Estimates of hot water consumption from the 1998 EFUS. Implications for the modelling of fuel poverty in England.

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A summary report presenting data from the 1998 EFUS produced by the BRE Housing Centre on behalf of DTI and DEFRA.

Background

The English House Condition Survey (EHCS) is a national survey that collects information about dwellings and their occupants. In 1991 and 1996 this was conducted on a large scale, surveying more than ten thousand dwellings. The data that was gathered has been utilised to provide realistic information about living conditions and energy use within the homes of the entire population of England.

In the first quarter of 1998 the English House Condition Energy Follow Up Survey (EFUS) was conducted. The EFUS follows on from the EHCS by revisiting a sub-sample of dwellings (approximately 2,600) that were included in either the 1991 and 1996 surveys. The main purpose of this survey was to collect detailed information relating to how households in England use energy in their homes. This document describes the summary results from the analysis of this data with respect to the use of hot water in homes – with particular emphasis on the implication of the results for fuel poverty modelling.

Introduction

The 2001 EHCS fuel poverty calculations use the BREDEM 12 algorithms, [1], to approximate the total fuel bill of a household. Included within these costs are estimates for the amount of hot water that is used by a household. Fuel poverty calculations currently assume that all comparably sized households have an "average" demand for hot water. This average is modelled as a function of the number of occupants within the household. Although the BREDEM algorithm can account for some variation in household demand above and below the average, this is not applied at present.

The purpose of this investigation is to determine the extent that hot water usage differs between households and if any particular household groups need to be assigned a higher usage level than others. In addition, this investigation considers any evidence relating to 'proposal five' of the fuel poverty methodology consultation [3] which suggests applying a 20% across-the-board increase in usage. Data from OFWAT [2] suggests that overall water use (both hot and cold) increased by 25% between 1979 and 2002. The underlying assumption behind 'proposal five' is that the hot/cold mix has remained approximately constant and that there has been a corresponding rise in hot water usage alone.

Within BREDEM, 'hot water' is effectively all hot water drawn from the boiler(s) or hot water tank(s) which is not used for space heating. Instantaneous heaters (such as electric power showers), and immersion heaters are covered by this definition but water heated internally by domestic appliances (such as dishwashers) are not. Instead, this water heating is modelled by the BREDEM lights and appliance algorithm.

The main uses of hot water in the home, under this definition, are for:

a) Baths
b) Showers (including instantaneous electric showers)
c) Hot water drawn from the tap
d) Hot-fill washing machines and dishwashers (i.e. appliances draw hot water direct from the boiler or tank as opposed to heating water internally)

Methodology

The 1998 EFUS collected information about usage levels of washing machines, dishwashers, showers and baths. However, it did not collect data on hot water use at basins and sinks.

Research for the DECADE project, [4], suggests that around 90% of washing machines used in the UK are hot-fill, whereas the majority of dishwashers are cold fill. Therefore, hot water used for washing machines is included in the usage analysis presented here, but hot water for dishwashers is not.

A value for the amount of hot water consumed by each household has been determined by combining the reported usage levels for each appliance with assumptions on the volume of hot water typically used by each type of appliance. In addition, further assumptions have been made about the amount of hot water drawn from the tap. These assumptions are outlined in Appendix 1.

The average water consumption per person can be calculated by dividing by the combined usages by the number of people in the household – information which was also collected by the EFUS survey.

Table 1 shows the percentage of households that have one or more of these appliances present:

Appliance	Ownership (percentage of all households)
Washing Machine	92%
Dishwasher	21%
Shower	69%
Bath	88%

Table 1: Presence of hot water appliances in households.

Some households did not provide the usage levels of the hot water appliances present in their home. The extent of missing information for each appliance is shown in Table 2.

Appliance	Of those with appliance, % with unknown usage
Washing Machine	3%
Dishwasher	10%
Shower	< 1%
Bath	< 1%

Table 2: Extent of unknown usage level of hot water appliances.

Any cases with unknown usage data have been excluded from this analysis.

