Comparison of theoretical energy consumption with actual usage

Introduction

The purpose of this analysis is to explore the difference between theoretical energy consumption (from fuel poverty statistics), and actual energy consumption (recorded in the National Energy Efficiency Data Framework) for English dwellings. We examine how this difference varies by dwelling and household characteristics, including fuel poverty status, payment type, energy efficiency rating, income and household type.

Fuel Poverty in England is currently measured using data derived from the English Housing Survey (EHS). The relationship between fuel poverty based estimates for gas and electricity consumption and actual consumption figures is therefore useful in understanding the variance and underlying patterns in fuel poverty.

The aim of this paper is to explore the relationship between fuel poverty and other characteristics, and actual energy consumption, with a view to identifying patterns of underconsumption and possible underheating. The methodology is detailed in full on page 76.

Executive summary

- The theoretical fuel expenditure derived from fuel poverty statistics (gas and electricity) is, on average, £133 higher than the actual consumption in NEED, or 9.9% in percentage terms.
- This average cost difference increases to £319 for people classed as fuel poor (19.9%) while for dwellings classed as non-fuel poor this difference is £110 (8.6%).
- FPEER[1] Band B actual consumption is on average the same as the theoretical, while for less efficient dwellings the difference between actual and theoretical consumption increases as the energy efficiency decreases.
- Dwellings with an actual consumption greater than theoretical figure have an income 21% higher on average than the rest of the sample.
- The gap between theoretical and actual energy consumption is negatively correlated with income, with households in the highest income decile using on average £27 more than the theoretical consumption, and those in the lowest income decile using on average £189 less.
- Households using prepayment meters use on average £186 less than their theoretical consumption while households using other payment types (standard credit and direct debit) use £113 less than in the theoretical, for the fuel poor on prepayment this gap rises to £340.
- The greatest difference between theoretical and actual consumption is for couples with children and lone parents with children. This trend is amplified further when looking specifically at fuel poor households.

Methodology outline

The data used in this study consisted of five years of data from 2012 to 2016 (inclusive) that was used in the production of fuel poverty statistics. The data was address matched (only for cases where full consent was given) and then joined to the NEED database to obtain the recorded consumption for electricity and gas.

The merged dataset produced included both the NEED actual consumption value, and the EHS derived, fuel poverty theoretical consumption value, for each case (household). Here, two new variables recreating the amount of money spent on energy by each household based on the NEED consumption data and on theoretical consumption data were created.

[1] Fuel Poverty Energy efficiency rating (FPEER) is a measure of the energy efficiency of a property based on the Standard Assessment Procedure (SAP) but accounts for policies that directly affect the cost of energy.

The money spent was obtained by computing actual gas and electricity consumption from NEED, and the theoretical fuel poverty consumption values, with energy prices from Quarterly Energy Prices (QEP) [2] for the relevant year of the survey. The average cost difference between actual money spent and the theoretical money spent was then compared across different variables.

What will comparing the datasets show?

The theoretical consumption value itself is calculated using BREDEM[3], which is based on SAP (standard assessment procedures) ratings for each dwelling that give an annual unit energy cost of space and water heating for a dwelling, based on a set heating regime of 21 degrees in the main living area and 18 degrees elsewhere[4]. It therefore represents the cost needed to heat a dwelling to what is deemed to be an adequate level for living.

As such, a positive reading for the cost difference can indicate a possible under-consumption, and therefore possible 'under-heating' of a dwelling, as it is not deemed to be consuming to the level for adequate heating established under fuel poverty methodology.

To simplify definition, unless stated; 'theoretical consumption' refers to the theoretical consumption value for each dwelling derived from fuel poverty data. The 'actual consumption' is derived from the NEED administrative dataset showing reported consumption from meter readings for each dwelling. The 'cost difference' is the gap between them in monetary terms, this may also be referred to as the 'consumption gap'.

