Welsh Housing Conditions Survey (WHCS) 2017-18
Fuel Poverty Estimates for Wales 2018: Methodology Report

Contents

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1. Introduction

This methodology report is a guide for all users of the WHCS 2018 fuel poverty statistics. Users will find detailed descriptions of the methods used to calculate the 2018 fuel poverty figures for Wales.

1.1 What is fuel poverty?

A household is classified as being fuel poor if they are unable to afford to keep their home adequately heated. Different definitions of what constitutes Fuel Poverty are used across the UK. The Welsh Government use the 10% and 20% definitions (see below).

1.1.1 10% definition

A household is defined as being fuel poor if they would need to spend more than 10% of their income on the fuel needed to heat their home to 'reasonable' level. This income in this definition uses the **full** household income for the final fuel poverty calculation (see section 3.5). This is calculated using the equation below:

$$Fuel\ Poverty\ Ratio = \frac{Fuel\ Costs}{Income}$$

If the ratio from the above equation is greater than 0.1, the household is defined as fuel poor. The value for total fuel costs for a household is modelled using standard heating regimes that consider how much money each household would need to spend on fuel in order to reach these established standards for comfort.

1.1.2 20% definition / severe fuel poverty

If the ratio to the above equation is greater than 0.2 the household is defined as being severely fuel poor.

1.1.3 Other definitions

There are other definitions that are also included in the analysis of the 2018 stats for comparison. These include the 10% and 20% fuel poverty definition using the **basic** household income (see section 3.4), in place of the full income used above. Another fuel poverty definition that is discussed in the 2018 stats for comparison is the Low Income High Costs (LIHC), which is the fuel poverty definition used in England. A household is considered fuel poor under the LIHC definition if they have required fuel costs that are above average and were they to spend that amount, they would be left with a residual income below the official poverty line (see section 6.2).

1.2 How is it calculated?

To calculate fuel poverty it is necessary to understand the characteristics of both the household and the dwelling in which they reside. The data used to model the 2018 fuel poverty figures for Wales came from two main sources; The National Survey for Wales and the Welsh Housing Conditions Survey. This is discussed further in the following sections.

2. Data sources

2.1 National Survey for Wales 2017-18

The National Survey for Wales (NS) is an interview survey that runs continuously across the whole of Wales. It collects information on a variety of subjects. Between July 2017 and March 2018 it collected specific information required for the calculation of fuel poverty. The NS interviews around 12,000 respondents each year. In 2017-18, the fuel poverty interview related data were collected for 7,777 cases (income, housing costs, energy payment method etc.). Detailed household composition and demographic information was collected from all respondents, as is usual. Further details on the National Survey can be found on the Survey webpages.

Being an interview survey, the NS does not collect detailed information about the dwellings in which the responding households reside.

2.2 Welsh Housing Conditions Survey 2017-18

Accurate and detailed information about the dwelling is crucial for the calculation of fuel poverty and therefore the Welsh Government commissioned the Welsh Housing Conditions Survey (WHCS) 2017-18. This involved a physical inspection of the dwelling by a trained surveyor. The WHCS 2017-18 survey ran from August 2017 until the end of April 2018. Surveys were conducted roughly one month after the initial interview was conducted. The data collected from WHCS provide information to create an accurate representation of the housing stock Wales.

Eligibility for the WHCS was established at the NS interview stage and permission was sought by the interviewer. This resulted in 2,549 full physical surveys. Only cases that had both an interview and a physical inspection were used to produce the final fuel poverty indicators.

Further details on the Welsh Housing Conditions Survey 2017-18 can be found on the Survey webpages.

2.3 Energy price information

Fuel prices used in the modelling of the 2018 fuel poverty figures were produced using information extracted from a variety of external sources. Details of these sources are given below:

- The Quarterly Energy Prices publication 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 Consumer Price Index (CPI), 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 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.

- SAP 2012 fuel prices (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 and 24 electricity tariffs.

These prices are then inflated to the survey year using the CPI.

2.4 Calculating the main components of fuel poverty

The majority of the information used to calculate the main components of fuel poverty (income, energy prices and energy requirements) was obtained from the NS interview and WHCS physical surveys:

- Income
  - The NS interview collected detailed information about the income of the Household Reference Person[2] (HRP) and any partner from different sources (earned income, savings, benefits and other sources e.g. pension, investments, rent from property etc.)
  - Income information for other household members aged 16 and over (who are not the HRP or partner) was also collected, but in less detail.
  - The NS also collected information on the households' housing costs and income e.g. rent payments, mortgage details and payments and housing benefit.
- Energy Prices
  - The NS interview collected information on the method of payment for gas and electricity, and the household's location in the country, which alongside a variety of external sources is used to calculate average regional fuel prices (See section 2.3).
- Energy requirements
  - Data on the occupancy characteristics, and region, is provided by the NS interview. The WHCS 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; and
    - Energy efficiency measures.

2.5 Strengths and limitations of the data used

Detailed information on the strengths and limitations of the WHCS is provided in Section 3.1 (Relevance) of the Quality Report available on the Survey website.

Specific strengths of the fuel poverty analysis which we have identified are:

[2] 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 and tenants, the person with the highest income is taken as the HRP. Where incomes are equal, the older is taken as the HRP.

1) Established processes and procedures, which have been used for multiple years and across multiple datasets both in Wales and across other nations of the UK
2) Use of high quality input data, primarily of National Statistics quality for interview, physical and fuel prices.

Limitations which we have identified are:

1) Data is from a sample survey so subject to sampling errors
2) Detail collected by both physical and interview surveys is limited by time available and access to elements of the property (physical survey is non-intrusive). No documentary evidence for income sources is required.

3. Income model

This chapter contains a detailed description of the income methodology, the process for calculating the final fuel poverty income variables and validation of them.

