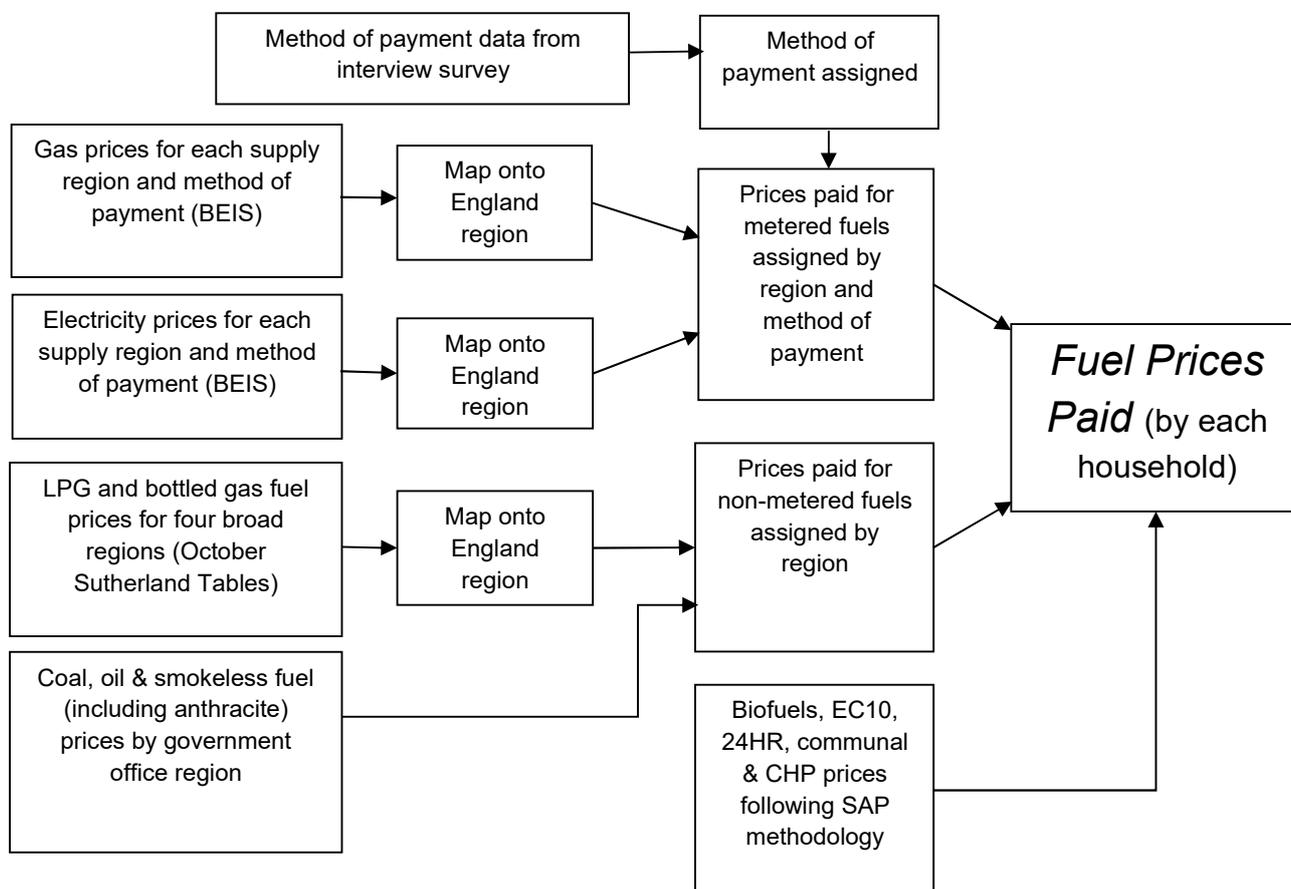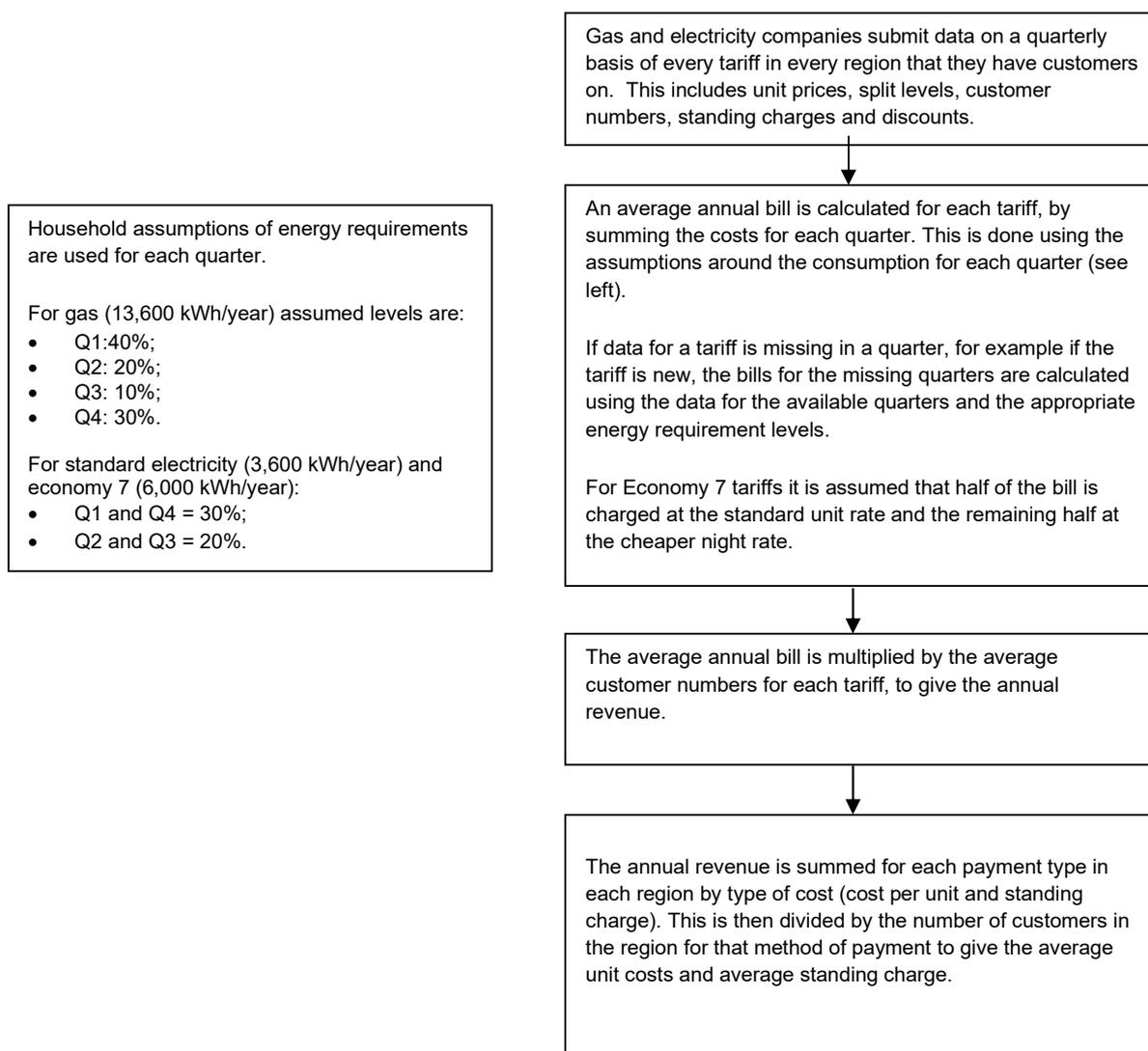

4.2 Data sources

Metered Fuels (electricity and gas)

As mentioned in Section 2.2, the average annual fuel prices for metered fuels are provided by BEIS on a calendar year basis as part of the Quarterly Energy Prices (QEP) publication[35]. This data provided by BEIS contains gas and electricity 'average unit price' and 'average fixed costs' (standing charges) for energy supply regions across England.

Prices are further split by three types of payment (direct debit, standard credit and prepayment). The method employed by BEIS to produce their energy prices is outlined in the flowchart in Figure 5.

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[35] The metered fuel price data used in the fuel poverty calculations are derived from the BEIS quarterly energy prices, in tables QEP 2.2.4 and QEP 2.3.4: https://www.gov.uk/government/statistical-data-sets/annual-domestic-energy-price-statistics

Figure 5: energy prices methodology used by BEIS to produce the prices used in the fuel poverty modelling (n.b. the estimates of consumption described in this flowchart are not used directly in any of the fuel poverty modelling).

Gas and electricity companies submit data on a quarterly basis of every tariff in every region that they have customers on. This includes unit prices, split levels, customer numbers, standing charges and discounts.

Household assumptions of energy requirements are used for each quarter.

For gas (13,600 kWh/year) assumed levels are:
- Q1: 40%;
- Q2: 20%;
- Q3: 10%;
- Q4: 30%.

For standard electricity (3,600 kWh/year) and economy 7 (6,000 kWh/year):
- Q1 and Q4 = 30%;
- Q2 and Q3 = 20%.

An average annual bill is calculated for each tariff, by summing the costs for each quarter. This is done using the assumptions around the consumption for each quarter (see left).

If data for a tariff is missing in a quarter, for example if the tariff is new, the bills for the missing quarters are calculated using the data for the available quarters and the appropriate energy requirement levels.

For Economy 7 tariffs it is assumed that half of the bill is charged at the standard unit rate and the remaining half at the cheaper night rate.

The average annual bill is multiplied by the average customer numbers for each tariff, to give the annual revenue.

The annual revenue is summed for each payment type in each region by type of cost (cost per unit and standing charge). This is then divided by the number of customers in the region for that method of payment to give the average unit costs and average standing charge.

An example of this data can be found in

Table 2: Example of electricity average unit price and average fixed costs (standing charge) in 2018 below[36].

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[36] Annual domestic fuel costs: https://www.gov.uk/government/statistical-data-sets/annual-domestic-energy-price-statistics

Table 2: Example of electricity average unit price and average fixed costs (standing charge) in 2018

Region	Average Unit Price (£/kWh):			Average fixed costs (£/year):		
	Credit	Direct Debit	PPM	Credit	Direct Debit	PPM
East Midlands	0.158	0.148	0.140	103.42	74.93	86.62
Eastern	0.163	0.151	0.148	103.37	76.15	90.39
London	0.167	0.154	0.139	97.79	78.44	99.93
Merseyside & North Wales	0.173	0.160	0.155	102.61	80.16	87.88
North East	0.164	0.151	0.153	101.75	76.67	71.18
North West	0.161	0.151	0.148	103.36	77.28	83.09
South East	0.172	0.157	0.153	97.49	76.60	84.14
South West	0.180	0.164	0.158	97.15	76.95	91.24
Southern	0.166	0.153	0.148	104.23	74.86	89.73
West Midlands	0.165	0.152	0.149	103.42	76.85	88.20
Yorkshire	0.161	0.149	0.147	103.30	76.49	81.59

Non-Metered Fuels

The prices paid for LPG and bottled gas (non-metered fuels) are taken from the Sutherland Tables[37]. These are independently produced reports which provide the average prices paid for fuels, split into four broad geographical regions.

The reports are published quarterly in April, July, October and January. For fuel poverty calculations the October Sutherland Tables prices of the survey year are used, as this reflects the time of year of high fuel demand and prices, taking the general methodological approach to not underestimate fuel costs. The prices produced by Sutherland are taken from a sample of prices collected over the preceding three months.

Prices for heating oil, coal and smokeless fuel (including anthracite) are currently obtained from the Consumer Price Index (CPI)[38], produced by the Office for National Statistics. These prices have been split by English region and represent a 12-month average over the calendar year for each fuel.

Other minor fuels

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[37] http://www.sutherlandtables.co.uk/
[38] https://data.gov.uk/dataset/consumer_price_indices

The price of Economy 10 and 24-hour electricity is set as the SAP 2012 prices[39], inflated to 2017 and 2018 prices using the CPI for electricity. The prices of wood and other biofuels are also based on SAP 2012 prices, which are inflated from 2012 prices using the change in the CPI for coal from this date. The price of communal heat is calculated using SAP 2012 communal prices, inflated using the Consumer Price Index for gas.