Results

The detailed results of this analysis are presented in Appendix 2.

Whole stock
The average consumption of hot water across all households is 4 litres per person per day for washing machines and 35 litres per person per day for baths and showers. An additional 10 litres of hot water is used for the cleaning of dishes at the sink and for hand and face washing. This gives a total average usage of 49 litres of hot water per person per day.

Household composition
Younger households tend to use more hot water than older households as shown in Figure 1. Households aged under 60 use more hot water than the mean for the stock as a whole. This is especially true for single people under 60 who use around 8 litres more hot water for baths and showers. Conversely, those aged over 60 use less than the mean - particularly single households over 60 who use approximately 1 litre less hot water for washing machines and 7 litres less for baths and showers.

Couples with dependent children use slightly less hot water than the mean whereas lone parents with dependent children use around 5 litres more per person than the mean.

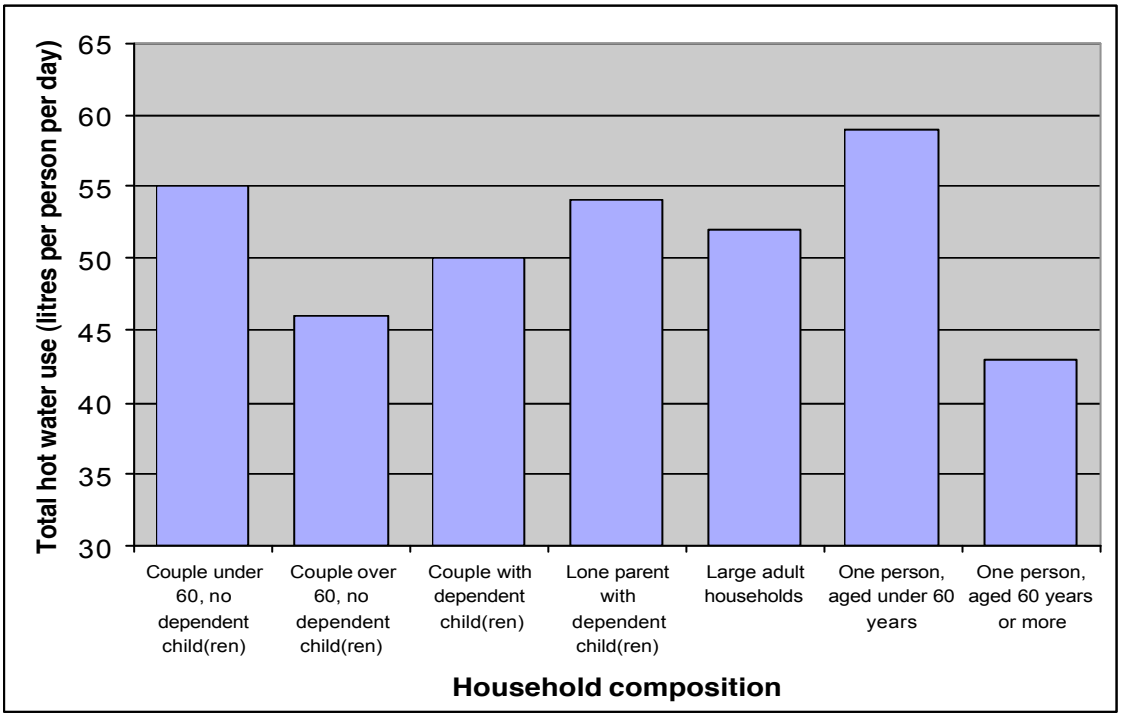

Figure 1: Mean water usage by household composition.

Household size
Hot water usage by household size can be seen in Figure 2. Those in larger households (five or more people) are more economical with their hot water, particularly for baths and shower usage. Five person households use approximately 6 litres less total hot water per person than the mean for the stock. Households containing six or more persons use even less hot water (around 7 litres less per

person per day than the mean). Households of two, three or four persons use slightly more than the mean (around 1 litre more). Single person households use around mean levels.