3.1 Overview

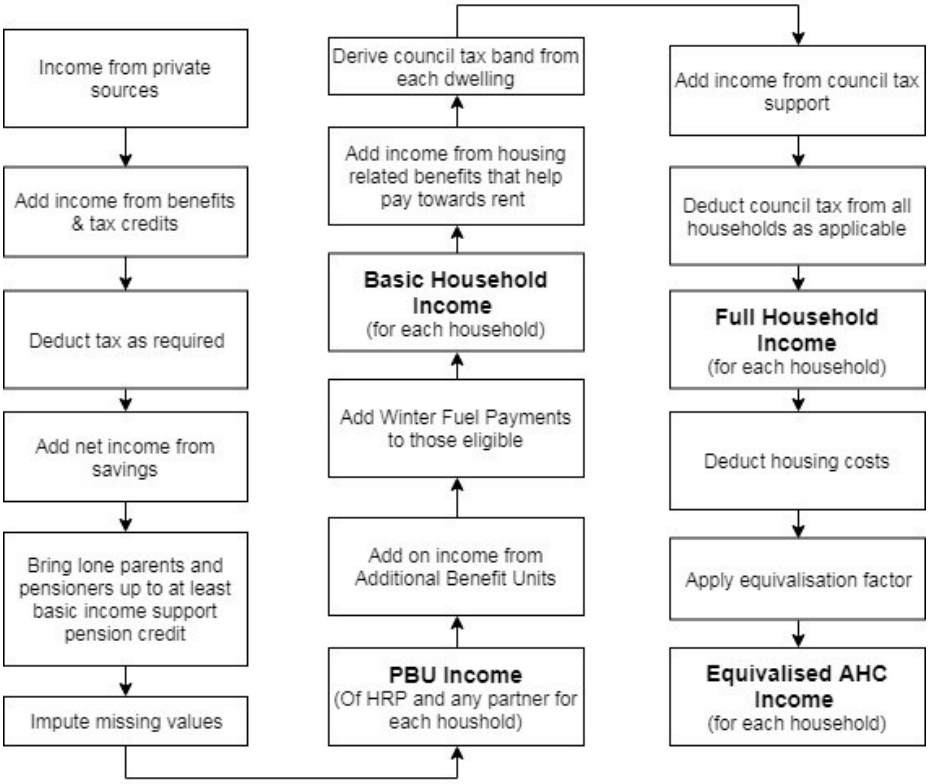
The two fuel poverty indicators (10% and LIHC) use different measures of income in their calculation. The main 10% definition uses an unequivalised, before housing costs income measure known as 'full household income'. The LIHC definition uses an income measure known as 'equivalised After Housing Costs (AHC) income'. The main derived income variables are produced by:

- Totalling the personal incomes of the Household Reference Person (HRP) and any partner, including any 'income' related benefits and other income source payments (from earned income, state benefits, savings etc.) to provide the **Primary Benefit Unit (PBU) income**[3]. Income from Additional benefit Units (ABU) and the Winter Fuel Payment (WFP), if applicable, is then added to give the '**basic household income**' which is calculated net of tax and National Insurance.
- Adding housing related income, including housing related benefits (HB), Council Tax Support (CTS), and the deduction of council tax payable, this then becomes '**full household income**'.
- Deduction of housing costs (net rent and mortgage interest payments), from full household income, gives an '**AHC income**' measure.
- Applying the relevant equivalisation factor (see section 6.2.2) to reflect the fact that different households have different spending requirements, the AHC income, creates the final '**equivalised AHC income**'.

Each of these derived variables is discussed in detail in the following sections. Figure 1 outlines the main steps in the income modelling process in calculating the full household income and the equivalised AHC income.

[3] The Primary Benefit Unit (PBU) refers to the HRP, partner of the HRP (if applicable) and any dependents of the HRP and partner of the HRP in the household i.e. a child under 16 years old or child 16-18 years old in full-time education. The income of any dependents is excluded from fuel poverty income calculations.

Figure 1. Wales income model



3.2 Missing data

The income calculation method assumes that the details given by the respondent are correct unless there is a strong reason to suggest otherwise (this is investigated on a case by case basis, looking at extreme values in the income distributions and deciding whether the data looked plausible based upon a range of personal characteristics). For cases that have been identified as providing incorrect, unreasonable information or more commonly have either refused or responded with unknown, a method of imputation is required. Within the final fuel poverty dataset a third (34%) of cases required imputations for the Primary Benefit Unit (PBU) income data. Of these cases: 14% had their private income sources only imputed; 7% had their benefits income sources only imputed or changed; 5% had some private and benefit incomes imputed; 3% had their PBU total imputed using the group median (due to missing/refused data); 3% had their PBU income uplifted to basic state pension; 2% had their PBU income uplifted using the group median; and 1% had their PBU income uplifted to their theoretical basic income support entitlement, this is similar portion of data that was imputed in 2008 Wales fuel poverty.

Table 1 below summarises the type and method of income imputations carried out:

Table 1 Summary of imputation methods for missing income data

Type of income	Type of missing data	Method of imputation
Private incomes		
Self-employed	Amounts missing	Uses a hot-decking imputation method for the respondent which uses the following input variables: tenure, age band, gender, full/part-time, whether the respondent was the HRP and receipt of means tested benefits. These cases were then matched with other cases (without missing data) that correspond to matching input variables. For the few cases that could not be matched these cases were then imputed using sample median based on banded age and whether the respondent was the HRP. The same was done for the partner of the respondent, however not including the full/part-time input variable as this was not asked of the partner of the respondent and replaced instead by household type.
Regular employment	Amounts missing	
Other employment	Amounts missing	Sample median based on gender and age band
Occupational/employer pension	Amounts missing	Sample median based on tenure and (for respondents only) gender
Private benefits from accident or sickness	Amounts missing	Theoretical amount of DLA (mobility) modelled
'Other' private income sources: - Occupational pension - Income from annuity, trust or covenant - Maintenance payments - Rent from property or subletting, including boarders - Benefit from accident/ sickness scheme etc. - Investment income - Student loan - Grant	Amounts missing	Individual assignment of missing amounts based on finding matching cases with similar situations
All other specified private income sources e.g. income from rent, student loans etc.	Amounts missing	Sample based on group median* for each other income source

State benefits		
- 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 - Bereavement allowance - Widowed parent's allowance - 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 - Statutory maternity/paternity/adoption pay - Guardian's Allowance - Grant from the Social Fund for funeral expenses - Grant from the Social Fund for maternity expenses - Sure Start Maternity Grant - Budgeting Loan from the Social Fund/ Budgeting - Social Fund loans - Welsh Government Discretionary Assistance Fund – Emergency Assistance Payment - Welsh Government Discretionary Assistance Fund – Individual Assistance Payments - Child Maintenance Bonus - Lone Parent's Benefit Run-on	Benefit amount is refused or unknown	Where the rates vary greatly depending on the situation of the respondent 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' benefit	Benefit amount is refused or unknown	An individual assessment was made for each case based upon the 'other' details specified in the interview survey
Savings	Amount of savings refused or unknown	Imputed using CHAID analysis using various household and dwelling characteristics

Primary Benefit Unit (PBU) income	Overall net PBU household income missing	Median sample income imputed based on the following: Respondent only (no partner) - employment status, gender and tenure Couple (respondent and partner) - combined working status and tenure

Additional Benefit Units (ABU)	Income amount missing for additional adults (on an individual basis)	Median sample income imputed using working status and, for the working/non-working group, banded age (the retired and long-term sick group used working status only)
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	An individual housing benefit assessment is carried out for each case based upon their net rent and theoretical entitlement to housing benefit
Council tax band	Value missing	The council tax band for each dwelling has been imputed using a method based on Chi Squared Automatic Interaction Detection (CHAID) analysis and the 2008 Living in Wales dataset
Council Tax Support (CTS)	No information given as to the actual amount received (applies to all CTS cases)	Full CTS – set as the council tax due Partial CTS/don't know if full or partial – individual CTB assessment carried out

*The group median is taking the average income value lying at the midpoint of the income distribution.