Plausibility checks

Metered and non-metered fuel prices are compared graphically against corresponding prices for previous years in order to identify any anomalies in prices or unexpected trends with time. This helps not only in the identification of suspect prices but also in understanding overall trends in relation to fuel costs and fuel poverty levels,

4.3 Method of payment data

The methods of payment are collected for mains gas and electricity only. Each household is asked in the interview survey how they pay for their electricity and gas. For each fuel there is the option of:

(1)   Direct debit (including online direct debit);
(2)   Payment on receipt of bill by post, telephone, online or at bank/post office;
(3)   Standing order;
(4)   Prepayment (key card, slot or token) meters;
(5)   Included in rent;
(6)   Frequent cash payment method (i.e. more frequent than once a month);
(7)   Fuel direct/direct from benefits;
(8)   Fixed Annual Bill (however much gas/electricity is used) e.g. StayWarm;
(9)   Other (Please specify);
(-9)   Not applicable;
(-8)   Don't know (spontaneous only).

There are more methods of payment collected in the EHS survey than the three methods of payment attached to the prices provided by BEIS. Therefore, assumptions are made in order to assign each household a method of payment, and the above categories are grouped as:

• Those stating, 'direct debit', 'included in rent', 'fuel direct/direct from benefits' or 'fixed annual bill (e.g. StayWarm)' are coded as Direct Debit.

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[39] http://www.bre.co.uk/filelibrary/SAP/2012/SAP-2012_9-92.pdf

- Those stating, 'payment on receipt of bill' and 'frequent cash payment method (more than once a month)' are coded as Standard Credit.
- Those stating 'prepayment (key card or token) meters' are coded as Pre-Payment.

For those coded as 'other', and where a written description is provided by the householder, the most suitable method of payment is imputed for each fuel, matching the written description to the above criteria, and additional criteria below:

- Direct debit for any reference to: 'Included in rent' (to include all mentioning 'paying landlord', 'paying employer', 'payments to family'), 'stay warm scheme' includes direct from benefit, 'Pay council', 'Internet'.
- Standard credit for any reference to: 'Regular monthly payments', 'secure homes', 'Easypay', 'Moneyway', 'Cash', 'Cheque'.
- Pre-payment for any reference to: 'Payment cards', 'coin meters', 'gas stamps', 'Paypoint payment'.

After this process there may be a small number of cases without a method of payment (i.e. those who have said they don't know or "other" and where the description is missing or insufficient). For these cases the higher price of the standard credit method of payment is assigned, taking the general methodological approach to not underestimate fuel costs where data is unknown.

Where the gas method of payment is NA (i.e. not applicable, no gas), the gas method of payment is nominally assigned to be the same as the electricity method of payment, and a gas price applied accordingly. If no electricity method of payment is present, the gas price is set to the default standard credit. This method ensures that any case which has a discrepancy between the householder response to the method of payment, and the surveyor response to the heating systems (e.g. where a householder says NA (no gas) to method of payment, but the surveyor says there is gas present and being used) allows reconciliation of the data to occur and prices still applied where applicable.

4.4 Mapping the fuel prices of each household

In addition to matching each household to a fuel based on the method of payment, the household must also be assigned a price based on its location within the country. The EHS collects information on which of the nine English regions each household is in, however the English regions do not correspond with the electricity supply regions, gas distribution zones or Sutherland Table regions.

The fuel prices for each supply/distribution/Sutherland region are matched with the English region using a geographical matching technique. This is based upon estimates of the proportion of each English region within each supply region or distribution zone, as shown in Table 3 and Table 4.

Table 3: Mapping technique for mains gas and electricity

EHS boundary (English region)	Prices calculated using proportions of electricity/gas distribution area prices as:
North East	(1.0) North Eastern
Yorkshire & Humberside	(0.48) North Eastern + (0.52) Yorkshire
North West & Merseyside	(0.7) North Western + (0.3) N. Wales and Merseyside
East Midlands	(1.0) East Midlands
West Midlands	(0.875) West Midlands + (0.125) East Midlands
South West	(0.7) South Western + (0.3) Southern
Eastern	(1.0) Eastern
South East	(0.55) South Eastern + (0.4) Southern + (0.05) Eastern
London	(1.0) London

Table 4: Mapping methodology for Sutherland tables non-metered fuels

EHS boundary (English region)	Prices calculated using proportions of Non-metered fuel region prices as:
North East	(0.95) Northern England + (0.025) Midlands + (0.025) Wales and South West
Yorkshire & Humberside	
North West & Merseyside	
East Midlands	(0.92) Midlands + (0.08) Northern England
West Midlands	
South West	(0.97) Wales and South West + (0.03) Midlands
Eastern	(0.95) South East + (0.05) Midlands
South East	
London	

For example, if a household's English region lies 40% within one supply region and 60% within another supply region the price applied will be a 40/60 weighted average of the two prices. This approach assumes a uniform population density across England.

The prices of biofuels, Economy 10 electricity, 24hr electricity, communal from boilers and communal from Combined Heat and Power (CHP) are calculated on a national scale, so no regional mapping is necessary. Prices for heating oil, coal and smokeless fuel are provided by English region and therefore do not require mapping.

4.5 Applying the Warm Homes Discount

The fuel costs are initially calculated without the receipt of Warm Homes Discount (WHD) applied, as this data is not available to match with the cases in the EHS survey data. It is important, however, that the WHD policy (and legacy tariffs included prior to 2015) are accounted for in the fuel poverty statistics. Receipt of WHD will change a household's FPEER rating. To achieve this, some final adjustments are made to the dataset which act to reduce the total fuel costs for those households considered likely to be in receipt of the WHD. The total number of households modelled to receive the WHD is set to be equal to the total number of households in receipt of support through these elements of the WHD scheme, as reported by Ofgem.

Information on eligibility for each element of the WHD is also provided by Ofgem[40] which allows the modelling of receipt of this discount. There are, however, more households theoretically eligible for this scheme than actually in receipt of these rebates. Therefore, a process of repeated sampling from the pool of eligible households, and selection of a representative iteration is undertaken (i.e. through Monte-Carlo type simulation or similar).

The process of assigning the WHD for the 2018 data is as follows:

a) Details of the number of households in receipt of each component of the WHD (core group and broader group) are provided by Ofgem.
b) Details of eligibility for each element of the WHD are provided by Ofgem, and flags are created in the EHS dataset.
c) A series of runs are made, sampling from the pool of eligible households, which subtracts the WHD cash amount (i.e. £140 for the 2018-19 data) from the final costs for those in the Core or Broader Groups. The number of households in receipt of each element of the WHD is used to constrain this modelling.
d) A representative iteration is selected from all runs.

The representative iteration is optimised towards a median position by examining the variation of each run from the median number of those receiving the rebate by income decile, tenure, region, age of oldest person in household, method of payment for gas and vulnerability.

The WHD has been applied for all years from 2011 to 2018.

4.6 Changes in prices methodology

Each year, minor modifications may be made to the fuel poverty fuel price calculation methodology as a result of improvements in the treatment of missing data, alterations or additions to fuels used, and updates and changes to the EHS survey questions or other data sources. In 2018, there were no major changes to the fuel price methodology.

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[40] https://www.ofgem.gov.uk/environmental-programmes/social-programmes/warm-home-discount-whd

5. How are household energy requirements calculated?

5.1 Overview

The amount of fuel required to provide the energy needs of each household is one of the components of fuel poverty and, combined with fuel prices, produces the modelled fuel bill.

Under the fuel poverty definition, the energy required to heat and power a home can be grouped into four categories:

i)   Space heating – Es (GJ);
ii)   Water heating – Ew (GJ);
iii)   Lights and appliances – ELA (GJ);
iv)   Cooking – Ec (GJ).

The Building Research Establishment Domestic Energy Model (BREDEM) methodology[41] is used to predict the energy requirements of a household where:

$$Total\ household\ energy\ requirements = E_S + E_W + E_{LA} + E_C$$

Total household energy requirements include space and water heating (to meet defined standards), energy for lights and appliances (including requirements for pumps, fans and electric showers, and energy generated by renewables), and energy for cooking. The amount of energy required to heat a dwelling will depend on the building's specifications such as insulation levels, heating systems, the geographical location of the dwelling, and construction type. A household's demand for energy will depend on the number of people within the household and the lifestyle and habits of these individuals. Information from the EHS is used to provide details about both dwellings and households. The calculation process is summarised in Figure 6 below. Reduced Data SAP (RdSAP) assumptions are used to deal with missing data and can be found in the SAP procedure document[42]. It should be noted that the figures now incorporate the revised U-values as published in RdSAP v9.93.

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[41] The BREDEM methodology used is described in Henderson J, Hart J, BREDEM 2012 A technical description of the BRE Domestic Energy Model, v1.1, January 2015. http://www.bre.co.uk/filelibrary/bredem/BREDEM-2012-specification.pdf
[42] BRE 2017. Appendix S: Reduced Data SAP for existing dwellings, RdSAP 2012 v9.93. https://www.bre.co.uk/filelibrary/SAP/2012/RdSAP-9.93/RdSAP_2012_9.93.pdf

Figure 6: Calculating household energy requirements and associated fuel costs
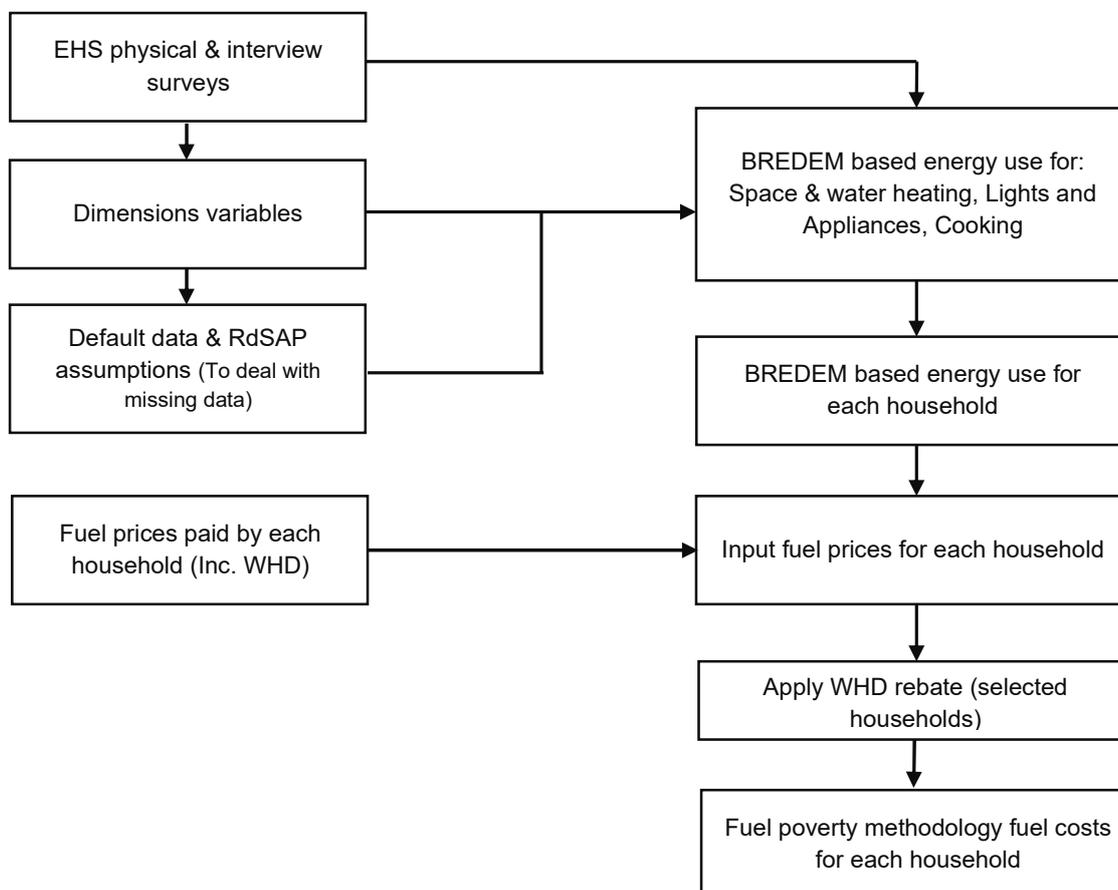
5.2 Dimensions calculation for energy requirements

Data from the EHS physical survey are used to calculate the dimensions of the dwelling and, in particular, the heated volume and heat loss areas. This involves utilising data from many different modules that relate to different parts of the EHS physical survey form.