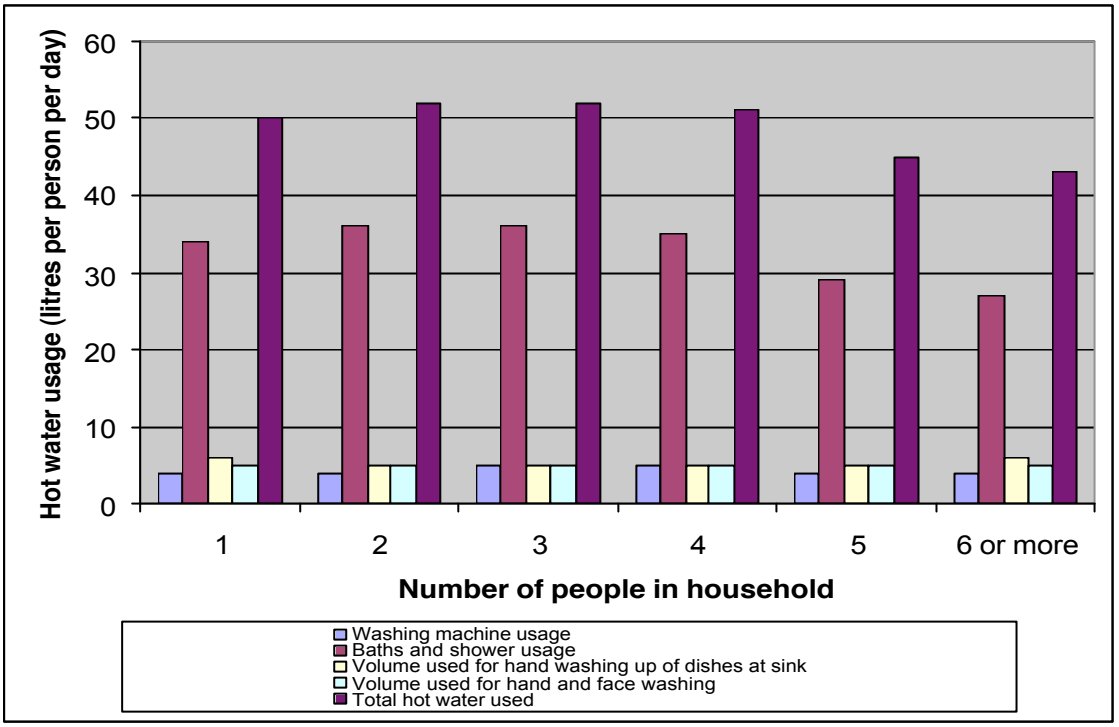

Figure 2: Mean water usage by household size.

The fuel poor
Fuel poor households use less hot water than households who are not fuel poor. The fuel poor use around 2 litres less total hot water per person per day than the mean – with savings coming from lower volumes of water used for baths and showers. The fuel poverty 'vulnerable' group uses around 2 litres less hot water than the mean.

Income
Lower income households tend to use less hot water, and those on higher incomes vice-versa. Households in the lowest third of income use around 1 litre less than the mean for the stock. The middle income group use around the same level as the mean and those on the highest income levels (highest third) use around 2 litres more than the mean. This is shown in Figure 3 below.

Type of hot water system
Hot water usage varies with the type of hot water heating system used. Households using their central heating system to heat water use slightly more hot water than the mean. Those with a dedicated boiler use around the same as the mean, whereas those with an electric immersion or instantaneous heater use less. Households using instantaneous systems tend to have the lowest level of hot water usage, around 5 litres less than the mean total use per person per day.