3.3 Primary Benefit Unit (PBU) income

The income of the PBU comprises of the personal income of the HRP and any partner of the HRP. The NS interview collected detailed income information on the respondent and the respondents' partner. Except for twelve cases, the sub-sample of the NS cases that collected the information required for fuel poverty calculations were based on cases where the respondent was either the Household Reference Person (HRP) or partner of the HRP.

Individual income components with the NS interview data (notably the HRP and partner of the HRPs private and benefit income), were modelled as income of the respondent and income of the partner of the respondent. Ultimately, when added together, this equates to the PBU income, as either the respondent, or the partner of the respondent was the HRP for the fuel poverty sub-sample cases. The modelling was carried out like this for two reasons. Firstly, due to ease with modelling as the income-based variables in the NS interview dataset are set up as respondent variables and partner of respondent variables. Secondly, more detailed information is available for the respondent in the NS interview data on the number of hours worked in their main job than for the partner of the respondent.

Modelling the individual employment/self-employment incomes based upon the respondent and the partner of the respondent allowed for more enhanced imputation routines of missing respondent employment/self-employment amounts due the additional information available on the number of hours worked.

Key indicators about the household are created from NS data. These are at the person and household level (for example, age/gender of the HRP/respondent and any partner, working status of HRP/respondent and any partner and the presence and number of dependent children etc.), which are subsequently checked for completeness and plausibility prior to modelling. These indicators are used to compute theoretical entitlement to benefits and are used in the process of imputing missing values and validation.

3.3.1 Income from private sources

Separate calculations are made for the annual private income of the respondent and the partner of the respondent (as explained above), this included: regular employment, self-employment, other jobs, and a suite of other private sources as indicated in Table 1 e.g. income from rent, occupational/employer pensions etc.

For each private income source selected, the respondent was asked to provide an income amount. If provided, the individual income amount was recorded. Where respondents stated receipt of private income sources (e.g. employment, self-employment income), but were unable/refused to specify an amount; then an estimated amount was assigned according to the methods outlined in Table 1.

Imputation of regular employment and self-employment are assigned using a hot-decking approach. The use of hot-decking methods accounts for any variability found in actual income data, which is less likely to distort the original distribution. 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 case with the missing value. For imputing missing income values, a specification to find similar cases was created for each case based on various household characteristics (as detailed in Table 1). For cases where there were no matches during the hot-decking, these were then imputed using median values based on banded age and whether the respondent was the HRP or partner of the HRP.

Where imputation of an income amount took place, it was recorded against the data. On-going validation of the amounts of income from private sources was carried out throughout the calculation and checks were included in the coding to ensure that all cases that selected an income source had a corresponding income value.

Respondents predominantly provided net income amounts for all the employment/self-employment/other job income values and where gross amounts were given (very few cases), the net income amount for that source was approximated. For all other private incomes, the NS did not specify whether these incomes were provided as net or gross. However, whilst net or gross income values are acceptable, the interview survey questionnaire probes for gross income. Therefore, the modelling assumes all other private incomes are provided as gross income. For detail on how these values were converted to net, refer to the 'Income deductions' section 3.3.3 below.

3.3.2 Income from state benefits

The NS interview asked about benefits received by the respondent and any partner and the amounts and time periods of the payments. Using this information, individual benefit amounts for the respondent and any partner were calculated.

Missing benefit amounts were imputed for cases where the respondent had 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 respondent and any partner and for these benefits, individual benefit assessments were carried out in the modelling process using the applicable NS interview data. For other benefits based on rates such as Disability Living Allowance, the prescribed rates were imputed.

Total benefit income was derived for the respondent and any partner separately, split between taxable and non-taxable benefit income.

3.3.3 Income deductions

The final fuel poverty income variables are described in terms of net income, which is the income net of tax and National Insurance.

National Insurance contributions are paid if an individual is aged between 16 and pension age is an employee or self-employed, with earnings above a threshold level. However, for the Welsh income modelling, respondent and partner earnings were reported in terms of 'take-home' pay, i.e. their income after deductions for tax and National Insurance. Therefore, there was no requirement to model the deduction of National Insurance.

Although earnings were reported in terms of net income, all other non-earnings private income sources and some benefit amounts (depending on the selected benefit receipt) were reported as gross income i.e. before the deduction of tax.

To calculate the applicable amount of tax from the reported gross income components only, the total taxable income from all sources was estimated for the respondent and partner to derive the applicable tax band for each individual. Using the tax band, combined with the associated income tax rates/thresholds and information on any remaining tax allowance after paid work had been accounted for, it was possible to derive the respondent/partner income tax payable on the reported gross income components.

The total net income for the respondent and partner were computed separately by adding together all gross and net income sources and subtracting the computed income tax payable.

3.3.4 Income from savings

The combined total amount of savings of the HRP and partner was provided as banded amounts. The mid-point of the reported band was taken as their savings amount.

Where the amount of savings was not provided, a method based on Chi Squared Automatic Interaction Detection (CHAID) was used to estimate the combined savings/investments of the HRP and any partner. The banded savings question from the interview survey was used as the dependent variable and a variety of household and dwelling characteristics such as tenure and age and gender of HRP were used as the predictor variables to estimate the savings amount. Once all the cases have a savings amount,

income received from these savings is then calculated using an interest rate of 3% net of tax. This savings amount is added onto the net private and benefit income of the PBU.

3.3.5 Low Incomes

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

Previous analysis from English fuel poverty statistics 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 the 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 the calculated income is below the theoretical income support entitlement it is raised to that level. For pensioners, if the calculated income is below state pension level, it is imputed to that level. If the amount is between that level and the calculated pension credit entitlement level, then the household income is set to missing and imputed later to a group median. The same approach was used to impute low incomes for the Wales fuel poverty statistics.

3.3.6 Impute missing income values

There are three main scenarios in which the total PBU income could still be missing:

I. If the respondent has answered 'don't know' or 'refused' in the private income section of the NS interview;

II. If the benefits sources received by the respondent/partner are answered as 'don't know' or 'refused'; or

III. If, for 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 stage.

In addition to the above, there were a few cases that had missing PBU incomes due to incorrect assignment of the HRP and question routing in the NS interview.

Missing PBU income values were imputed to the group median, for respondents only (no partner), this is based upon employment status, tenure and gender, and for couples (respondent and partner), combined working status and tenure.