The following information is calculated:

- Internal and external wall areas;
- Roof area;
- Room specific floor areas;
- Habitable floor area and footprint area[43];
- Perimeter of building;
- Ceiling heights;
- Window and door areas;

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[43] Footprint area is the area of the dwelling in contact with the ground.

- Number of floors and rooms in a dwelling.

Key variables are the width and depth of the main and additional parts of the dwelling, which are directly collected in the EHS physical survey. These are used to determine the area (m2) of each floor. All physical data relating to the dwelling must have a value for the width and depth of the building to be considered part of the main data set. The EHS survey form collects the widths and depths of up to three levels, so the dimensions of any further levels are imputed. They are assumed to be the same size as the floor below, with the exception of any attics, which are imputed based on the floor area dimensions, and basements, which are assumed to be the same size as the floor above. In general, wherever possible, imputations are based on the case in question, not on archetypes or on the rest of the data set.

Initial consistency and plausibility checks

Ahead of the production of derived dimensions variables, a period of raw data input validation takes place. The internal integrity and the consistency of the data is checked. The purpose of these checks is to firstly detect and eliminate certain logical inconsistencies that would cause problems for modelling, and secondly to identify highly implausible answers which, if deemed necessary, are corrected. Where a conflict exists, these investigations take the form of inspection of all relevant data items by an analyst and a judgement being drawn on the most appropriate course of action for each case. In some cases, the raw EHS physical survey data is altered following these consistency and plausibility checks.

Checks include:

Levels checks – data may be inconsistent with regard to the number of storeys in the building, and the floor occupied by the dwelling. The following possible errors are:

- A room on a level that does not exist (e.g. 3rd floor of a three-storey module);
- A room on a level that is not part of the flat (e.g. room on the 3rd floor but flat on the 2nd floor);
- A measured level that is not part of the module (e.g. dimensions for 3rd floor when the dwelling only has three storeys);
- A flat on a level that does not exist (e.g. flat on the 3rd floor when the module only has three storeys);
- Cross checks for presence of a habitable attic/basement and number of floors.

Plausible dimensions – statistical range checks are carried out on the dimensions, to identify any floor area that seems too large or too small for the number of rooms.

Non permissible values – if a dimension is equal to a value that is reserved for special purposes in the EHS coding scheme. The numbers 77, 88 and 99 are reserved to indicate

the section not applicable, question not applicable, or unknown. When investigation suggests these figures occur as real measurements, they are reduced by one.

Incorrect number of flats – the dimensions of the surveyed flat are checked against the total floor area of the survey module to identify if the number of flats per module seems realistic.

Incorrect roof type – in the EHS, certain roof types (chalet and mansard) can only be defined where the dwelling has an attic. On occasions, surveyors may mistake steep pitched roofs for chalet roofs. In this situation, the data for pitched and chalet roofs is swapped over.

Implausible wall and window areas – where a dwelling seems to have a wall or window area that is too high or too low the data is checked.

Wall thickness – cases are identified and checked where the wall thickness as measured by the EHS surveyor is not typical of the wall selected.

Heating system consistency checks – where cases contain inconsistent heating system data on the EHS physical survey the data is checked.

Dimensions variables for use in fuel poverty energy modelling

Due to the complexity in producing dwelling dimensions, a specific derived file is produced within the EHS called: Dimensions.sav, and provides additional data on dwelling dimensions[44]. The dimensions derived data file is available to researchers on request under the EHS Special Licence (SL) through the UK Data Service[45] following publication of the EHS Annual Reports. Users are strongly advised to use these dimensions for any secondary analysis.

Details of the derived dimensions variables are provided below. All variables in this file are described in detail in the EHS data dictionary which can be obtained from the UK data service. Users are recommended to refer to this when using the Dimensions.sav file. All EHS raw data files mentioned in this section are also available under the EHS Special Licence (SL) through the UK Data Service.

Floor area

The EHS records the external dimensions, and these dimensions are converted to internal ones using the wall thickness[46], to calculate a floor area at each level.

Party walls are considered to have a thickness of 0.125m, which is derived by dividing the average wall thickness for the EHS stock by two. The area of each floor consists of the

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[44] Note that the *Dimensions.sav* file now includes variables previously found on the *EnergyDims.sav* file.
[45] https://ukdataservice.ac.uk/
[46] Thickness of walls was measured for the first time in the 2013 EHS.

main part, additional part and the join between the two. The floor area of conservatories with no separating door are also included (taken from page 16 of the EHS form).

For fuel poverty modelling, the floor area variable to be used is the banded variable FloorArea, which is available to researchers on request under the Fuel Poverty Special Licence (SL) through the UK Data Service. Note, that the variable "Energy floor area" on the derived EHS Special Licence Dimensions.sav file should not be used for this purpose.

Storey heights

Data on storey heights (floor to ceiling distance) is collected on page 3 of the EHS form[47] and can be found in the interior.sav raw data file. Following the data consistency, plausibility and integrity checks, derived storey heights for each level are produced by taking the mean of the ceiling heights on each level. These are included in the Dimensions.sav derived file and are defined in the data dictionary.

Wall areas

Following the data consistency, plausibility and integrity checks, derived wall areas are produced. Wall areas for houses are determined from page 13 of the EHS form and can be found in the shape.sav raw data file.

Gross areas (inclusive of openings) are obtained by multiplying the internal dimensions of each floor by the storey height. Assumptions based on the RdSAP methodology for inter-floor thickness are applied so that 0.25m is added to each storey height except the lowest. Basements are included in the wall area, however, a storey containing a room in the roof is not (RdSAP has a separate methodology for modelling rooms in the roof, which is used instead).

The party wall area of each face is calculated by taking the fraction of the gross area that is recorded as attached. This information is collected on page 14 of the EHS form and can be found in the elevate.sav raw data file. The exposed wall area of each face is calculated by removing the party wall area, window and door area from the gross wall area. The same procedure is followed for flats with dimensions that are not the same as the module, except information is used from page 9 of the EHS form (flatdets.sav). The variables relating to the fraction of wall "to outside air" and fraction of wall "to internal accessways" are used to determine the exposed and semi-exposed wall areas respectively. For flats with dimensions the same as the module, the wall area for the whole module is calculated as described above for houses, using data from page 13 of the EHS form. This is then divided by the number of flats, factoring in if there is any non-residential use in the module. This information is collected on page 11 of the EHS form and can be found in the

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[47] e.g. https://www.gov.uk/government/publications/english-housing-survey-2016-to-2017-questionnaire-and-physical-survey-form and subsequent years

numflats.sav raw data file. Flats wholly within a room in the roof are treated as timber framed dwellings according to RdSAP procedures.

Derived wall areas for the module are included on the Dimensions.sav derived file but need to be adjusted to remove the area of wall at ceiling height on the top floor and converted to internal dimensions for the purpose of BREDEM fuel poverty modelling.

Door areas

The area of external doors is not directly collected as part of the EHS, but the number of external doors is collected on page 17 of the EHS form and can be found in the doors.sav raw data file. For the purposes of BREDEM fuel poverty energy modelling, it is assumed that all external doors are of area 1.85 m2 which is the standard RdSAP assumption.

Window areas

Window areas for houses are calculated by taking the fraction of gross wall area that the surveyor records as fenestration (windows + doors) and then subtracting the door area. This information is collected on page 14 of the EHS form and found in the elevate.sav raw data file. In the case of flats, the window area (m2) can be taken directly from page 9 of the EHS form and can be found in the flatdets.sav raw data file. The fenestration area is produced in the Dimensions.sav derived file. The age of the windows is collected on page 17 of the EHS form and can be found in the windows.sav raw data file. It is used to determine whether the double glazed windows are assigned a pre-2003 or post-2003 U-value.

Roof area

The roof area is taken as the floor area of the largest storey, unless there is a room in the roof in which case RdSAP assumptions are applied.

5.3 Dwelling energy requirements

The calculation of energy requirements for fuel poverty uses information from the raw physical and interview survey files, along with the derived EHS datasets Physical.sav, Interview.sav and Dimensions.sav. These files are available to researchers on request under the EHS Special Licence (SL) through the UK Data Service[48] following publication of the EHS Annual Reports. The data is used to derive the following:

- Heat loss due to conduction from all the external house structure to the external environment, for example heat lost through the walls or roof (fabric heat losses);
- Heat gain from solar fluxes and other gains such as from lights, appliances and occupants;
- Heat loss due to ventilation;

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[48] https://ukdataservice.ac.uk/

- Energy required for space and water heating systems;
- Heating regime of the inhabitants (when and to what extent they heat their home);
- Energy required for lights, appliances and cooking;
- Energy generated from renewable technologies (photovoltaics, solar hot water and micro generation wind turbines).

This information is calculated using data collected from the interview and physical surveys, as outlined in sections 5.4 to 5.9.

5.4 Information used in the calculation of fabric heat losses

Fabric heat loss is calculated for the dwelling using information on each of the external building elements (e.g. wall, floor, roof, windows, doors) and details of thermal bridging.

U-values

The rate of heat loss through each element is calculated by multiplying the element area by the U-value of the material that the element is constructed from. The U-value is a measure of the effectiveness of a material as a heat conductor. U-values of external elements are assigned according to the actual construction date of the property, as recorded in the firstimp.sav file. These are matched to the RdSAP default U-values.

Where the age of individual elements is different from the age of the dwelling, U-values are assigned in line with RdSAP defaults by subtracting the age of the element (as reported on the EHS) from the whole-year date of the EHS single survey year. For example, a window identified as 10 years old in the EHS survey year which ran between April 2015 and March 2016 (the '2015 EHS single year') is considered for the purposes of the fuel poverty modelling to date from 2005 (i.e. 2015 – 10 = 2005). This remains the case if the actual survey took place in the first three months of 2016.

If the main wall type is predominantly cavity (≥50%) then a party wall U-value of 0.25 W/m2K is assumed for houses and flats with dimensions that are the same as the module, otherwise, no heat loss is assumed for the party wall. Access corridors are assumed to be unheated and an adjustment factor, for the thermal resistance of 0.4 m2K/W, is applied to the U-values of walls adjacent to these areas.

Non-repeating thermal bridging

For the purposes of fuel poverty BREDEM modelling, the effect of non-repeating thermal bridges is taken into account. The heat loss rate for non-repeating thermal bridges is calculated in line with table S13 of RdSAP for dwellings of different ages.

5.5 Identification of space and water heating systems

All data of relevance to the identification and use of space heating systems in fuel poverty modelling can be located in the derived EHS Physical.sav file and EHS raw data services.sav file. For the purposes of secondary analysis, users are strongly recommended to use the derived Physical.sav variables where possible. They should also refer to the detailed documentation of these variables as provided in the Physical.sav data dictionary available from the UK Data Service.

The type and characteristics of the space and water heating systems present in the dwelling are collected on pages 5, 6 and 7 of the EHS form. In particular, these pages collect data on:

- Mains gas and electricity connections;
- Primary space heating system type and fuels;
- Boiler names and models;
- Heat distribution systems;
- Heating controls;
- Secondary heating system type and fuels;
- Water heating systems types and systems; and
- Hot water tank presence and levels of insulation.

Two types of space heating system are defined and used in the BREDEM modelling: main heating and secondary heating. In addition, one water heating system is defined. The method of determining these systems from the EHS data are described below.

Main heating

Information relating to the heating systems assigned for each dwelling is taken directly from the EHS physical survey. The primary heating group, fuel and type are essential for the allocation of the primary heating system and the calculation of energy use for each household.