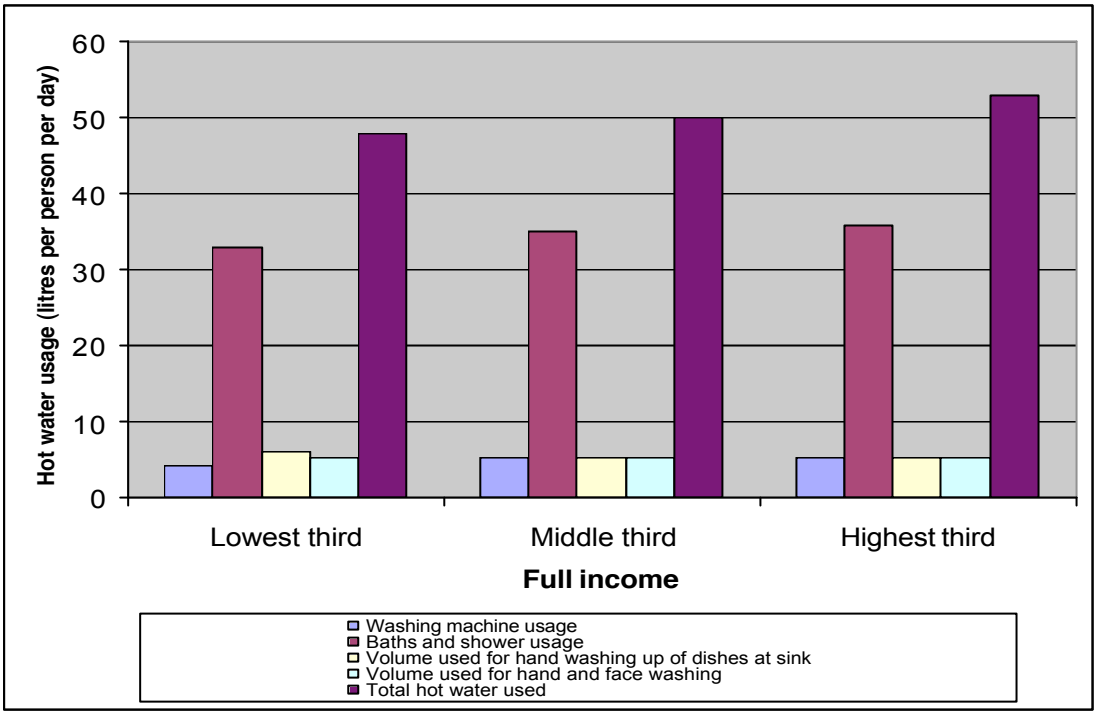

Figure 3: Mean water usage by household full income.

Attitudes to energy efficiency

The 1998 EFUS also collected data about the householder's attitudes towards water usage. They are asked whether they consider it to be the most costly fuel expenditure, whether they would cut back on energy usage if fuel prices were to increase, and how they would cut back on energy usage were they to do so.

Single households under 60 have the highest usage rate per person and in turn are the group most likely to have the highest expenditure on fuel. They are also the second most likely group to try and reduce energy usage if fuel prices were to increase by 10% - 19% of which would target the reduction at hot water.

Single households over 60 (who have the lowest hot water usage) are those least likely to rate hot water as their greatest source of fuel expenditure. They are also the least likely to try and cut back on energy usage if fuel prices increased by 10%. Also, if they were to make any cut backs, they are least likely to target them towards hot water.

Fuel poverty status appears to have little-to-no effect on attitudes towards the cost of hot water. The non-fuel poor seem almost as likely to try and cut back on energy use if fuel prices increase as the fuel poor.

If fuel costs were to increase by 10% then households with the highest income levels (highest third) are the least likely to cut energy use, whereas those in the lowest income group are most likely to try and cut back. However, of those that would cut back, the highest income group are those most likely to target this towards hot water.

Conclusions

The results presented in this analysis and the detailed tables provided in Appendix 2 show that hot water use varies with a range of factors. The best indicators appear to be income and age – with older households consuming less. However, the picture is far from clear.

Across the stock as a whole each person consumes on average 39 litres per day for washing machines, baths and showers. We can make further assumptions about the use of hot water at sinks and basins which adds a further 10 litres to this amount – giving a total use of 49 litres per person per day.