3.3.7 Output

The final PBU income variable in the dataset combines the respondent/partner's incomes (private, benefit and savings) with missing PBU incomes assigned/uplifted as appropriate. This translates to the HRP and partner's income.

$$PBU\ income = Net\ private\ income + Net\ benefit\ income + Net\ savings/investment\ (all\ based\ on\ the\ HRP\ and\ any\ partner)$$

3.4 Fuel poverty basic household income methodology

3.4.1 Additional Benefit Unit (ABU)

The PBU is made up of the HRP, their partner (if applicable) and any dependent children. Additional Benefit Units (ABU) 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 ABU can include up to two adults, but only if they are a couple, otherwise each adult makes up its own separate ABU. For the fuel poverty calculations, the income of these additional adult household members is considered as part of the household income[4].

Income from additional benefit units (ABUs) is needed to calculate fuel poverty basic income. The income of additional adults was provided as banded income amounts, as asked in the NS interveiw. The mid-point of the band was taken as the additional adult income amount, except for those that selected the lowest income band of 'less than £200 a week' (there is no 'no income' option); for these cases those that had an employment status of working or retired, they were set the mid-point of the band i.e. £100 a week as these groups are more likely to be in receipt of income, and the remaining non-working/non-retired groups were set to £0 as more uncertainty exists as to whether these cases were in receipt of any income.

Missing additional adult incomes were imputed to the group median based upon working status and, banded age (16-21, 22-29, 30-39, 40-49 and 50+ years old). The retired and long-term sick group were based upon working status only. Once all the additional adults had a gross income amount, it was then converted to a net amount by deducting the applicable income tax and National Insurance. The net income of the additional adults was aggregated up to the household level to provide the total net income from ABUs in the household.

3.4.2 Winter Fuel Payment (WFP)

Winter fuel payment is an annual tax-free payment to help older people with their heating costs. For households with at least one resident aged over female state pension age, which at the time of calculating was 64 years old, that receives a state benefit (not including housing benefit, council tax support, child benefit or universal credit) then payments are automatically given. For those that do not receive state benefit, they must claim the payments.

In the income modelling, using the specified rates (either under the age of 80 or above the age of 80), WFP was assigned to households with anyone in the household aged over female state pension age. Additional amounts are modelled for those aged 80 or over.

3.4.3 Output

The final fuel poverty basic household income variable (fpbasinc), is created by adding the total income from the ABUs in a household and the total winter fuel payments to the PBU income.

$$fpbasinc = PBU\ income + ABU\ income + WFP$$

[4] Additional adult household members reported during the NS interview 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

There were small number of cases with a fuel poverty basic income amount of £0. This can happen when:

- the HRP and any partner are under female state pension age suggested they are not eligible for WFP;
- no income sources nor savings were selected; and
- there are no ABUs in the household with a reported income.

3.5 Fuel poverty full household income methodology

The fuel poverty full household income measure (fpfullinc) is created by adding housing related income to the fuel poverty basic household income (fpbasinc). The fuel poverty full household income measure is the final output used in the calculation process for fuel poverty 10% statistics.

3.5.1 Income from Housing Related Benefits

Housing benefit, Local Housing Allowance and Universal Credit help households on low incomes pay their rent. Housing related benefit was derived from the respondents' response to the questions in the rent and housing benefit module in the NS interview. Households that receive housing related benefit that covered all their rent, had their housing benefit amount set to their total net rent amount. Households that receive partial housing related benefit towards their rent (or for cases where it was unknown whether the housing benefit covered all or some of the rent) were asked how much they pay towards their rent. This information was used in combination with the total net rent to derive the housing benefit component. Households that receive a housing related benefit that covered some of their rent (or unknown if full or partial) but did not provide enough information to derive their housing benefit component, were modelled a housing benefit amount based upon their net rent payable and their theoretical entitlement to housing benefit.

3.5.2 Council Tax Deduction

The council tax band for each dwelling was not available for use in the fuel poverty income modelling. Therefore, the council tax band for each dwelling has been imputed using a method based on Chi Squared Automatic Interaction Detection (CHAID) analysis. Using the Living in Wales Property Survey 2008 dataset (from which the 2008 Wales fuel poverty figures were derived), the council tax band variable as provided by the householder for the 2008 data was set as the dependent variable and the predictor variables consisted of: dwelling type; local authority; number of bedrooms; net household income; floor area and tenure. Using the same predictor variables in the 2017-18 dataset, the council tax band was then predicted for each case using the code generated from the 2008 based CHAID analysis. After all households had been assigned a council tax band, the approximate amount of council tax payable for each property was derived using external data from StatsWales, that provided information on the annual amount of council tax paid by local authority and council tax band. A 'smoothing' methodology was applied to the local authority charges to minimise identification of lower geographical details. Several household adjustments were then made to the council tax payable: Households that selected 'not liable' for council tax had their council tax payable set to £0 and council tax discounts of 25% were applied where appropriate based on whether the respondent reported receipt of a discount on their council tax.

3.5.3 Income from Council Tax Support

Low income households may be eligible for Council Tax Support (CTS), previously known as council tax benefit. The NS interview asked whether the respondent or partner were in receipt of CTS, and whether it covered full or partial payments. Information on the amount of CTS was not collected, if the household is in receipt of full CTS payments, their CTS amount was set to the full modelled amount of the council tax payable for their property. For households in receipt of partial CTS or households that did not know if they were in receipt of CTS, a CTS amount was assigned based on the council tax payable for the property and their theoretical entitlement to council tax support.

3.5.4 Output

The fuel poverty full household income variable (fpfullinc) was created by adding housing related incomes to the fuel poverty basic income variable and subtracting the council tax payable (council tax deduction).

$$fpfullinc = fpbasinc + HB + CTS - Council\ tax\ payable$$

There were a small portion of cases with a fuel poverty basic household income of £0, or a relatively low income amount. In these situations, this can lead to a negative fuel poverty full household income if the household does not report that they are in receipt of housing related payments and where they are liable for council tax for which a deduction is made from their £0/low income, these negative incomes have been left in the dataset.

3.6 Fuel poverty equivalised after housing costs income methodology

The fuel poverty equivalised After Housing Costs (AHC) income is the final output in the income calculations and is used in the calculation of the LIHC fuel poverty statistics. In this part of the income model the housing costs are deducted from the full household income of the household (fpfullinc), and the household income is equivalised to reflect the fact that different households have different spending requirements (see section 6.2.2 for income equivalisation factors)

3.6.1 Rent

The NS interview collects detailed information on household rents and housing related benefit receipt. This was only collected from households that rent their own home or households in shared ownership. Renter households that lived rent-free were not asked the series of rent and housing related benefit questions in the NS. For rent-free cases the rent (and housing related benefit amounts) were set to zero.

The total weekly rent payable for the dwelling includes the rent paid by the householder plus any housing related benefit received towards the rent payment i.e. housing benefit, Local Housing Allowance and the housing component of Universal Credit. These variables were calculated based on the householder's response to the set of detailed rent and housing related benefit questions asked in the NS interview. For households with a rent holiday, an adjustment was made so that the actual total amount of rent paid over the course of the year was averaged out over the full year (as if it was paid over 52 weeks).