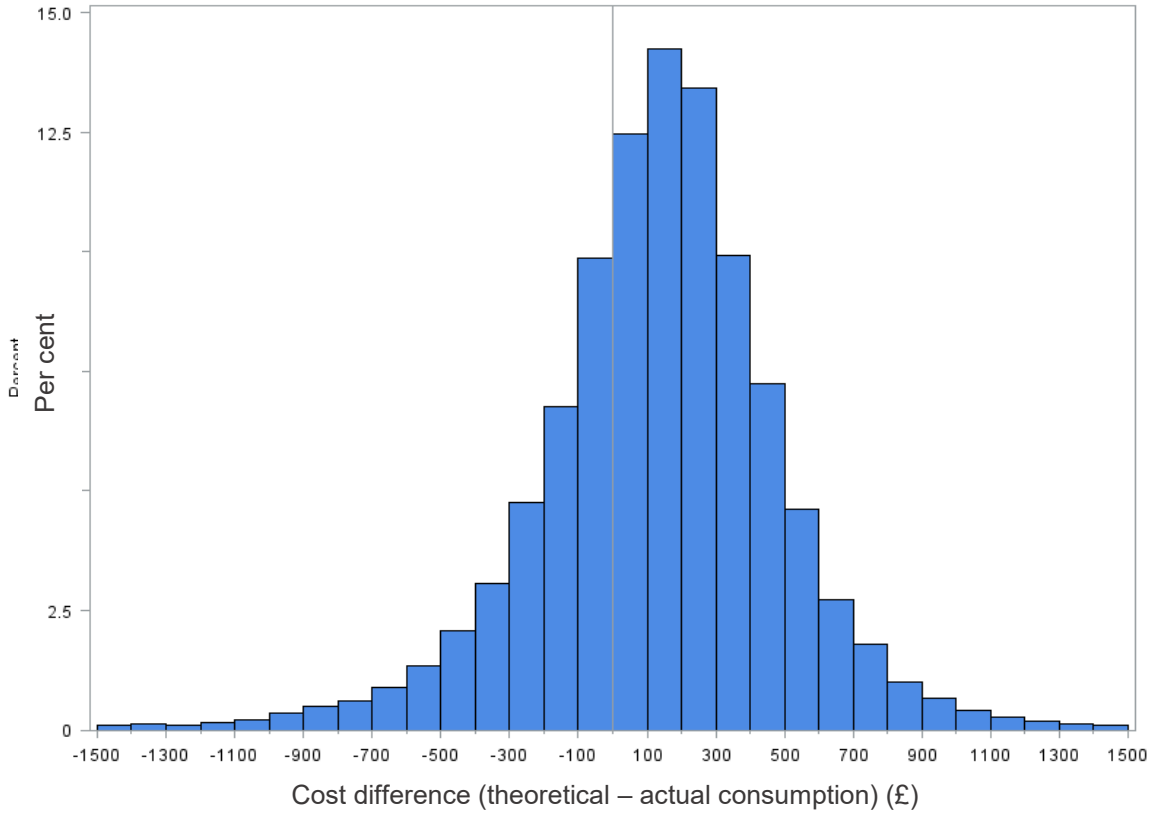
[2] The prices used were UK average prices specified for year, payments type and electricity plan (E7 vs standard tariff), all other fuel types were excluded
[3] BRE Domestic Energy Model
[4] (Page 49-50) Fuel Poverty Methodology Handbook

Analysis

Comparison between theoretical consumption and actual consumption

The distribution of the cost difference between theoretical energy consumption and actual consumption shows that the actual amount of energy used, in the majority of cases, is lower than the theoretical figure, with an average cost difference of £133.

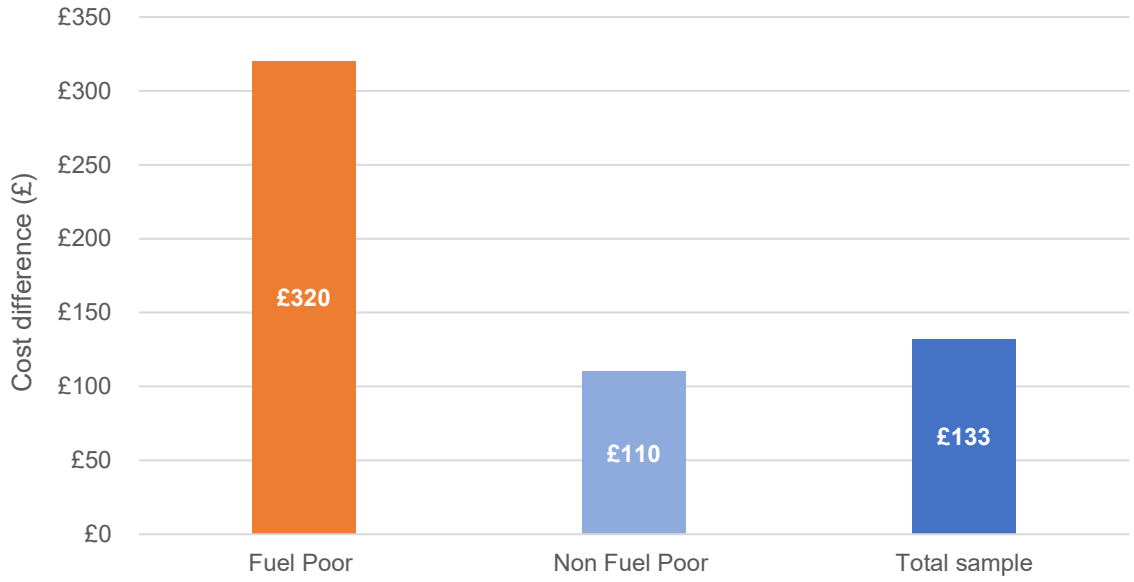
Figure 1: Histogram of the average cost difference showing that 69% of households had theoretical consumption higher than their actual consumption