When an EHS surveyor first inspects the heating systems in a dwelling, they are required to identify firstly whether there is any system which can be considered a "Primary System" and then to identify what this system is. A primary heating system is a system which provides heat to more than one room. Where multiple systems exist, the primary system is the one in the main living room. The vast majority of dwellings contain a primary heating system and this is recorded on the page 6 of the EHS form. Where a primary heating system is identified by a surveyor, details about the primary heating system are used as the main heating system within the BREDEM modelling. In cases where primary data are missing for the heating systems, information from 'other heating' (secondary heating) is used in its place according to the SAP methodology.

The surveyor records:

- Primary heating group (e.g. central heating, storage radiators);
- Primary heating type (e.g. boiler type);
- Primary heating code (a three digit coding system that allows more details such as type of flue to be recorded);
- Primary heating fuel;
- Primary system age;
- Boiler name and model information (if applicable);
- Distribution type (radiators or underfloor); and
- Details about primary heating controls.

The initial source for information about the type of heating system is the boiler name and model. The boiler model is searched for in the Product Characteristics Database (PCDB)[49] of efficiencies, and where a match is found, details on the boiler efficiency and flue type are used within the BREDEM modelling. For combination boilers, additional information is extracted from the PCDB for use in the modelling where available, such as combi loss factors, keep-hot information and storage details (if the system is a storage combi). Following requests from users, a flag indicating a successful match with the PCDB, and the assumed efficiency are included as part of the Special Licence fuel poverty dataset, which researchers can obtain through the UK Data Service for 2014 data onwards.

Where no match can be found or these data are missing, the Primary heating code is used to define the type of heating system. If the Primary heating code is insufficient to define the system the Primary heating type fuel, and age are determined from these items on the EHS form. The type of heating system is then used to determine the default efficiencies via a lookup table of heating system efficiencies in SAP.

Secondary heating

Surveyors are also asked whether there is an "other" heating system within the home. This is recorded as the system in the main living room, where present, otherwise it is the system in any other room. The data on these systems is recorded on page 6 of the EHS form. The type of system recorded as "other" heating is taken as the secondary heating system in the home. SAP defaults for each type of system provide the data on the relative efficiencies of each system. Where no "other" system is indicated the BREDEM calculation uses the primary heating system only. According to SAP rules, storage heaters require a secondary heating system so if a secondary heating system is not already recorded, electric room heaters are added.

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[49] http://www.ncm-pcdb.org.uk/sap/

Water heating

Information relating to the presence and specification of the water heating system is also obtained from the EHS physical survey. Water heating systems are identified on page 7 of the EHS form.

The EHS surveyors are able to specify and list the various water heating systems present in the dwelling. Only one of these systems is taken forward into the BREDEM modelling. In the case of multiple systems, the order of system preference is:

- Boiler with central heating;
- Boiler for water heating only;
- Back boiler;
- Communal;
- Single immersion;
- Dual immersion;
- Single point instantaneous;
- Multi point instantaneous[50]; and
- Other.

Data on the cylinder dimensions and insulation (where present) and water heating controls are also collected on page 7 of the EHS form and affect the water heating efficiency and water heating energy requirement. Where the system is with the central heating system, the data on the main heating system is used for the calculation of water heating system efficiency.

In BREDEM 2012 the water heating demand is a function of the number of showers and baths taken per day, as well as the type of shower. The specific rules applied for calculating water heating from EHS data are as follows:

- If the dwelling has two water heating systems, a main and an electric instantaneous, an electric shower is assumed
- If the dwelling has a combi boiler then set the shower type to Mixer (combi)
- Otherwise assume shower type is Mixer (not combi).

5.6 Space heating assumptions and definition of heating regime

The amount of energy required for space heating is estimated using the BREDEM algorithm using information on the space heating systems (Section 5.5), applied insulation, dwelling construction and materials, in addition to the external climate conditions and acceptable level of heating.

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[50] If there is an instantaneous water heater and another water heating system, it is assumed that the instant heater is an electric shower

The external conditions are determined for the geographic location of the dwelling and time of year. The acceptable level of heating is defined in terms of the demand temperature of a dwelling, the extent to which the dwelling space is heated, and the number of hours that the occupants heat the house for (the heating regime). These are described below.

Geographical Location

BREDEM defines twelve geographical regions for England. These BREDEM regions define monthly average climatic conditions such as temperature, solar flux (i.e. heat gains from the sun) and wind-speed. Each dwelling in the EHS has a geographical identifier that can be used to determine in which BREDEM region the property is located.

Demand Temperature

BREDEM suggests that (generally) a house can be split into three distinct zones: a primary heated zone, secondary heated zone and unheated zone. For the modelling of fuel poverty, the demand temperature of all dwellings within the primary zone is assumed to be 21°C, the secondary zone is assumed to be heated to 18°C and the temperature of the unheated zone relates to the external temperature and therefore varies depending on the local climatic conditions.

Extent of Heating/under-occupancy

Some dwellings are considered excessive in size for the number of occupants that live there. In these cases, the house is assumed to be "under-occupied", and that only a proportion of the dwelling will need heating. For a dwelling to be considered under-occupied it must fulfil criteria that depend on both the number of bedrooms in a dwelling and the total floor area of the dwelling. These criteria are described in more detail below.

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.

A separate bedroom is allowed for each married or cohabiting couple, any other person aged 16 or over, each pair of adolescents aged 10-15 of the same sex, and each pair of children under 10. Any unpaired person aged 10-15 is notionally paired, if possible, with a child under 10 of the same sex, or, if that is not possible, he or she is counted as requiring a separate bedroom, as is any unpaired child under 10.

There is considered to be surplus floor area in a property if the floor area of the property is over double that considered to be the "standard" living area required for the number of occupants, as defined by the Parker-Morris Standard[51]. This standard is defined as in Table 5 below.

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[51] "Homes for today and tomorrow", Department of the Environment, HMSO 1961.

Table 5: Parker Morris Standard

Occupants	Standard living area required (m2)
1	33.0
2	48.5
3	61.0
4	79.0
5	89.5
6	97.0
7	114.5
8	128.0
9	140.0

For the purposes of fuel poverty, a dwelling is considered to be under-occupied if there are both surplus bedrooms and surplus floor area.

If a dwelling is under-occupied then it is assumed that exactly half of the dwelling is heated, that is:

$$A_{heated} = 0.5 * A$$

Where A is the total floor area of the dwelling.

The remaining space is declared as a BREDEM unheated space. Because under-occupying households will always live in large dwellings (to be classed as under-occupying the floor area must be large), Zone 1 (living area) is assumed to be fully heated under this methodology. This will result in the area of Zone 2 that is heated being reduced for all under-occupying households. The proportion of Zone 2 that is heated can be calculated as follows:

$$Area\ of\ Zone\ 1\ =\ Z1$$

$$Area\ of\ Zone\ 2\ =\ Z2$$

$$Unheated\ Zone\ 2\ area\ for\ under-occupancy\ =\ (Z1\ +\ Z2)\ /\ 2$$

$$Heated\ Zone\ 2\ area\ for\ under-occupancy\ =\ Z2\ -\ (Z1\ +\ Z2)\ /\ 2$$

$$Proportion\ of\ Zone\ 2\ heated\ =\ (Z2\ -\ (Z1\ +\ Z2)\ /\ 2)\ /\ Z2$$

Heating Season

The heating season is defined as the months of October to May, in line with the SAP methodology.

Heating Regimes

A standard heating regime assumes that the occupants are not occupying the dwelling during normal working hours. In this case it is assumed that the occupant heats the dwelling for two hours first thing in the morning and then for seven hours from late afternoon. During the weekend it is assumed that the property is heated throughout the day for 16 hours. The SAP methodology also makes this assumption to calculate the energy requirements in a dwelling.

This heating pattern does not apply for large sectors of the population, in particular the vulnerable such as the elderly and those caring for young children. The EHS interview survey includes a direct question on whether anybody within the household occupies the dwelling during the morning or afternoon in the winter. This question is directly utilised to approximate the heating pattern. If anybody is in the house in either the morning or afternoon during weekdays, the house is assumed to require all day heating. In these cases, all day heating is assumed throughout the week as well as the weekend.

In dwellings that are under-occupied, it is assumed that some of the rooms in the dwelling are not heated and a "half-house" heating regime is applied. For example, where a single person occupies a four-bedroom house, it would be assumed that some of the bedrooms are not heated.

The following heating regimes are defined and used to calculate the energy requirements of a household:

Table 6: The standard heating regime for the fuel poverty heating calculations

	Details of STANDARD heating regime
Heating Pattern	Weekday 9 hours of heating Weekend 16 hours of heating
Heating Extent	Whole house
Demand Temperature	Primary living zone 21°C Secondary living zone 18°C

Table 7: The full heating regime for the fuel poverty heating calculations

	Details of FULL heating regime
Heating Pattern	Weekday 16 hours of heating Weekend 16 hours of heating
Heating Extent	Whole house
Demand Temperature	Primary living zone 21°C Secondary living zone 18°C

Table 8: The partial standard heating regime for the fuel poverty heating calculations

	Details of PARTIAL STANDARD heating regime
Heating Pattern	Weekday 9 hours of heating Weekend 16 hours of heating
Heating Extent	Half house
Demand Temperature	Primary living zone 21°C Secondary living zone 18°C

Table 9: The partial full heating regime for the fuel poverty heating calculations

	Details of PARTIAL FULL heating regime
Heating Pattern	Weekday 16 hours of heating Weekend 16 hours of heating
Heating Extent	Half house
Demand Temperature	Primary living zone 21°C Secondary living zone 18°C

5.7 Water heating

Energy demand for water heating (QU) is the energy required to heat the volume of water needed for baths, showers and other uses. The detailed equations are presented in the BREDEM 2012 documentation[52], and use information on the water heating systems as discussed in Section 5.5.

Most methods of water heating involve energy losses that relate to storing the water in hot water tanks and distribution losses. Therefore, the total water energy demand must satisfy the hot water requirements and account for the energy losses inherently involved in satisfying the supply required. Hot water storage losses are mostly influenced by tank insulation and tank volume.

The energy required for water heating EW (GJ/yr) is given as:

$$E_W = (kQ_U + Q_{Loss} - Q_S)/\mathcal{E}W$$

Where QLoss are losses through water storage/distribution, QS is solar hot water heating, ƐW is the efficiency of the water heater and k is a constant.

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[52] Henderson J, Hart J, BREDEM 2012 A technical description of the BRE Domestic Energy Model, v1.1, January 2015, http://www.bre.co.uk/filelibrary/bredem/BREDEM-2012-specification.pdf

5.8 Lights and appliance requirements

Energy demand for electricity ELA (GJ/yr) includes lights, appliances, pumps, fans and electric showers, less the household electricity generated by renewable electricity sources such as photovoltaics and wind turbines (where applicable). The algorithm for lighting energy requirements includes provision for low energy lighting. The full equations can be found on page 6 of the BREDEM 2012 documentation51.

5.9 Cooking energy requirements

Energy demand for cooking is given as EK (GJ/yr) and is a function of household size:

$$E_C = f_{gas}(1.7316 + 0.3456N) + f_{electricity}(0.990 + 0.1198N)$$

Where fgas and felectricity are the proportions of demand satisfied from gas or electric cooking, respectively, and N is the number of people in the household. The full equations can be found on page 6 of the BREDEM 2012 documentation.

Several types of cookers can be modelled in BREDEM 2012, but data on cooker type is not collected in the EHS. For the fuel poverty modelling, if the dwelling is fully electric it is assumed that a normal sized electric cooker is in use. Otherwise it is assumed that a normal sized gas/electric cooker is in use. Therefore:

- Where a gas connection is present (i.e. a gas meter is identified by the surveyor), but no gas space or water heating appliances are present, it is assumed that the gas connection is not in use. In these cases 100% of energy demand for cooking is assumed to be met by electricity. No gas standing charge will be applied in the final calculation of fuel cost.
- Where both gas and electricity are present in a dwelling it is assumed that the proportion of gas and electrical energy demanded for cooking is split equally. Consequently, in this case fgas =0.5 and felectricity =0.5.

5.10 Total fuel costs

Total energy requirements are given as:

$$Total\ energy\ requirements\ (GJ/yr) = E_S + E_W + E_{LA} + E_C$$

Where:

E_S: Energy for space heating;

E_W: Energy for water heating;

E_{LA}: Energy required for lights and appliances;

E_C: Energy required for cooking.