For households with missing rent values (i.e. where the respondent had refused to answer the question) these values were then imputed to the guide rent. The guide rent was the average rent amounts based on tenure, number of bedrooms and area where they lived extracted from StatsWales. Parameters are created to flag up cases with implausible rent amounts, these values are interrogated on a case-by-case basis, and a decision was then made to either impute or leave the cases.

In the NS interview, households are also asked what services (if any) were included in their rent costs. These services included:

- Council tax;
- Heating;
- water and sewerage;
- lighting;
- hot water;
- fuel for cooking;
- regular meals; and
- TV licence.

If the rent amount provided by the householder included one or more of the services stated above, then an estimated amount for the selected services was modelled. If the amount of rent the householder provided did not include any of those services, then the total weekly rent payable for the property is the same as the total weekly rent payable for the property excluding the cost of services. The estimated service amount (if applicable) was subtracted from the total gross rent payable to compute the net rent. The net rent is the rent figure used in the AHC income (AHCincome) calculations.

3.6.2 Mortgages

For owners buying with a mortgage, the NS interview collected mortgage information such as property ownership year, property value, property purchase price, deposit amount, and interest rate applied to their current mortgage. Interest-only mortgage payments (as required for the AHC income measure) were only calculated for households that own their home with a mortgage, or those cases of shared ownership.

A key variable that was needed for all cases with a mortgage is the interest rate that applies to the mortgage. Where the interest rate is missing, a value has been estimated for each case based on the reported type of interest rate e.g. fixed, tracker, capped etc. and, for fixed rate deals, the year the current mortgage was taken out in combination with monthly average annual fixed and variable interest rate statistics from the Council of Mortgage Lenders (CML). For fixed rate mortgages, where the year that the householder took out their current mortgage was either deemed unsuitable, as the year provided did not correspond with the length of the fixed term, or unknown, the corresponding interest rate was derived by averaging the interest rate between the year of the NS interview and length of the fixed term prior to the survey year. Where the type of mortgage was unknown, the average financial year CML interest rate across all mortgage types was used for the year of the WHCS. Where the interest rate and type were provided by the household, these were checked against the external statistics and substituted with modelled rates if deemed implausible (e.g. too high/low).

The second key variable needed was the outstanding mortgage amount. The majority of cases provided an outstanding mortgage amount, but those that did not have an amount were imputed based upon the purchase price, deposit, mortgage length and the modelled average mortgage interest rate since the property was purchased.

The imputation procedure for the outstanding mortgage amount was done in a step-wise manner, aiming to have an original purchase price for all cases. First, if the original price was provided by the householder, this was used, next the current property value was used, and failing this, an amount was imputed in based on external property purchase price statistics (HPI annual data table 26). Cases that used a current property valuation (as provided by the householder) had this figure deflated to give a better estimate of the original purchase price (this was done using external data on property price fluctuations).

The original purchase price minus any deposit gives the original mortgage amount. This in conjunction with the average interest rate and the total mortgage length, can then be used to calculate the modelled monthly mortgage payment using the formula:

$$MortPayment = OriginalMort * \frac{\big((CalRate * (1 + CalRate) ** TotalLength)\big)}{\big((1 + CalRate) ** TotalLength - 1\big).}$$

The modelled outstanding mortgage balance was then derived by subtracting the capital portion of the mortgage amount paid to date from the modelled original mortgage amount.

Modelling interest-only mortgage payments: An interest-only mortgage payment is calculated for all homeowners using the monthly mortgage repayment formula and the input data; current outstanding mortgage amount and interest rate. This monthly figure was converted to a weekly one and was only applicable to cases with a mortgage (renters and outright owners did not have an amount calculated). Cases with shared ownership had their mortgage amount calculated in the exact same way as other buyers with a mortgage, but also had the proportion they own applied to this figure. The mortgage interest-only payment was the mortgage payment used in the AHC income calculations.

3.6.3 Output

The AHC variable (AHCincome) is created by subtracting housing costs from the full income variable.

$$AHCincome = fpfullinc - rent - mortgages - services$$

This is the final income variable then used in the fuel poverty calculations.

3.7 Validation of income

Prior to the calculation of incomes, initial checks by BRE were performed on the NS interview files to ensure the data was as clean and complete as possible. Further checks were also done through each stage of the income modelling process. Implausible values within these checks were interrogated, and values were imputed only where we can be as certain as possible that they were incorrect and otherwise these were left. Checks were also completed to ensure all missing values have been dealt with and

amounts had been imputed for these missing values. Lastly the final income calculations were then validated against income trends from other external statistics, such as the Family Resource Survey (FRS) and the previous national Welsh housing surveys.

4. Fuel prices

4.1 Overview

Fuel price is another component needed to calculate fuel poverty. The fuel price component of the fuel poverty model generates an output that is fed into the energy consumption model to produce the final fuel costs (section 5).

4.2 Data sources

4.2.1 Metered fuels (Electricity and Gas)

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. The data provided by BEIS contains gas and electricity 'average unit price' and 'average fixed costs' (standing charges) for energy supply regions across the UK. The QEP data divides Wales into two regions, namely 'South Wales' and 'Merseyside and North Wales'. The fuel prices for Wales were calculated on the assumption that 74% of households are in South Wales and 26% of households are in Merseyside & North Wales. This assumption was based on analysis of the population density in each region.

After collecting the data for the 'average unit price' and 'average fixed costs' for energy supply regions in Wales, prices were then further split by three types of payment (direct debit, credit and prepayment).

4.2.2 Non-metered fuels except wood (e.g. coal, LPG, fuel oil)

The fuel prices for LPG and bottled gas (non-metered fuels) are taken from the Sutherland Tables published in October 2017, as this reflects the time of year of high fuel demand and prices, taking the methodological approach not to underestimate. These were independently produced reports which provide the average prices paid for fuels, split into four broad geographical regions. The prices produced by Sutherland were taken from a sample of prices collected over the preceding three months.

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

4.2.3 Wood, Economy 10 Electricity, 24hr Tariff Electricity, Communal Heat From Boilers and Communal Heat from CHP

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

4.3 Method of payment data

The NS interview collected information regarding the method of payment for mains gas and electricity only. Each household was asked how they pay for their electricity and gas. For each fuel there was 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) Pre-payment (keycard, slot or token) meters;

(5) Included in rent;

(6) Frequent cash payment method (i.e. more frequent than once a month);

(7) Fuel Direct / paid direct from benefits;

(8) Fixed annual bill (however much electricity is used) e.g. StayWarm;

(9) Other (please specify);

(-8) Not applicable;

(-9) Don't know (spontaneous only).