We would expect an overall positive cost difference, due to the standardised nature of how the theoretical consumption figures are calculated. EHS technical guidance does accept that this is more likely to result in a slight overestimation of actual energy consumption. However, what would distinguish this difference from fixed systematic overestimation is whether this difference is constant or not across various household characteristics.

The overall pattern is true for both households classed as fuel poor and as non fuel poor. However, the average difference between actual and theoretical consumption was £110 for the non fuel poor, whereas the average cost difference for fuel poor households (11 % of all households in England[5]) was almost three times higher at £320.

Figure 2: the average difference between actual and theoretical consumption is much larger for fuel poor households



These results would suggest that there is more underconsumption among the fuel poor, in that there is a much larger difference between theoretical consumption required, and actual consumption for fuel poor households.

Fuel Poverty Energy Efficiency Rating (FPEER)

When looking at the cost difference for each FPEER[6] band it reveals that for dwellings rated in Band B (second highest energy efficiency) the actual consumption matches on average the theoretical consumption[7].

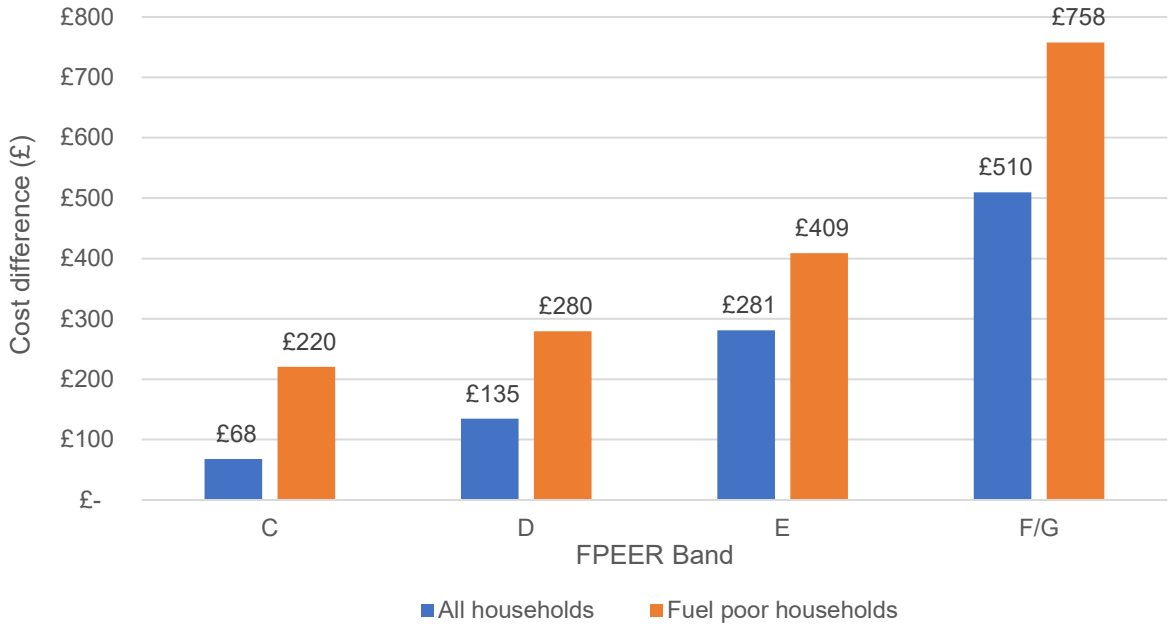
However, for dwellings with a lower FPEER rating, C and below, the actual consumption on average is lower than the theoretical value, and this gap increases as the energy efficiency class of a property decreases, as can be seen in Figure 3. Here, the cost difference is £510 for dwellings in Band F/G compared to just under £68 in Band C. The results suggest that the lower the energy efficiency rating