Single households aged under 60 are the highest users of hot water. However, the reasons for this are not clear. Possible reasons for the high usage levels could be:

- No limitations on the use of appliances such as the shower and bath as there is no one else in the household to consider.
- Using the washing machine with a less than full load because certain items are wanted.
- No overlapping savings for combined use of appliances.

Reasons such as those described above are generally the householder's choice rather than necessity, which is supported by their attitudes toward water usage. If fuel prices were to increase by 10% they are the second most likely group to try and cut down on energy usage.

The elderly tend to use the least hot water, in particular the single elderly group. It is difficult to reconcile the low hot water use seen within the single elderly group with the possible reasons for higher use outlined above for the single under 60 group. However, it may be that there are other factors which reduce hot water use in the elderly groups. These factors may include lower incomes among this group and problems with mobility which may affect the ability of an occupant to take baths and showers as regularly.

Non-vulnerable households tend to use high levels of hot water. However, vulnerability is heavy influenced by the issues found within household composition. For example, the elderly pull down vulnerable hot water usage levels and those aged under 60 inflate the non-vulnerable usage levels.

Large households (containing five or more persons) tend to use less hot water than average, but there are no apparent savings for households smaller than this. The savings seen in large households may reflect limitations on use imposed by time available for baths and showers, or by the size of the hot water cylinder.

Analysis by income shows that hot water usage levels are influenced by how much a household can afford. Those with an income level in the lowest third use the least amount of total hot water and are most likely to try and cut back on energy use if prices were to increase by 10%. However, any cut backs made are unlikely to be targeted at hot water as they already use a limited amount. Those in the middle income band use the same total level of hot water as the whole stock. Those in the highest band use the most hot water and are least likely to cut back on energy use if prices were to increase by 10% - probably as they are more likely to be able to afford the price increase. However, if they were to make cutbacks, they would more be more likely to be targeted towards hot water.

Discussion and recommendations

The results of this study show a very mixed picture of hot water use. The best indicators of hot water use appear to be income and age. Other data summarising use by different household groups is less clear.

The analysis presented can only provide an estimate for the total household hot water use because of the limitations of the data. Data about hot water use for washing, shaving and other activities in sinks and basins was not collected in the 1998 survey and assumptions on daily per person use have been made. Additionally, assumptions are made about the amount of hot water used for baths, showers and washing machines. Monitoring data that *measured* the quantity of hot water consumed has not been collected. Consequently, the results can only provide an indication of total hot water use and should not be taken as strictly quantitative without detailed monitoring data. The results are best interpreted as indicative of levels of use, and of relative usage levels between different household groups.

With this in mind, we are able to draw some initial conclusions for fuel poverty calculations.

The current method for estimating hot water use is based on a BREDEM algorithm [1] - which is the following function of the number of household occupants:

Hot water demand (litres/day) = 38 + 25 N (N = number of occupants)

For example, based on this algorithm, all single occupant households are given the same allocation for hot water use (of 63 litres per person per day). All two person households are given an allocation of 44 litres per person per day, all three person households given 38 litres and so on for larger households.

Whereas the estimation of hot water use from the BREDEM algorithm decreases significantly for two, three and four person households, the results presented here from the EFUS data show no decrease over the same range. One of the recommendations of the fuel poverty peer review [6] is to carry out a sensitivity analysis into the effect of adjusting the algorithm to match this characteristic of the EFUS data. This analysis has been completed and the results are presented in a note in Appendix 3 below.

When the unadjusted BREDEM algorithm for hot water use is applied to EHCS data an average figure for hot water consumption of approximately 40 litres per person per day is produced.

Comparing this figure to that presented here (49 litres of hot water per person per day) suggests that households use around 20-25% more hot water than is currently being applied in the fuel poverty modelling. However, caution should be taken with these results for the reasons outlined above. Many assumptions have been made which need to be researched further. Nevertheless, it seems reasonable in the absence of further data, to apply a 20% across-the-board increase in hot water use as outlined in proposal five of the fuel poverty methodology consultation [3].