As there were more methods of payment collected than the three methods of payments attached to the prices provided by BEIS, assumptions are made in order to assign each household a method of payment, and the above categories are grouped as follows:

- Those that stated , 'direct debit', 'included in rent', 'fuel direct/direct from benefits' or 'fixed annual bill (e.g. StayWarm)' were coded as Direct Debit.
- Those that stated, 'payment on receipt of bill' and 'frequent cash payment method (more than once a month)' were coded as Standard Credit.
- Those that stated, 'prepayment (key card or token) meters' were coded as Pre-Payment.

For cases that selected 'other' and provided a written description, the most suitable method of payment was imputed for each fuel, matching the written description to the above criteria. For the few cases with a missing method of payment, the higher price of the standard credit method of payment was assigned, taking the general methodological approach to not underestimate fuel costs where data is unknown.

Where the gas method of payment was NA (no gas), the gas method of payment was nominally assigned to be the same as the electricity method of payment, and a gas price applied accordingly. If no electricity method of payment was present, the gas price was 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 Applying the Warm Homes Discount

After the calculation of fuel costs. Warms Homes Discounts (WHD) were then applied to households that are in receipt of support thought these elements of the WHD schemes, as reported by Ofgem. Information on eligibility for each element of the WHD is also provided by Ofgem which allowed the modelling of receipt of this discount. There were, however, more households theoretically eligible for this scheme than actually in receipt of these tariffs Therefore, a process of repeated sampling from the pool of eligible households, and selection of a representative iteration was undertaken (i.e. through Monte-Carlo type simulation). Approximately 12% of cases from the 2018 fuel poverty data were claiming WHD.

The process of assigning the WHD for the 2017-18 data was as follows:

a) Details of the number of households in receipt of each component of the WHD (core group[5] and broader group[6]) were provided by Ofgem.

b) Details of eligibility for each element of the WHD were provided by Ofgem, and flags were created in the NS dataset.

c) A series of runs were made, sampling from the pool of eligible households, which subtracted the WHD cash amount (i.e. £140 for the 2017-18 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 was used to constrain this modelling.

d) A representative iteration was selected from all runs.

The representative iteration was 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.

[5] Low income pensioners in receipt of pension credit
[6] Low income households that meet your energy supplier's criteria for the scheme.

5. Energy consumption

5.1 Overview

The last component needed for the calculation of fuel poverty is the amount of fuel consumed to provide the energy needs of the household.

Under the fuel poverty definition, the energy required to heat and power a home includes energy for:

i. Space heating – E_S (GJ)

ii. Water heating – E_W (GJ)

iii. Lights and appliances – $E_{L\&A}$ (GJ)

iv. Cooking – E_C (GJ)

The BRE Domestic Energy Model (BREDEM) was used to predict the energy use of a household where:

$$Total\ household\ fuel\ consumption = E_s + E_w + E_{L\&A} + E_C$$

The amount of energy required to heat a dwelling varies depending on the building specification (i.e. insulation levels, heating systems, and the geographical location of the dwelling), and the household's demand for energy, this will depend on the occupancy of the dwelling and the habits of the occupants. The WHCS and NS collected information on the dwelling and the household respectively.

The BREDEM model used to derive the energy consumption is consistent with standard energy models such as the Standard Assessment Procedure (SAP) for calculating energy use in dwellings, however the BREDEM model allows users to adjust inputs which are fixed in SAP. For example, in BREDEM you can input the number of people in the dwelling which will take into account under-occupancy (see section 5.4.3 for more detail) whereas in SAP this standardised based on floor area[7].

5.2 Dimensions calculation for energy requirements

The data collected from the WHCS are used to calculate the dimensions of the dwelling, which in turn were used to calculate the heated volume and heat loss areas. By utilising data collected from different parts of the WHCS form, the dimensions model can calculate:

- Internal & external wall areas
- Roof area
- Room specific floor areas
- Habitable floor area and footprint area
- Perimeter of building
- Ceiling height
- Window areas
- Number of floors and rooms in a dwelling

[7] Henderson J, Hart J, BREDEM 2012 A technical description of the BRE Domestic Energy Model, v1.1, January 2015

In the 'Shape' section of the WHCS form, the width and depth of the main and the additional parts are key variables used to determine the area (m^2) of each floor. For the physical data to be considered as part of the main dataset, the dwelling must have a value for width and depth. The WHCS form only allows the surveyor to record the widths and depths of three levels, any more levels values were imputed to the same as the floor below. The width and depth of attics were assumed to be half the size of the floor below, however with basements the width and depth was assumed to be the same size as the floor above. Any imputations done in the dimension model was interrogated on a case by case basis.

5.3 Dwelling energy requirements

Data from the WHCS and NS interview, and the outputs from the dimension model were used to derive the following:

- Heat loss due to conduction from all the external house structure to the external environment;
- Heat gain from solar fluxes and other gains such as from lights and appliances and occupants;
- Heat loss due to ventilation;
- Energy required for space and water heating systems;
- Heating regime of the inhabitants (the details of which will be developed below); and
- Energy required for lights, appliances and cooking.

Table 2 summarises the data required from the WHCS and NS interview and how they are used in the energy calculations.

Table 2 Data required from the NS interview and WHCS needed for energy calculations

	Database	Description of information used in energy calculations
WHCS	Firstimp	Key dwelling components: • Tenure • Type e.g. mid-terrace • Construction date
	Interior	Rooms in the dwelling – function, dimensions, floor level
	Introoms	Details of the rooms e.g. presence of solid floors
	Services	Utilities available e.g. main gas, off-peak electricity Primary & secondary heating systems and controls Water heating system Type and quantity of roof insulation
	Flatdets	Dimensions and details specific to flats
	Numflats	Information about complete building that contains the flat
	Shape	Complete building dimensions including presence of attics and basements

		Construction material of building
	Elevate	Proportion of external walls that have wall insulation
	Chimneys	Number of chimneys and construction type
	Roofstruc	Describes the structure of the roof e.g. flat roof
	Wallstruc	Detailed construction information for each external wall
	Dormers	Presence of dormers and bay windows
	Windows	Number of windows and glazing/ frames of windows
	Doors	Number and type of doors
	Around	Information about surrounding gardens
NS Interview	Attitudes	Information about the daily routine of occupants Information about methods of payment for gas and electricity
	People	Information about the number, sex, age and occupation of inhabitants
	Workdone	Details of any energy improvements that have been recently installed in the dwelling

5.4 Space heating and definition of heating regime

5.4.1 Geographical location

BREDEM 2012 includes three geographical regions for Wales. These BREDEM regions define average climatic conditions such as temperature, solar flux (i.e. heat gains from the sun) and wind-speed. Each dwelling in Wales has a geographical identifier that can be used to determine in which BREDEM region the property is located.

5.4.2 Demand Temperature

BREDEM 2012 generally splits a house into three zones: a primary heating zone (i.e. living room), secondary heated (i.e. kitchen, dining room, bedrooms and conservatories) zone and unheated zone (i.e. garage). In the modelling of fuel poverty, the demand temperature of all dwellings within the primary zone was assumed to be 21°C, the secondary zone was 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.