[5] Annual Fuel Poverty Statistics Report
[6] FPEER is a measure of the energy efficiency of a property based on the Standard Assessment Procedure (SAP) but accounts for policies that directly affect the cost of energy.
[7] Band A dwellings (highest efficiency) were analysed however there were not enough cases to be included.

of a dwelling, the larger the difference between actual and theoretical gas and electricity consumption[8].

The same trend is observed when considering only those households classified as being fuel poor, whereby the cost difference increases with decreasing energy efficiency, however the differences are markedly larger.

Figure 3: cost differences increase as FPEER band decreases[9]



An analysis of cost difference by floor area, split by houses and for flats, was also carried out alongside FPEER analysis. Whilst this showed that floor area and cost difference were broadly correlated, the relationship was not linear and by comparison it was deemed that energy efficiency had a stronger relationship to the difference between theoretical and actual consumption of a household. There was also a relatively small difference between the average cost difference of houses and flats (£131 and £138 respectively).

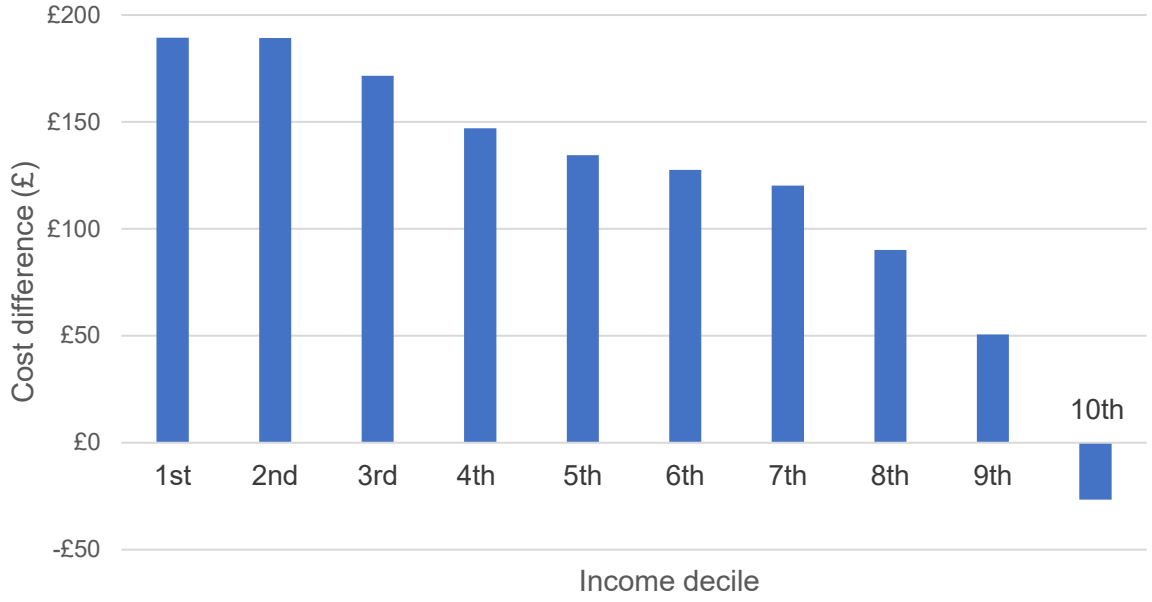
Income decile

As expected, in Figure 4, there is a relationship between the difference in actual and theoretical consumption and income, with this difference being the highest for lowest income group (1st income decile) at £189, and a progressive reduction as income increases, to the point that the gap becomes negative for the highest income group (10th income decile) at -£27 (i.e. people in the highest income group spend on average more than the theoretical requirement).

This trend shows a negative relationship between energy underconsumption and income and suggests that those households with less financial capability are much more likely to restrict consumption to less than suggested adequate levels. It also suggests that at the higher income end, there is a tendency to consume more than theoretically required.