The fuel cost for each energy component is calculated by multiplying the total number of units required under each of the components by the unit cost for the fuel used and adding the appropriate standing charge. Each survey case is unique, with the appropriate fuel prices being applied based on the type of fuel given for each component of energy use. The total fuel cost is the sum of the fuel cost for each component:

$$Total\ energy\ cost\ (£) = £_S + £_W + £_{LA} + £_c$$

Where:

£$_S$: Fuel cost for space heating (including standing charges where appropriate);

£$_W$: Fuel cost for water heating;

£$_{LA}$: Fuel cost for lights and appliances (including standing charges and Warm Homes Discount);

£$_C$: Fuel cost for cooking.

In the fuel poverty datasets, standing charges are assigned to the most appropriate component of fuel cost as follows:

Fuel cost for space heating (£$_S$) includes cost of space heating (units consumed multiplied by unit cost) and:
- The gas standing charge if gas is present;
- Standing charges associated with communal systems or other fuels;
- Standing charges from off-peak electricity tariffs, above the standard rate charge.

Fuel cost for lights and appliances (£$_{LA}$) includes the cost of lights and appliances (units consumed multiplied by unit cost) and:
- The standard electricity charge, not related specifically to heating;
- The Warm Homes Discount rebate if applicable.

Due to the simplified way of assigning standing charges to the fuel costs, this may result in a few cases where a standing charge is assigned to space heating despite the fuel not being used in this way. For example, households with a gas space heating cost but no gas space heating usage can be due to the standing charge allocated to the space heating costs arising from a gas-based water heating system. Households with an off peak electric tariff, which do not use electricity for their space heating, can also show this type of anomaly. These cases are, however, rare and this method of assigning standing charges is done to simplify the dataset.

5.11 Handling missing values

Alteration to the dwelling data

When performing detailed checks on the outputs, there are cases that are flagged where values recorded on the physical survey form are deemed implausible and require alteration to the raw data within the energy modelling process. Each case is assessed on a case-by-case basis using other information from the survey form in order to apply the appropriate action for the data to be processed correctly.

Missing dwelling data

Most of the data required to calculate the energy requirements of the household are available from the EHS survey. Where there are missing data items, these are dealt with in accordance with RdSAP assumptions for existing buildings as specified in Appendix S[53] of the SAP 2012 booklet. The exception is where data for loft insulation is missing and the occupant has access to the loft space. Loft insulation is assigned using the mean value for dwellings of that age and tenure using what is referred to as 'default data'. This data is constructed using national averages from the EHS.

Missing household data

The number of occupants living in a dwelling and the composition of the household is provided in the interview survey. Data are required for each individual household. If this information is not available then the property is considered to be vacant – vacant dwellings are not included in fuel poverty calculations, therefore, the combined (paired) sample in the EHS dataset compared to the combined (paired) sample in the Fuel Poverty dataset will not be identical.

Validation

Validation of the energy requirements and cost outputs is an important process in the delivery of reliable results. The level of validation applied will depend on the level of accuracy quoted, the significance of the indicator, the type of result quoted and the resource provided for the task. Several layers of data validation are applied to the fuel poverty energy use and cost variables. These include cross checking from an independent member of staff, time series analysis, interrogation of important metrics, and comparing results against external data sources such as the Digest of UK Energy Statistics (DUKES)[54].

Outliers

Outlying cases are identified in the data and validated to ensure that the data modelling processes are being performed correctly. In rare cases where the data are deemed to require modification, the fuel costs are imputed based on the median value from a group

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[53] https://www.bre.co.uk/sap2012/
[54] DUKES, Digest of United Kingdom Energy Statistics: https://www.gov.uk/government/organisations/department-ofenergy-climate-change/series/digest-of-uk-energy-statistics-dukes

with similar characteristics (grouped according to dwelling type and main heating fuel category).

5.12 BREDEM versions

BREDEM is the calculation procedure used for modelling energy requirements in dwellings for fuel poverty. It was first developed in the early 1980s and has been continuously updated as a result of changes to our understanding of dwelling energy requirements and the use of energy in the national housing stocks.

The latest version of BREDEM 2012, version 1.1[55], is used for both years in the combined 2017 and 2018 datasets and trends data. All years in the timeseries also use U-value and other default assumptions from the latest version of RdSAP (version 9.93). These data are, therefore, produced on as comparable a methodology as possible to allow comparison between years and assist interpretation.

5.13 Changes in energy modelling methodology

Each year, minor modifications may be made to the fuel poverty energy modelling calculations as a result of improvements in the treatment of the data, changes to the modelling methodology, and alterations to the EHS physical survey data collection. In some years more major methodology changes have been implemented.

Incorporation of RdSAP 9.93 U-value (2016 dataset)
U-values for solid brick, stone, system build and cavity walls have been updated in timeseries data to reflect the updated U-values in version 9.93 of the RdSAP procedure document. Overall, this had a minor effect on energy requirements at a stock level, as energy reductions in dwellings with wall types that received an improved (lower) U-value were offset by the increased energy demand in dwellings which received a higher wall U-value under new RdSAP assumptions

Pumps and fans methodology update (2018 dataset)
The methodology for calculating energy use from pumps, flues and fans was updated for the 2018 (single year) half of the dataset to align with the RdSAP methodology. The principal change was a switch from external observations (e.g. chimneys) to internal (e.g. open fireplaces). Analysis indicates that this change will have increased the mean SAP ratings of the stock as a whole by approximately 0.3 SAP points (measured using the combined year datasets).

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[55] Henderson J, Hart J, BREDEM 2012 A technical description of the BRE Domestic Energy Model, v1.1, January 2015, http://www.bre.co.uk/filelibrary/bredem/BREDEM-2012-specification.pdf

6. Calculating fuel poverty under Low Income High Costs (LIHC)

This chapter describes the method used to identify households living in fuel poverty under the Low Income High Costs (LIHC) indicator. Under this indicator, households are considered to be fuel poor if:

- they have required fuel costs that are above average (the national median level); and
- were they to spend that amount, they would be left with a residual income below the official poverty line.

The depth of fuel poverty is defined as the amount by which the assessed energy requirements of fuel poor households exceed the threshold for reasonable costs. This is referred to as the fuel poverty gap. Figure 9 shows the four possible groups a household can fall into under this indicator.

Figure 9: Classifications under the Low Income High Costs matrix
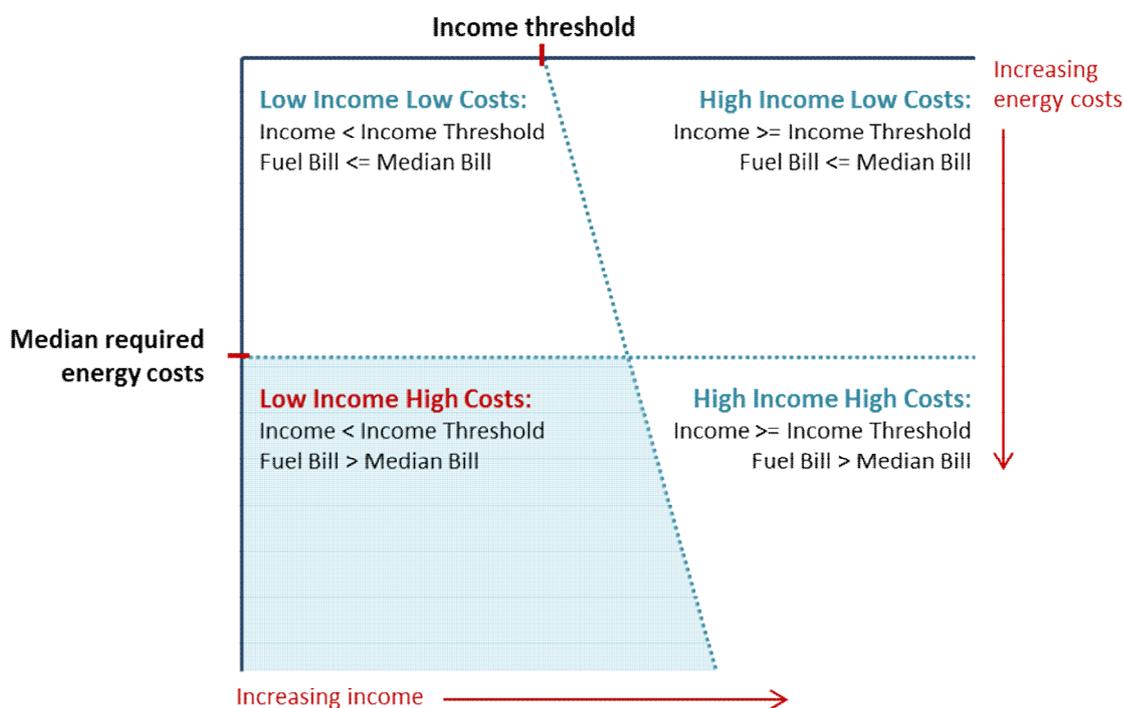
6.1 Calculating the number of households in fuel poverty

The following section describes how to calculate whether a household has a 'low income' coupled with 'high costs'.

Fuel costs threshold

Households with required fuel costs that are above average (the national median level) are calculated by:

1. Taking the required fuel costs for the household from the fuel poverty dataset (the "fuelexpn"[56] variable)
2. Applying the corresponding equivalisation factor for each household. These are shown in Table 10 below.

Table 10: Equivalisation factors for fuel costs under the Low Income High Costs indicator

Number of people in the household	Equivalisation factor
One	0.82
Two	1.00
Three	1.07

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[56] https://www.ukdataservice.ac.uk/get-data

Four	1.21
Five or more	1.32

The fuel costs equivalisation factors are not intended to be reviewed on an annual basis. They may however be revisited periodically in the future to ensure they do not become dated.

The fuel costs equivalisation factors are based on three years of required fuel cost data from the English Housing Survey (using the 2008, 2009 and 2010 Fuel Poverty datasets). The combined 3 year weights (from the EHS"3yr_weight890"[47] file) were used to arrive at the above set of equivalisation factors. Median fuel costs for each of the above five household size group from this dataset[57] are calculated. These medians are then indexed to the two-person households. Adults and children are treated equally in the equivalisation of fuel costs - that is, a household with two adults and two children are treated the same as a household with four adults.

3. Then, divide the required fuel costs by the equivalisation factor to get the equivalised required fuel costs for that particular household. Equivalising effectively increases the costs of single person households, and decreases the costs of multiple person households, with the aim of making them comparable.
4. The fuel cost threshold is the weighted median of equivalised required fuel costs for the whole sample.

In other words, half of all households will have "high costs" i.e. above the threshold, and half will have "low costs" i.e. below the threshold.

The threshold for fuel costs is the same for all households in each year of the fuel poverty dataset, irrespective of the combined dataset.

Household income threshold

Households are below the income threshold if fuel spend leaves the household with a residual income below the official poverty line[58]. This is calculated by:

1. Taking the full income for the household from the fuel poverty dataset[59] (the "fpfullinc" variable).
2. Subtracting housing costs from the income to arrive at After Housing Costs (AHC) income. Housing costs consist of:
   a. Weekly total mortgage repayments ("mortwkx" variable from the EHS interview file)

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[57] Based on the "hhsizex" variable from the EHS interview file.
[58] Relative low income (or poverty) is defined as 60% of the median equivalised disposable income, and is used in official UK statistics. For example:
https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/articles/persistentpovertyintheukandeu/2014
[59] https://www.ukdataservice.ac.uk/get-data

b. Weekly net rent payments ("rentExS" variable from the EHS interview file). This variable also includes housing benefit. Note, the "rentExS" variable is used rather than the "rentwkx", as "rentwkx" includes the cost of any services that the household pay alongside their rent. To ensure consistency in reporting only the true housing costs, variable "rentExs" is used.

3. Divide the after housing costs income by the relevant After Housing Costs (AHC) income equivalisation factor. Equivalising effectively increases the incomes of single people, and reduces the incomes of larger households, similarly to fuel costs, with the intention of making them comparable. The equivalisation factors for each person in the household are shown in Table 11 below.