5.4.3 Extent of Heating

There are some dwellings that were considered excessive in size for the number of occupants living in the dwelling, these were labelled as “under-occupied”. In under-occupied dwellings only a portion of the dwelling will need heating. The criteria for a dwelling to be classed as under-occupied is dependent on both the number of bedrooms and the total floor area of the dwelling. Under-occupancy uses the Parker Morris standard which is different to over-occupied which uses the bedroom standard.

A dwelling is considered to have surplus bedrooms if there are one or more extra bedrooms than required for homes without dependent children, or there are two or more extra bedrooms than required for homes with dependent children. The number of bedrooms required depends on the household constitution. The standard states that:

- A bedroom is required for each couple
- Children of different sexes below the age of 11 years can share a room
- Children/adolescents below the age of 21 years of the same sex can share a room

A dwelling is considered to have surplus floor area in a property if the floor area is over 200% of the "standard" living area required for the number of occupants, as defined by the Parker-Morris[8] Standard. Table 3 below shows the thresholds defined by the Parker-Morris standard.

Table 3 Parker-Morris standard living-area required (m^2)

Occupants	Standard living area required (m^2)
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 under-occupied dwellings it was assumed that exactly half of the dwelling is heated, and the other half is declared as BREDEM unheated space. Below summarises this in a simple formula where A is the total floor area of the dwelling:

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

In the BREDEM methodology the main living area is described as Zone 1 and was assumed to be fully heated. Zone 2 is the remaining areas of the dwelling; with under-occupied dwellings Zone 2 heating was reduced. Below summarises how the proportion of Zone 1 was heated and how Zone 2 was heated.

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

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

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

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

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

[8] Homes for today and tomorrow, Department of the Environment, HMSO 1961

Under the BREDEM methodology, the heating season is defined as the months of October to May.

5.4.4 Heating regimes

The BREDEM methodology uses four different heating regimes: Standard, Full, Partial (full) and Partial (standard). The choice of which heating regime to assign to the household is dependent on the composition of the household, their employment status and whether or not the dwelling is considered under-occupied.

The model used the full heating regime if a household was considered likely to be 'in all day', which was determined from the working status of the household. The partial heating regimes only refer to dwellings that were under-occupied, to consider whether the model should use the partial-standard or partial-full heating regime the same rules from above apply.

Standard heating regime:

The standard heating regime assumes that the occupants are not occupying the dwelling during normal working hours. It was assumed that the occupants heat the dwelling for two hours in the morning and then for seven hours in afternoon. During the weekend it is assumed that the property is heated throughout the day for 16 hours. Table 4 is a summary of a standard heating regime.

Table 4 Standard heating regime

	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

Full heating regime:

The full heating regime was applied for households considered to be 'in all day'. In these cases, all day heating was assumed throughout the week as well as the weekend. Below table 5 summarises the full heating regime:

Table 5 Full heating regime

	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

Partial heating regime (Standard & Full)

For under-occupied dwellings, it was assumed that some of the rooms in the dwelling are not heated and a 'half-house' heating regime is applied. Below tables 6 and 7 summarise the partial heating regime for under-occupied dwellings.

Table 6 Partial standard heating regime

	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 7 Partial full heating regime

	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

5.4.5 Alternative heating regimes and temperatures used for 2016 projections

The main 2018 fuel poverty report refers to alternative heating regimes as applied to the 2016 projections work. In this work, an alternative heating regime was used for elderly households and those with a long term sickness or disability. For these households, living room temperatures were increased from 21°C to 23°C and hours of heating in the week increased to 16 hours on all days. Trends from 2016 to 2018 fuel poverty statistics are further discussed within the main report.

5.5 Water heating

The energy demand for water heating (Q_U) is the energy required to heat the volume of water needed for the household. The detailed equations are accessible in the BREDEM 2012 documentation[9].

The total water energy demand considers not only the methods of water heating, but also the energy losses that relate to storing the water in hot water cylinders and distribution losses. Hot water storage losses are mostly influenced by tank insulation and tank volume.

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

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

[9] Henderson J, Hart J, BREDEM 2012 A technical description of the BRE Domestic Energy Model, v1.1, January 2015

Where Q_{Loss} are losses through water storage/distribution, Q_S is solar hot water heating, E_W is the efficiency of the water heater and K is a constant.

5.6 Lights and appliances requirements

Energy demand for electricity E_{LA} (GJ/yr) includes lights, appliances, pumps, fans and electric showers; which was modelled based on the data collected from the WHC survey such as heating systems and presence of low energy lighting in rooms etc. This then deducts the total household electricity generated by renewable electricity sources such as photovoltaic and wind turbines (where applicable). The algorithm for lighting energy requirements includes provision for low energy lighting. The full equations can be found in the BREDEM 2012 documentation[10].

5.7 Cooking energy requirements

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

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

Where f_{gas} and $f_{electricity}$ 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 WHCS. For the fuel poverty modelling, if the dwelling is fully electric it was assumed that a normal sized electric cooker was in use. Otherwise it was assumed that a normal sized gas/electric cooker is in use. Therefore:

- Where a gas connection was present (i.e. a gas meter is identified by the surveyor), but no gas space or water heating appliances were present, it was assumed that the gas connection is not in use. In these cases 100% of energy demand for cooking was assumed to be met by electricity. No gas standing charge was 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 f_{gas} =0.5 and $f_{electricity}$ =0.5.

[10] Henderson J, Hart J, BREDEM 2012 A technical description of the BRE Domestic Energy Model, v1.1, January 2015

5.8 Total fuel costs

Total energy consumption is given as:

$$Total\ energy\ use\ (GJ/yr) = E_S + E_W + E_{L\&A} + E_C$$

Where:

E_S: Energy for space heating;

E_W: Energy for water heating;

$E_{L\&A}$: Energy use for lights and appliances;

E_C: Energy use for cooking.

Different fuels may be used for some or all of these energy contributions and therefore different tariffs, and in some cases standing charges, were applied to approximate the total cost of energy to the household as described earlier in the fuel price section (section 4).

$$Total\ energy\ use\ (£) = £_S + £_W + £_{L\&A} + £_C + £_{Standing}$$

Where:

$£_S$: Energy cost for space and water heating;

$£_W$: Energy cost for water heating;

$£_{LA}$: Energy cost use for lights and appliances;

$£_C$: Energy cost use for cooking;

$£_{Standing}$: Standing charges for all fuels.

5.9 Handling missing values

5.9.1 Alteration to the dwelling data

During detailed checks on the outputs, parameters are set up to flag cases that are deemed to be implausible and require alteration to the raw data within the energy modelling process. Each case is interrogated 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.

5.9.2 Missing dwelling data

Where a dwelling is missing data required to calculate the energy requirements of the household, these are dealt with in accordance with RdSAP assumptions for existing buildings. The exception is missing loft insulation where the occupant does not have access to the loft space. Loft insulation is assigned using the mean value for dwellings of that age and tenure using UK averages.