[8] The possibility that the current energy rating model overestimates the amount of energy required by less efficient dwellings must be noted.
[9] Bands A & B were excluded due to small sample sizes

Figure 4: cost differences decrease as the income decile increases



Furthermore, an analysis of the subgroup within the sample with an actual consumption that is above the theoretical consumption in NEED shows that the income for this group is 21% higher than that of the rest of the sample. Suggesting further that consumption relative to theoretical consumption standards is strongly linked to income.

Pre-payment meters

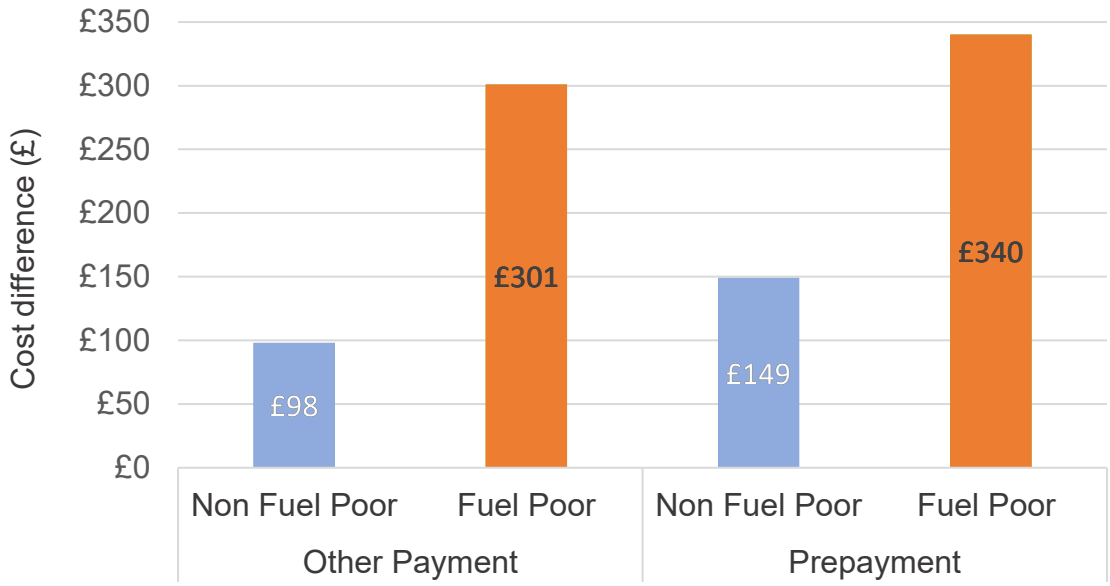
It has widely been theorised that lower income households are more likely to be users of pre-payment meters. From analysis of the fuel poverty data, it shows that of dwellings in the lowest two income deciles, 47% use pre-payment meters for electricity.

Households using a pre-payment electricity meter consume considerably less, on average, than the theoretical consumption value. In particular the gap between actual and modelled consumption is £186 for dwellings using pre-payment meters while only £113 for customers using other payment methods (standard credit or direct debit)[10].

The consumption gap for the fuel poor households is higher than for the non fuel poor. For pre-payment this gap is £149 for non fuel poor households and £340 for fuel poor, while for dwellings using other methods of payment this gap is respectively £98 for non fuel poor and £301 for fuel poor.

[10] For the prepayment variable we have used the payment method for electricity. All figures for using gas pre-payment meters, or pre-payment for both gas and electricity, are largely the same as for electricity. As such electricity pre-payment meter usage has bene taken as indicative of overall pre-payment usage.

Figure 6: the cost difference for households on prepayment is higher than for other payment methods



This variance in the difference in theoretical and actual costs, could be down to a variety of factors, however it is likely that pre-payment overlaps with those already facing low incomes and high costs, as well as pre-payment meter energy tariffs being generally higher[11]. It can also be theorised that pre-payment meters can be used as a more immediate form of under-consumption via self-disconnection, and therefore have higher rates of underconsumption in users.