Table 11: After housing costs income equivalisation factors for the LIHC indicator

Number of people in the household	After Housing Costs (AHC) income equivalisation factor
First adult in the household	0.58
Subsequent adults (includes partners and children aged 14 or over)	0.42
Children under 14	0.20

The AHC income equivalisation factors used are consistent with that used by the DWP in their production of Households Below Average Income (HBAI) statistics. These factors were first devised by the OECD, and are used widely across Europe, including by Eurostat.

Two key elements are needed to derive an individual household's equivalisation factor: the number of occupants in the household, and their age (as the OECD scale distinguishes between under and over 14 year olds).

The number of household occupants is taken from the "hhsize" variable (from the EHS "interview file") and combined with information on the occupants age from the "DVHsize" variable (from the EHS "people" file)[60]. The difference in the number of additional adults between "hhsize" and "DVHsize" are assumed to be additional adults who live in halls of residence. These adults are removed from these calculations. The AHC income equivalisation factor therefore, excludes any

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[60] The "hhsize" variable only excludes people living in halls of residence from 2008 onwards, following a change from the EHCS to the EHS. Prior to that, "hhsize" was consistent with "DVHsize", and so people living in halls of residence were included in our income equivalisation method. There is therefore a small break in the consistency of the time series between 2007 and 2008.

household members who are living away in halls of residence, making the calculation of AHC income equivalisation factors consistent with fuel costs equivalisation factors, by counting only household members living in the residence.

A worked example of how to arrive at a households AHC income equivalisation factor is given below. Suppose a household consists of the following members:

Table 12: Worked example household details

Household member	Age (years)	Status	AHC equivalisation factors
HRP	54	Lives at home	0.58
HRP partner	52	Lives at home	0.42
Additional adult	21	Lives in halls of residence	0.42
Additional adult	18	Lives in halls of residence	0.42
Additional adult	16	Lives at home	0.42
Child	12	Lives at home	0.2
		Total	2.46

Here the:

Hhsize = 4 (excludes the two people living in halls of residence)

DVHsize = 6 (includes the two people living in halls of residence)

The overall equivalisation factor, after accounting for the 2 people living in halls of residence, is given by:

AHC income equivalisation factor = 2.46 – (2 * 0.42) = 1.62

The key assumptions here are:

i)   We assume the difference between the "hhsize" and "DVHsize" is due to people living away in halls of residence; and more crucially

ii)   that all individuals living in halls of residence will be over 14 years old, and so have an equivalisation factor of 0.42 rather than 0.20.

4. To calculate the income threshold for each individual household, take the following steps:
    a. Take the weighted median of all of the AHC equivalised incomes in the dataset
    b. Calculate 60% of this value, to produce the relative low income threshold[61] .
    c. Add on the equivalised required fuel costs of the particular household.

The income threshold is therefore higher for households with large energy costs compared to those with smaller energy costs. In other words, households with larger costs require a greater level of income to meet this greater cost. As a result, the income threshold will appear as a diagonal line on diagrams of the indicator, as seen in Figure 9.

The threshold for income varies by household, depending on the fuel costs of the household.

Summary of income and fuel costs thresholds
The fuel poverty household income threshold is set at the poverty line = 60% of the weighted median of AHC equivalised income for the whole sample, plus the equivalised fuel costs of that household.

The fuel poverty fuel cost threshold is set at the weighted median for the equivalised fuel costs of all households.

The weighted median equivalised fuel costs and weighted median equivalised AHC income are used to provide averages for all households. The median values are used rather than the mean as the values are not as skewed towards extremes, and as fuel poverty is measured in a relative way, using the median values means the income and fuel cost thresholds are less sensitive to changes across all households. This method was recommended by the Hills review[62].

Worked example (2013): fuel poverty status
Family composition : lone parent (one adult, one dependent aged >14 years, one dependent aged <14 years)

Number of people : 3

Fuel costs : £1,602

Total income : £15,596

Housing costs : £96.92 mortgage repayments per week

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[61] Relative low income (or poverty) is defined as 60% of the median equivalised disposable income, and is used in official UK statistics. For example:
https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/articles/persistentpovertyintheukandeu/2015
[62] https://www.gov.uk/government/publications/final-report-of-the-fuel-poverty-review

Equivalised fuel costs   = £1,602/ equivalisation factor (1.07)
                                           = £1,497

AHC equivalised income   = (income – annual housing costs)/ equivalisation factor
                                           = (£15,596 – 52*£96.92) / (0.58+0.42+0.2)
                                           = £10,555 / 1.2
                                           = £8,797

Median equivalised fuel costs threshold for 2013 data = £1,239
60% of equivalised AHC median income for 2013 data = £12,212
Household income threshold = £12,212 + £1,497 = £13,709

Here:

Equivalised fuel costs (£1,497)   >   Median equivalised fuel costs threshold (£1,239)
AHC equivalised income (£8,797)   <   Household income threshold (£13,709)

Therefore, the household is considered fuel poor under the LIHC indicator.

6.2 Calculating the fuel poverty gap

Under the Low Income High Costs indicator of fuel poverty, the depth of fuel poverty is represented by the 'fuel poverty gap'. This is defined as the amount by which the assessed energy needs of fuel poor households exceed the threshold for reasonable costs.

Figure 10 below shows the overlap between the equivalised AHC household income and the equivalised fuel costs (shaded trapezium area) under which a household is considered to be fuel poor. The fuel poverty gap for a particular household is the difference between the household's required fuel costs and what these fuel costs will need to be for them not to be in fuel poverty. This is shown by the vertical arrows for households A and B below. Equivalisation provides a value that allows households of different sizes and composition to be compared, however as such, the fuel poverty gap does not represent an actual value and therefore the fuel cost equivalisation factors (Table 10) need to be applied to return the gap to an unequivalised value in pounds (£). This is done through multiplying the equivalised gap by the respective equivalisation factor for the household.

Figure 10: Fuel poverty gap under the Low Income High Costs indicator
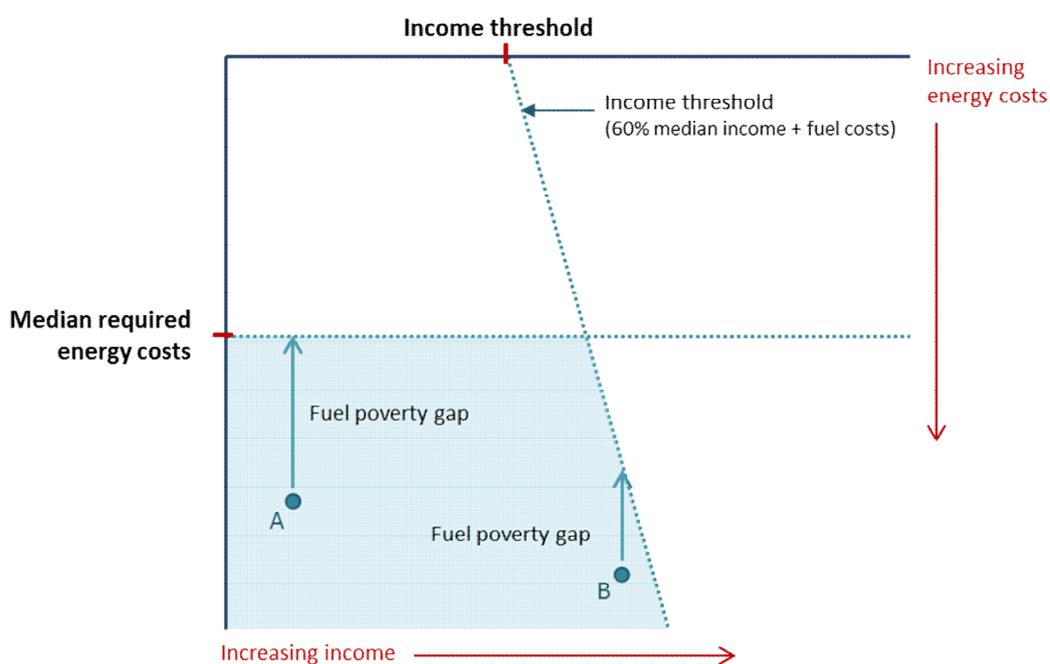
For fuel poor households, the fuel poverty gap can be generalised as:

Fuel poverty gap = $(y - y_m) - \max\{[x - (x_m + y_m)], 0\}$

Where:

x	= equivalised household income
xm	= 60% of equivalised AHC median income
y	= equivalised household fuel costs
ym	= median equivalised fuel costs (fuel cost threshold)

From the 2017 fuel poverty dataset:

- 60% of equivalised AHC median income = £13,672
- Median equivalised fuel costs = £1,158

These are based on the equivalised incomes and equivalised fuel costs. For more information on equivalisation, and the factors used for both incomes and fuel costs, please see Section 6.1.

Worked example (2017): fuel poverty gap

Figure 11: Worked example: fuel poverty gap calculation11 below illustrates the fuel poverty gap calculation for two typical fuel poor households, A and B. In 2017, the Income threshold (defined as 60% of equivalised AHC median income) was £13,672 and the Fuel cost threshold (defined as the median required fuel costs, equivalised) were £1,158. The

Overall income threshold at the median fuel costs is defined as the sum of the two: £13,672 + £1,158 = £14,830. In this example, household A has an income below this threshold while household B has an income above it. The income (x) and fuel costs (y) for each household is shown in Figure 11: Worked example: fuel poverty gap calculation 11 below as (x, y).

60% of equivalised AHC median income (x_m) = £13,672
Fuel cost threshold (median equivalised fuel costs, y_m) = £1,158
Overall income threshold (at median fuel costs) = $(x_m + y_m)$ = £13,672 + £1,158 = £14,830

Household A is below the Overall income threshold (equivalised household income = £11,643) and therefore their fuel poverty gap is calculated as their excess fuel costs alone $(y - y_m)$.

(Equivalised household income)A = £11,643
(Equivalised fuel costs)A = £1,311

Fuel cost equivalisation factor = 1.21

(Fuel poverty gap)A = Equivalised fuel costs – Fuel Cost threshold
                     = £1,311 - £1,158
                     = £153

(Final unequivalised fuel poverty gap)A   = (Fuel poverty gap)A x equivalisation factor
                     = £153 x 1.21
                     = £185

Household B is above the Overall income threshold (equivalised household income = £15,414) and therefore their fuel poverty gap is calculated as the excess fuel costs minus their extra income above the overall income threshold: $(y - y_m) - (x - (x_m + y_m))$.

(Equivalised household income)B = £15,414
(Equivalised household fuel costs)B = £2,751

(Fuel poverty gap)B = Equivalised household fuel costs – Fuel cost threshold
                        – (Equivalised household income – Overall income threshold)
                     = £2,751 – £1,158 – (£15,414 – £14,830)
                     = £1,009

Fuel cost equivalisation factor = 1.21

(Final unequivalised fuel poverty gap) B = (Fuel poverty gap)B x equivalisation factor
                     = £1,009 x 1.21
                     = £1,221

The resulting gap for each individual household is then aggregated across all fuel poor households to produce an overall aggregate fuel poverty gap. This gives a sense of the depth of fuel poverty on a national level. In addition, this aggregate gap can then be divided by the total number of fuel poor households to give an average fuel poverty gap. By examining the average fuel poverty gap for different groups of households, the severity of the problem can be compared by examining the average fuel poverty gap for different groups of households.