5.9.3 Missing household data

The number of occupants living in a dwelling and the composition of the household is provided in the NS interview. These data are required for calculating the energy requirements.

5.10 BREDEM versions

The most significant difference in methodology for calculation of fuel poverty from 2008 to 2018 is the BREDEM methods used to calculate energy use (consumption). In 2008, energy use was calculated using BREDEM 12 (2001) and 2017 energy use figures were calculated using BREDEM 2012. The change in BREDEM/SAP methods have resulted in improvements in U-values for solid walls and a drop in floor area, which reduces energy use.

6. Producing the final indicators

6.1 The 10% definition

In Wales, if a household needs to spend more than 10% of its income on fuel to maintain an adequate level of warmth (as defined under the heating regime in the BREDEM methodology[11] or in section 5.4.3) they are deemed to be fuel poor.

For each case on the WHCS, a 'fuel poverty ratio' is calculated. This calculation has three components – energy prices (unit and standing charges), fuel consumption and income. The equation takes the following simplified form:

$$Fuel\ Poverty\ Ratio = \frac{Fuel\ Costs}{Income}$$

Or the following more detailed form:

Where for each household the following applies:

- The unit fuel price (£/GJ) is applied to each fuel type
- Fuel consumption (GJ) is the energy use for each fuel type
- Standing charges (£) are applied where applicable for each fuel type and
- Income (£) is the annual income of the whole household.

Note that for every household all applicable use and cost values are summed for each fuel type.

If the fuel poverty ratio is greater than 0.1 (i.e. a household spends more than 10% of their income on fuel) then the household is considered to be fuel poor. If the ratio is greater than 0.2 then the household is considered to be severely fuel poor.

6.2 The LIHC definition

Low Income High Cost (LIHC) is the measure of fuel poverty used in England. Under this definition, households are considered to be fuel poor if:

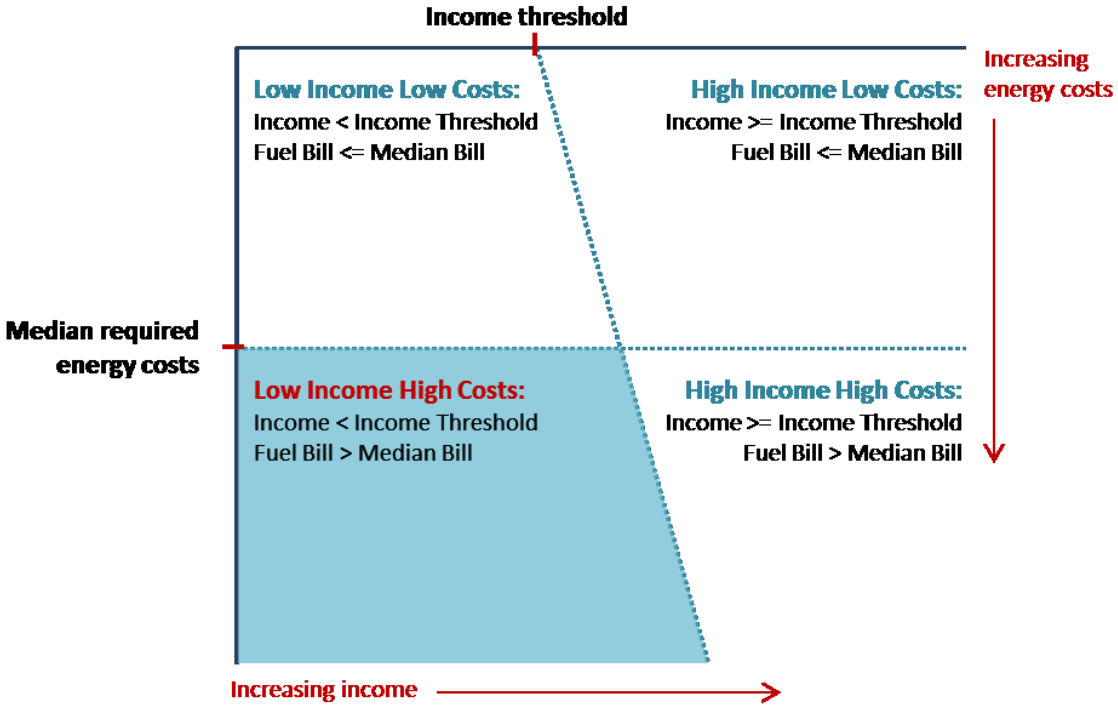
- they have required fuel costs that are above average (the Wales national median level);
- were they to spend that amount, they would be left with a residual income below the 60% median income, as observed by the NS.

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 (see section 6.2.3). Figure 2 shows the four possible groups a household can fall into under this indicator.

$$Fuel\ Poverty\ Ratio = \frac{\sum(Unit\ Fuel\ Price * Fuel\ Consumption) + \sum Standing\ Charge}{Income}$$

[11] Henderson J, Hart J, BREDEM 2012 A technical description of the BRE Domestic Energy Model, v1.1, January 2015

Figure 2. Low income high costs



The following section describes how to calculate whether a household has a 'low income' coupled with 'high costs'; and is therefore considered fuel poor.

6.2.1 Fuel costs threshold

To be "High Costs" a household must have required *equivalised* fuel costs that are above average (the national median level).

Equivalised fuel costs are calculated for all households by:

1. Taking the unequivalised required fuel costs for all household
2. Applying the corresponding equivalisation factor for each household. These are shown in Table 8 below. Dividing 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.

Table 8 Equivalised factors for fuel costs under the LIHC indicator

Number of people in the household	Equivalisation factor
One	0.82
Two	1.00
Three	1.07
Four	1.21
Five or more	1.32

The fuel cost threshold is calculated by taking the weighted median of all of these equivalised required fuel costs.

Half of all households should have “high costs” i.e. above the threshold, and half should have “low costs” i.e. below the threshold.

6.2.2 Household income threshold

Households are below the income threshold if fuel spend leaves the household with a residual income below the official poverty line. This is defined as 60% of the median equivalised disposable income.

Each household’s median equivalised disposable income is calculated by:

Dividing the After Housing Costs (AHC) income by the relevant 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 9 below.

Table 9. After housing costs income equivalised 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

To calculate the income threshold for each individual household, take the following steps:

1. Take the weighted median of all of the AHC equivalised incomes in the dataset
2. Calculate 60% of this value, to produce the relative low income threshold.
3. Add on the equivalised required fuel costs of the particular household.

The income threshold is therefore higher for households with large costs compared to those with smaller 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.

6.2.3 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.

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

x_m = 60% of equivalised AHC median income

y = equivalised household fuel costs

y_m = median equivalised fuel costs (fuel cost threshold)

Further details

The document is available at: www.gov.wales/whcs

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