Household composition

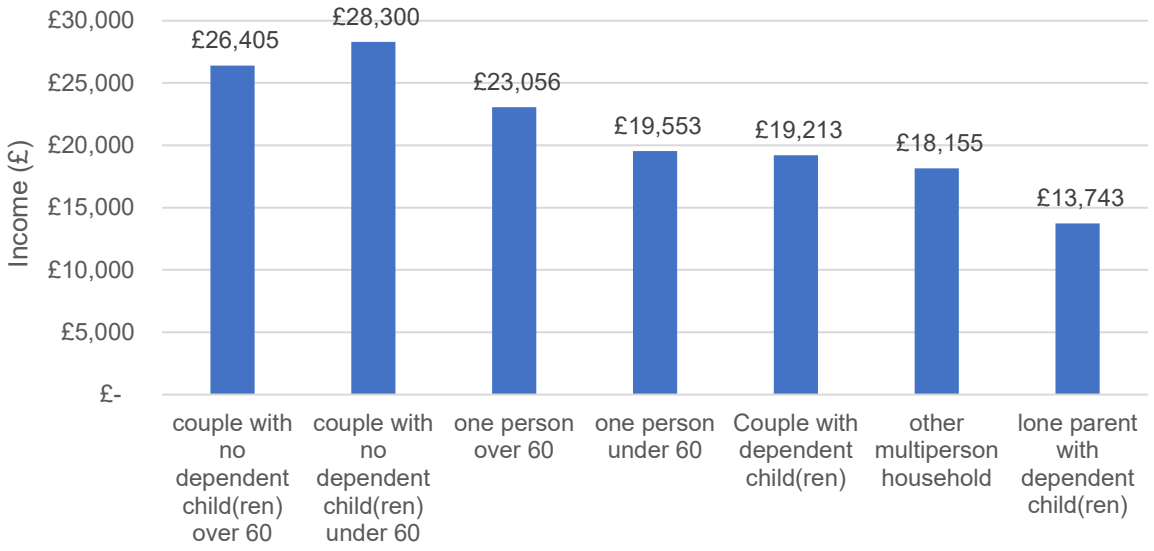
Figure 7 shows the difference between actual and theoretical consumption grouped by household type, as recorded in the EHS. The results show that the highest difference in energy consumption is for lone parents with child(ren) showing a difference of £191 and couples with dependent child(ren) at £171[12], while single people aged over 60 and couple without children (both aged 60 or over or under 60) have a much lower gap between the theoretical and actual energy use at just £73.

This shows that older households and those with no dependent children have a lower difference between actual and theoretical costs, suggesting a lower rate of underconsumption comparative to younger households with dependants. It is possible that this reflects differences in current policy such as the winter fuel allowance for older households, as well as the relative income impacts of having dependent children, particularly on single income households. Multi-person households[13] also have the second highest cost difference, however due to the variability of these household types it is hard to conclude too much from this result.

[11] These results use data from 2012 to 2016 and therefore do not take into account the pre-payment price cap introduced in April 2017.
[12] It should also be noted that the median values for lone parents and couples with dependents were markedly higher than their mean values, suggesting that more of the distribution of these households have a higher cost difference than the mean would suggest.
[13] Multi-person households 'include unrelated adults sharing, student households, multi-family households and households of one family and other unrelated adults'

Figure 7: households with children had the largest average under consumption

Figure 8: average income is negatively correlated to the average cost difference in Figure 7



Furthermore, in Figure 8, when household types are broken down by equivalised, after housing costs income, it follows that the income for each household type negatively correlates with average cost difference. Suggesting that the after housing cost income could be broadly related to the cost difference of the relative household types.

Analysis of fuel poor households showed a similar trend as for all household types, however the cost difference amounts were markedly higher, with lone parents with dependants showing a cost difference of £337. Also fuel poor couples with dependent children had the second highest cost difference after multi person households, at £339, compared to the total population, where this household type had the fourth highest cost difference. This supports the trend suggesting lower income households with dependants are potentially more likely to under consume than other households.

Conclusions

To draw conclusions on the significance of the underlying patterns in the difference between actual consumption figures and theoretical data it is important to refer to how theoretical consumption figures are calculated. Based on SAP ratings, they are a modelled theoretical cost needed to provide an adequate level of heating to a dwelling, given its energy efficiency.

As such, a systematic pattern of higher estimates in the theoretical data compared to actual consumption could point to two of several real-world scenarios for underconsumption:

a) Certain households are systematically under consuming due to costs.
b) The base line assessment for the adequate levels of energy or heating required for a dwelling are overstated.