Figure 11: Worked example: fuel poverty gap calculation
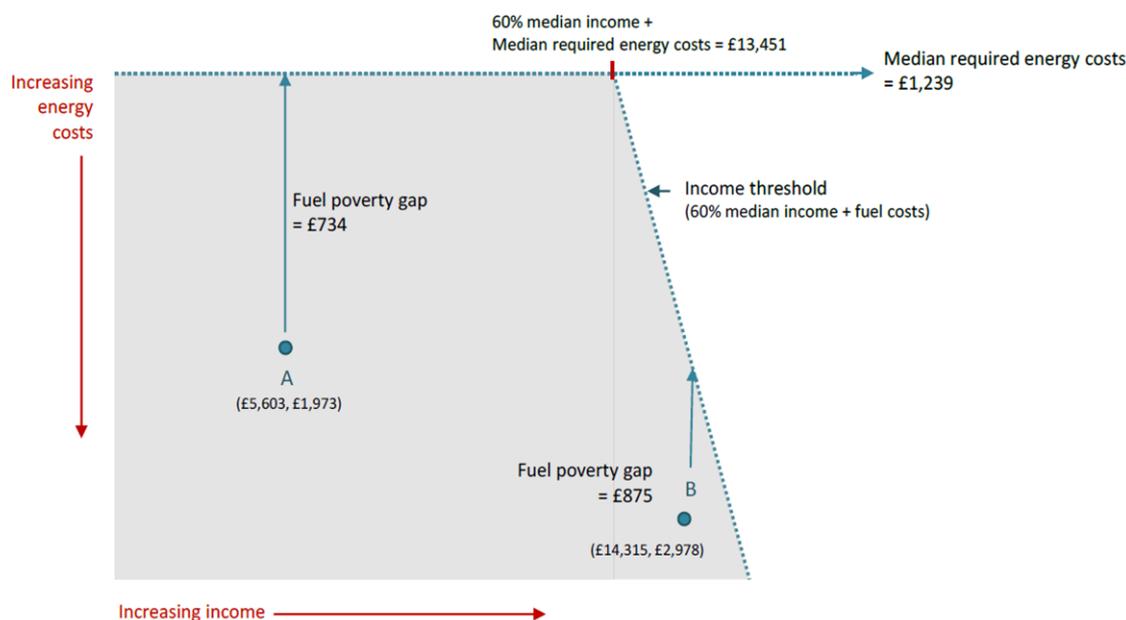
6.3 Calculation of the FPEER

The Fuel Poverty Energy Efficiency Rating (FPEER) is calculated as laid out in the Fuel Poverty Energy Efficiency Rating methodology documentation available at:

https://www.gov.uk/government/publications/fuel-poverty-england-regulations-2014-and-methodology

The FPEER is a measure of the energy efficiency of a property based on the Standard Assessment Procedure (SAP), and accounting for polices that directly affect the cost of energy, such as the Warm Homes Discount, that is applied to selected households (see Section 4.5). It is produced based on SAP 2012 costs, and generates a rating of energy

efficiency between 1 (low) and 100 (high), which is also translated into an energy efficiency, from G (lowest) to A (highest).

7. Projections methodology

7.1 Introduction

The fuel poverty projections methodology is split into five sections, with one section for each area that is projected: household energy efficiency, household income and fuel prices. The calculation of the projected fuel poverty figures is then detailed in the fourth section with the final section covering projections against the Government's fuel poverty energy efficiency rating (FPEER) targets.

This year we have decided not to publish projections for 2020 due to the unprecedented nature of the ongoing coronavirus (COVID-19) pandemic. We do not yet have enough information to develop assumptions for what is likely to happen to incomes, energy efficiency installations and energy prices between April 2020 and March 2021. Therefore, in this chapter the focus is the projection of fuel poverty forward to 2019, from a base year of 2018.

This year, the fuel poverty model has been re-developed by refining a number of the assumptions and improving the process of estimating fuel poverty in future years, although broadly the principles remain the same as in previous years.

As discussed in Section 2.1 the EHS data for the 2018 year is made up of two single year datasets collected April 2017 to March 2018 (17-18 single year dataset) and April 2018 to March 2019 (18-19 single year dataset). This is called the combined year dataset for 2018. Previously, to project to 2019 we would apply assumptions to and model the whole combined year dataset for 2018. This year we have improved the structure of our projections model. We have carried out our projections on the 17-18 single year dataset and kept the 18-19 dataset the same. This improvement means that the projections modelling is more comparable to the method used to produce the 2018 dataset.

Figure 12: Improved projections process
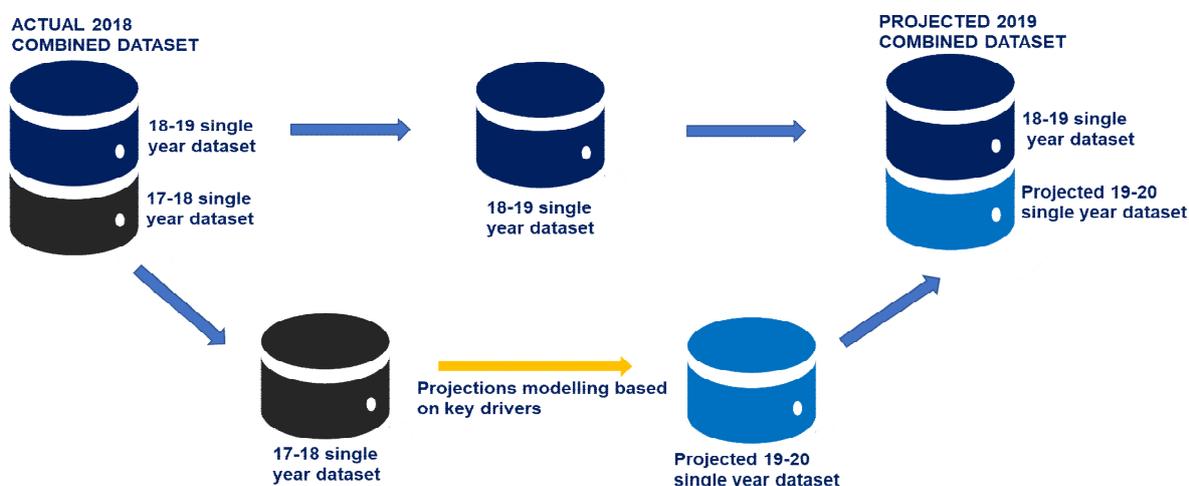
7.2 Projecting energy efficiency

One of the key drivers of fuel poverty is how energy efficient a dwelling is, and therefore, what the energy requirements are to maintain an adequate standard of warmth. For example, if a dwelling is poorly insulated, its energy requirements are likely to be high, which is one of the main criteria of fuel poverty. To establish if the levels of fuel poverty are likely to increase or decrease, the number and type of improvements to the housing stock needs to be modelled.

The number of measures to allocate

There are several different types of measures that can be installed to improve the energy efficiency of a dwelling. For this model, the key measures that have been used are:

- Cavity wall insulation
- Solid wall insulation
- Loft insulation
- Solar photovoltaic panels
- Condensing boilers
- Central heating
- Heating controls
- Double Glazing
- Draught Proofing

The first step is to establish how many of each of these measures have been installed in the time period that is being projected. Additionally, these measures can be installed under different policies. The number of measures installed under each policy for the year being

projected is required, so that measures can be allocated to appropriate properties to model the change in energy requirements over time.

Changes to ECO (Energy Company Obligation) eligibility criteria introduced as part of ECO 3[63]. From October 2018, the ECO scheme was wholly targeted to low income vulnerable households. In previous phases of the ECO scheme, any household was entitled to subsidies towards energy efficiency improvements, regardless of their income.

From 1st April 2019, the Private Rented Sector Minimum Energy Efficiency Standards[64] regulations for the domestic private rented sector required private landlords to improve their properties to an efficiency of at least an E, to meet the minimum standards. This is captured in the 2019 projections.

BEIS publish national statistics on the number of installations by policy area and these are available for 2019.

Another area that is important to consider is improvements to the energy efficiency made by householders or property owners not under a Government policy, a key example is boiler improvements. According to the English Housing Survey (EHS), the proportion of households with condensing boilers is increasing each year. In order to estimate how much this will increase for the projected years, the change between 2017 and 2018 in the EHS is used as a proxy. The number of boilers installed under ECO is then deducted from this figure.

Furthermore, the projections model continues to account for the incremental improvements in the housing stock that occurs as newer, more energy efficient, properties are built, and older buildings are demolished. These changes are captured in the projections model by altering the household weights of the original EHS sample. Household weights of newer A/B/C and D properties are increased in line with ONS and MHCLG statistics on population figures and the number of households in 2019[65],[66].

Allocating installations

For the first time this year, we have been able match households that have received a measure under ECO in 2019 with the EHS data (this match has been undertaken only for households that have consented for their data to be matched). This has improved the accuracy of allocations within the model.

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[63] For more detail on ECO3 eligibility, please refer to Ofgem's website: https://www.ofgem.gov.uk/publications-and-updates/energy-company-obligation-2018-22-eco3-guidance-delivery

[64] http://www.legislation.gov.uk/ukdsi/2018/9780111175217/contents

[65] ONS population figures available here: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/regionsinenglandtable1

[66] MHCLG households figures available here: https://www.gov.uk/government/statistical-data-sets/live-tables-on-household-projections

Measures under the PRS policy are then randomly allocated to households that meet the criteria. These are then combined to make up the total number of allocations within the half year sample.

Different types of installations are only available to certain types of households. For example, to receive cavity wall insulation, the house must have uninsulated cavity walls. Eligibility criteria for each household are then matched from the energy performance dataset. An SQL model then allocates measures based on meeting relevant criteria.

The random allocation of measures is repeated in turn for each of the individual measure (e.g. insulation) and policy (e.g. ECO) combinations. If a household is eligible for more than one type of measure, they can receive multiple measures, for example loft insulation and cavity wall insulation.

Energy Requirements Calculation

Once individual energy efficiency measures have been allocated, they are combined to create an overall allocation per household, this could be one measure, multiple measures, or none. The next step is to model the impacts of these measures on a household's energy requirements, and ultimately, fuel costs.

Savings factors for every possible combination have been created to indicate the level of savings for different dwelling types for every possible combination of measures. The relevant savings factor for the measures allocated is then applied to a household's energy requirement. This is done for each fuel type (e.g. gas) and each type of use (e.g. space heating). This provides an estimate of the reduction in energy requirements that each given combination of measures allocated would have on that household. The total energy use by fuel type is then used to calculate the total new fuel cost per household using the prices (see Section 7.4 below). This whole process is completed for each half year of the projections, as a different number of measures are allocated for each half year, along with different fuel prices.

SAP Costs calculation

The standard assessment procedure (SAP)[67] is a measure of energy efficiency. The SAP costs are part of the SAP calculation, which is used to create the fuel poverty energy efficiency rating (FPEER). FPEER is based on the SAP methodology, however, it additionally considers any energy rebates given to the household. In a similar way to the recalculation of the energy requirements, savings factors are applied to the original SAP costs, based on the combination of measures allocated to the household.

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[67] SAP manual: https://www.bre.co.uk/filelibrary/SAP/2012/SAP-2012_9-92.pdf

7.3 Income

Within the fuel poverty dataset, sources of household income are recorded. This is categorised into income from: earnings, savings, benefits and 'other'. Council tax is then deducted from the full income. Income is uprated dependent on its source, for the subsequent two years. Figures from the Economic and Fiscal Outlook[68] which is produced by the Office for Budget Responsibility (OBR) are used to uprate incomes from: earnings, savings, benefits and 'other' income sources.

Earnings

We continue to capture the differential rate in the increase in earnings between different deciles. This is based on data from ONS' Average Weekly Earnings data[69] and is validated against OBR fiscal outlook figures on the annual change in average earnings.

Savings

Any income from savings is uprated by Gross Domestic Product (GDP).

Other

Any income from sources categorised as 'other' is uprated by GDP.

Benefits

Benefits are a broad term for any type of financial support, of which the amount received increases or decreases at different rates, dependent on the type of benefit received. However, for simplicity, they are treated as one type of benefit and are simply inflated by the Retail Price Index (RPI) figures, sourced from OBR fiscal outlook tables.

Council Tax

Average changes to council tax are applied for each year. These are based on figures published by MHCLG on council tax levels in England in 2018-19 [70].

7.4 Prices

The main fuel prices considered in projections are the price of gas and electricity. The changes to average prices are known for 2019 and have been published as part of BEIS' Quarterly Energy Prices publication[71]. This shows the average unit and fixed costs for gas and electricity. Average costs split by region, payment type and tariff type (for electricity) are applied to the individual households in the EHS sample.

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[68] https://obr.uk/efo/economic-and-fiscal-outlook-march-2020/
[69]https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/bulletins/averagew eeklyearningsingreatbritain/latest
[70] Council tax changes:
Table 3 : https://www.gov.uk/government/statistics/council-tax-levels-set-by-local-authorities-in-england-2020-to-2021
[71] https://www.gov.uk/government/statistical-data-sets/annual-domestic-energy-price-statistics

The new methodology uplifts the fuel prices of those household that have not received a measure based on the payment type and fuel type while it re-calculates the fuel prices for those households that have received a measure based on the new calculated consumption.