The overall conclusion across all variables and scenarios is that in most observations, theoretical figures are higher than actual consumption. If this relationship was consistent in its correlation across all the variables outlined in this analysis, then it could be an implication that the theoretical figures are overestimating the energy needed to adequately heat a household. This, however, is not supported from the analysis of the impacts of the different variables on the difference.

The analysis suggests instead that the indicated underconsumption is greater the lower the income and energy efficiency of a household and is exacerbated when this is combined with the use of pre-payment meters. This indicates that households with the least purchasing power and more immediate autonomy over heating are under-consuming more, relative to their higher income and more efficient counterparts. A logical explanation for this is that lower income, less energy efficient and fuel poor households, have a much greater financial imperative to under-heat their respective households, and pre-payment meters offer more autonomy with which to do so.

Inversely, the highest income households are more likely to have their consumption underestimated when compared to actual consumption. Suggesting a choice to over-consume rather than save money in comparison to the adequate levels of heating outlined in the fuel poverty methodology.

Evaluations

The aim of this analysis was to draw conclusions on the potential difference between actual energy consumption and theoretical consumption, and the possible variables that explain that difference. As well as to analyse what this might mean for fuel poverty policy and analysis.

The EHS technical guidance does refer to the possibility that it may overestimate energy cost, stating that due to the need for standardised assumptions to compare energy performance the methodology is '*more likely to result in an overall overestimation than underestimation of actual energy consumption'* [14].

However, given the skew towards a higher difference, and therefore overestimation in the most vulnerable groups (low income, high cost) whom traditionally need to be targeted by fuel poverty initiatives, this variance can be seen to be indicative of the nature of interaction between households and underconsumption.

Here the study indicates, that rather than paying costs of heating – either made higher by lower energy efficient homes, or relatively higher by a lower income or competing child costs, many households may be choosing to under consume relative to the standards laid out on page 2, rather than pay to consume adequately. This is a trend pronounced mainly the lower the income, fuel poverty status and higher the energy inefficiency of a household.

[14] English Housing Survey 2016 to 2017: Technical Report

Fuel poverty statistics are measured using a low income high cost methodology, which will flag up where vulnerable groups may be faced with high costs. However, policy decisions should take into consideration that these figures do not necessarily indicate that vulnerable and fuel poor households are *actually paying* those costs or consuming the indicated level of energy from the fuel poverty data. Instead, fuel poor groups are much less likely than more well-off groups to be consuming at those levels. Particularly younger households with dependants. This should be factored in to the scope and size of targeted fuel policy initiatives such as fuel allowances and the Warm Home Discount.

Appendix and methodology notes

Further to the methodological summary, a more detailed breakdown of the methodology is as follows.

The starting sample included six single year datasets totalling 47,738 cases, excluding households that did not give permission for their data to be used (approximately 5%). NEED does not record consumption other than gas and electricity, therefore all properties in the EHS using other methods of heating (oil, coal, biogas, community schemes or other) were excluded, as well as cases that appeared twice, to create a final database with 22,178 rows.

After combining the two datasets, two new variables recreating the actual amount of money spent on energy by each household based on the NEED consumption data and the theoretical gas and electric consumption data (both originally in Kwh) were created. The total money spent (in £) for each was obtained by computing actual gas and electricity consumption from NEED, with energy prices coming from tables 2.3.4 and 2.2.4 from the Quarterly Energy Prices (QEP)[15] for the relevant year of the survey. The prices used were UK average prices specified for year, payments type and electricity plan (E7 vs standard tariff), all other fuel types were excluded. This process was then repeated for the theoretical consumption variable.

The new monetary variable based on NEED consumption was then subtracted from the new theoretical consumption variable to produce the cost difference between theoretical and actual consumption.

This difference has a positive reading if the actual consumption was lower than the theoretical consumption, while a negative reading means that actual consumption was higher than the theoretical consumption.

These results have also been filtered to exclude those dwellings where the difference between modelled and actual consumption was greater than £1,500, as being in the top 1% of observations, they are thought to be extreme observations.

Further points

Gas consumption in NEED is weather corrected using a complex procedure that uses a geography matrix, which can result in a small change in the gas consumption figure. A preliminary analysis of the time series showed that results across the years were consistent and with limited effect coming from the weather correction.

A further point to note is that this study compares total energy consumption for a whole year and is including energy used for heating water, lighting and appliances throughout the year.

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[15] The QEP publication and tables can be found at the following link: www.gov.uk/government/collections/quarterly-energy-prices#2018