Prices are calculated in two ways this year.

1. For those households that *have not* received a measure and
2. For those households that *have* received a measure.

For point one, the standing charge for 2017 is deducted from the total fuel costs depending on the main fuel type and if applicable. The difference is then uplifted (by multiplying it with a calculated factor derived from QEP) and the total fuel cost is achieved by adding the standing charge for 2019 to this new calculated figure.

For point two, the unit costs of each of these fuel types are then multiplied by the new number of units of energy required. This is done at a household level and is done separately for the half sample. Any standing charges associated with each fuel type are added to give a total fuel cost per fuel. The total fuel costs by fuel are added together to give a total fuel cost per household per year.

For heating oil, coal, and smokeless fuel, prices are known because they are used in the calculation of the CPI for 2018 and are used in the 2019 projection.

7.5 Projecting fuel poverty

To calculate the proportion of households projected to be in fuel poverty, and their average fuel poverty gap, projected national level fuel costs and incomes for each year are used to calculate new fuel poverty thresholds.

For each projected year, the relative position of households to the new thresholds, and ultimately their fuel poverty status, is recalculated along with their associated fuel poverty gap, following the methodology defined in Chapter 6.

7.6 Projecting against the target

New SAP costs are calculated based on the projected allocation of energy efficiency measures (considering savings factors) and are then used to calculate FPEER following the standard methodology[72.] The FPEER methodology includes the Warm Home Discount (WHD). Allocation of WHD, for the first time this year has been kept as original data i.e.

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[72] FPEER methodology:https://www.gov.uk/government/publications/fuel-poverty-england-regulations-2014-and-methodology

households that have received this discount in the original dataset (2018) continues to receive the discount within the projections model.

Following the FPEER methodology, new FPEER bands for all households are created. Using the projected fuel poverty status of the households, the projected progress against the target (see Chapter 2 of the main fuel poverty publication) can then be calculated. These targets require the projection of the proportion of fuel poor households that have an energy efficiency rating of Band E or above, Band D or above and Band C or above.

8. What fuel poverty statistics are available to users?

8.1 Fuel poverty data

BEIS publish a large set of detailed tables, which accompany the main report, showing fuel poverty by income decile, tenure, dwelling type, household composition and many other factors concerning both the householders and the dwelling itself (e.g. insulation measures). BEIS also publish an Excel workbook looking at trends in fuel poverty since 2003 for a range of sub-groups. To allow comparison, these tables show the results, under the LIHC definition and under the consistent (BREDEM 2012 v1.1) time series.

Both of these can be found on the BEIS website at:

https://www.gov.uk/government/collections/fuel-poverty-statistics

The detailed 2018 fuel poverty dataset, along with datasets from previous years, will be available via the UK Data Service later in 2020. These datasets contain the underlying data used to calculate fuel poverty and the corresponding crosstab variables used within the fuel poverty report and are intended for advanced users of fuel poverty data. Documentation covering variable names and descriptions are also provided alongside the datasets.

Anonymisation techniques are applied to the End User Licence and Special Licence fuel poverty datasets deposited on the UK Data Service to maintain the confidentiality of respondents. Prior to releasing the data on the UK Data Service, and in-line with EHS disclosure control, all disclosive variables are removed to maintain the confidentiality of respondents. Some response categories are also condensed, several variables are top coded, and, in a few rare situations, data swapping between cases takes place for disclosure control reasons.

Most fuel poverty variables are included in the dataset deposited at the UK Data Service under the standard End User Licence. To comply with the data disclosure control guidance issued by the Government Statistical Service, supplementary fuel poverty variables are released under the more restricted Special Licence on the UK Data Service.

In addition to this, BEIS also publish fuel poverty data at a sub-regional level. Data for Local Authorities, Counties, Parliamentary Constituencies and Lower Super Output Areas (LSOAs) can be found on the BEIS website at:

https://www.gov.uk/government/collections/fuel-poverty-sub-regional-statistics

8.2 Fuel poverty publications

The 2020 Annual Report on Fuel Poverty Statistics reports the headline fuel poverty statistics for 2018. The report provides an explanation of these figures, and the reasons for change from previous years, by looking at household income, household energy efficiency and energy prices. In addition, the report explores the trends in fuel poverty since 2003 amongst various subgroups. This publication is available, alongside the reports from previous years, on the BEIS website:

https://www.gov.uk/government/collections/fuel-poverty-statistics

8.3 Methodology information

Although this document supersedes all previous methodology documents, the methodology documents from previous years are also available from the archive section of the BEIS website. Up to and including 2014 fuel poverty statistics, a technical annex with addition details on the fuel cost modelling was published alongside the main methodology handbook. The technical annex is now incorporated within this document, to provide a single methodology document for the fuel poverty statistics.

8.4 Consultation

Through the Energy Act 2013, the Government implemented a new legal framework to monitor fuel poverty in England using the Low Income High Costs Indicator (LIHC). This indicator of fuel poverty was first proposed in Professor Hills' review of Fuel Poverty[73] and following consultation, the Government confirmed its intention to adopt the indicator in July 2013[74]. In the accompanying strategic framework document, 'Fuel Poverty: a framework for future action'[75], the Government set out how the new indicator will inform the strategic approach to tackling fuel poverty, including setting a new fuel poverty target which will be underpinned by a new fuel poverty strategy.

A draft strategy and consultation document, 'Cutting the cost of keeping warm' was then published in July 2014. This proposed the creation of an additional indicator known as the Fuel Poverty Energy Efficiency Rating (FPEER) for use in targeting, and a number of targets tied to specific dates. Secondary legislation was put forward in December 2014 for this rating, alongside the LIHC fuel poverty definition, to form the basis of the statutory target for fuel poverty. This requires, as far as reasonably practicable, for all persons living in fuel poverty to have an FPEER of Band C or above by 31st December 2030.

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[73] See https://www.gov.uk/government/publications/final-report-of-the-fuel-poverty-review
[74] See https://www.gov.uk/government/consultations/fuel-poverty-changing-the-framework-for-measurement
[75] See https://www.gov.uk/government/publications/fuel-poverty-a-framework-for-future-action

In March 2015 the final Fuel Poverty Strategy was published, confirming the main and interim targets, alongside the responses to the July 2014 consultation.

In July 2019 the Government published the 'Fuel Poverty Strategy for England: Consultation' document[76], in order to assess the implementation of the 2015 fuel poverty strategy[77] so far and to seek views on proposals to update the fuel poverty strategy. In light of the ongoing COVID-19 response, Government has taken the decision to temporarily delay publication of the response to this consultation. The Government plan to publish the response to consultation, the updated Fuel Poverty Strategy for England and related documents later this year.

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[76] https://www.gov.uk/government/consultations/fuel-poverty-strategy-for-england
[77] https://www.gov.uk/government/publications/cutting-the-cost-of-keeping-warm

9. How accurate are the fuel poverty statistics?

Fuel poverty in England is published as a point estimate of the number of households affected. A series of models are used to calculate the figure using inputs from a variety of sources, many of which are approximations. Therefore, the modelling process requires numerous assumptions. For example, there is no information on the energy supplier and the tariff that a household uses. Instead, households are assigned an average price depending on the region that they live in and the way in which they pay for their energy (e.g. standard credit, direct debit, etc.).

In 2014, DECC (now BEIS) published analysis that estimated the uncertainty around the point estimates of fuel poverty for 2012. This analysis looked specifically at the uncertainty around household incomes, fuel prices and energy requirements, using these to then estimate the levels of uncertainty around the overall national estimates of fuel poverty. This analysis suggests that the addition of uncertainty is likely to increase the levels of fuel poverty observed.

We can interpret this in the context of the distribution of households across the LIHC metric – particularly in terms of how many households can be placed into the LIHC quadrant by the addition of uncertainty, compared to how many can be removed from this quadrant. Since on average, just over 10% of households are in fuel poverty, there are more households outside the LIHC quadrant than inside and in particular more households outside the LIHC quadrant close to the income and fuel costs thresholds (in the HIHC and LILC quadrants).Therefore the application of uncertainty is able to move more households into fuel poverty than out of it (i.e. of 10 households, one would be in fuel poverty and nine not fuel poor – so it is more likely to place a number of the nine households into fuel poverty than remove the one household out of fuel poverty). This has the net effect of increasing the average number of fuel poor households, resulting in a slightly higher distribution of possible values for the number that are fuel poor, and so consequently the aggregate gap, after the addition of uncertainty.

These results need to be interpreted with caution. Any analysis of this kind is ultimately dependent on the input distributions used within the modelling, and the majority of the input distributions used are in themselves best estimates of uncertainty in each factor. Further to this, the analysis has been designed with a cautious approach, with conservative assumptions made throughout. As a result, these figures should be treated as indicative of the effect of uncertainty upon the national estimates of fuel poverty, rather than strictly quantitative.

10. Statistical Assessment

The UK Statistics Authority (UKSA) is an independent body operating at arms-length from the Government as a non-ministerial department, directly accountable to parliament. The UKSA's objective is to promote and safeguard the quality and comprehensiveness of official statistics and to ensure good practice in relation to official statistics.

Between February and July 2010, the UKSA carried out an assessment of BEIS's (then DECC) fuel poverty statistics against the Code of Practice for Official Statistics. The Code is structured in terms of 8 principles and 3 protocols, which encompass meeting user needs, impartiality and objectivity, and sound methods, amongst others. If, after an assessment by the UKSA, official statistics are found to comply with the Code, they are designated as National Statistics. This indicates to users that the statistics have been produced in line with the Code. More details of the Code can be found on the UKSA website at:

https://www.statisticsauthority.gov.uk/code-of-practice/the-code/

In this assessment, the UKSA judged that the fuel poverty statistics are readily accessible, produced according to sound methods and are managed impartially and objectively in the public interest. As a result, the UKSA confirmed that the statistics published in the Annual Report on Fuel Poverty Statistics can be designated as National Statistics.

The continued designation of these statistics as National Statistics was confirmed in August 2017 following a compliance check by the Office for Statistics. The statistics last underwent a full assessment against the Code of Practice for Statistics in 2014.

11. Acronyms

Acronym	Definition
ASHE	Annual Survey of Hours and Earnings
AHC	After Housing Cost
BEIS	Department for Business, Energy and Industrial Strategy
BRE	Building Research Establishment
BREDEM	BRE Domestic Energy Model
CAPI	Computer Assisted Personal Interviewing
CHAID	Chi-squared Automatic Interaction Detector
CHP	Combined Heat and Power
CPI	Consumer Price Index
CTB/CTS	Council Tax Benefit/Support
DLA	Disability Living Allowance
DUKES	Digest of UK Energy Statistics
DWP	Department of Work and Pensions
EHCS	English House Condition Survey
EHS	English Housing Survey
FPEER	Fuel Poverty Energy Efficiency Rating
FPMG	Fuel Poverty Methodology Group
FRS	Family Resources Survey
HB	Housing Benefit
HBAI	Households Below Average Income
HRP	Household Reference Person
LA	Local Authority
LCFS	Living Cost and Food Survey
LHA	Local Housing Allowance
LIHC	Low Income High Cost
LPG	Liquefied Petroleum Gas
MHCLG	Ministry of Housing, Communities and Local Government
MPPI	Mortgage Payment Protection Insurance
OBU	Other Benefit Unit
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
PBU	Primary Benefit Unit
PIP	Personal Independence Payment
PPM	Prepayment Meter
RdSAP	Reduced Data Standard Assessment Procedure
RSL	Registered Social Landlord
SAP	Standard Assessment Procedure
SMI	Support for Mortgage Interest
UKSA	UK Statistics Authority
WFP	Winter Fuel Payment
WHD	Warm Homes Discount

OGL

This publication is available from: https://www.gov.uk/government/collections/fuel-poverty-sub-regional-statistics

If you need a version of this document in a more accessible format, please email fuel.poverty@beis.gov.uk. Please tell us what format you need. It will help us if you say what assistive technology you use.