In conclusion, this research has not provided specific and consistent evidence which would allow the application of different standards of hot water use to different household groups in a balanced way. Therefore, in the absence of further data, the most reasonable action is to increase the allowance for hot water by at least 20% for

all household groups as suggested in proposal five of the fuel poverty methodology consultation [3].

Further work

Several assumptions have been applied about the quantity of hot water used for all appliances, and for the water used at the tap. All assumptions could be tested and confirmed or improved through a detailed monitoring programme of hot water use. Further research could inform the assumptions in BREDEM.

References

[1] Anderson B R, P.F Chapman, N.G Cutland, C. M. Dickson and L. D. Shorrock, BREDEM-12. The BRE Domestic Energy Model – background, philosophy and description, BRE Report: BR 438, BRE, Watford, 2001.

[2] Patterns of demand for water in England and Wales: 1989 to 1999, Ofwat Report, www.ofwat.gov.uk.

[3] Consultation on the methodology used for calculating the number of households in fuel poverty for England, DTI and Defra. April 2004.

[4] Boardman, B *et al.* DECADE 2nd year report, ECI, Oxford University. November 1995.
www.eci.ox.ac.uk/lowercf/decade.html

[5] Washing Machines, Driers and Dishwashers - Final Report. Group for Efficient Appliances (GEA), Working group, European Energy Network. June 1995.
Published by the Danish Energy Authority www.ens.dk

[6] Sefton, T & J. Chesshire. Peer review of the methodology for calculating the number of households in fuel poverty in England. Final report to the DTI and DEFRA.

Appendix 1 – Usage assumptions

Appliance	***Total water used per cycle / use (litres)***	***Percentage hot water***
Washing machine [1]	80	20%
Bath	100	67%
Shower	50	67%

Hand washing of dishes at the sink:
For those without dishwasher = 6 litres hot water per person per day
For those with dishwasher = 3 litres hot water per person per day

Hand and face washing:
5 litres hot water per person per day.

[1] Usage assumptions based on analysis of data contained in GEA report [5].

Appendix 2 - Hot water usage levels (litres per person per day)

	Washing machine usage (litres per person per day)	Bath and shower usage (litres per person per day)	Volume used for hand washing up of dishes at sink (litres per person per day)	Volume used for hand and face washing (litres per person per day)	Total hot water used (litres per person per day)
Whole stock	4	35	5	5	49
Household composition					
Couple under 60, no dependent child(ren)	5	38	5	5	53
Couple over 60, no dependent child(ren)	4	31	5	5	45
Couple with dependent child(ren)	5	33	5	5	48
Lone parent with dependent child(ren)	5	38	6	5	54
Large adult households	4	37	6	5	52
One person, aged under 60 years	6	43	6	5	59
One person, aged 60 years or more	3	28	6	5	42
One or more 60 or more					
None 60 or more	5	38	5	5	53
One or more 60 or more	4	29	6	5	44
One or more under 5 yrs					
None under 5 yrs	4	35	5	5	50
One or more under 5 yrs	5	33	5	5	48
Number of people in household					
1	4	34	6	5	49
2	4	36	5	5	51
3	5	36	5	5	51
4	5	35	5	5	50
5	4	29	5	5	43
6 or more	4	27	6	5	42

Full Income (thirds)					
Lowest third	4	33	6	5	48
Middle third	5	35	5	5	49
Highest third	5	36	5	5	51
Full income (quintiles)					
1st income quintile (lowest)	4	33	6	5	49
2nd income quintile	4	33	6	5	48
3rd income quintile	4	34	5	5	49
4th income quintile	5	36	5	5	51
5th income quintile (highest)	5	37	5	5	51
Vulnerable status					
Not vulnerable	5	41	5	5	56
Vulnerable	4	32	5	5	47
Fuel poverty status (full income definition)					
Not fuel poor	5	35	5	5	50
Fuel poor	4	32	6	5	47
Main water heating					
With central heating	5	36	5	5	50
Dedicated boiler	4	34	6	5	49
Electric immersion	4	32	6	5	47
Instantaneous	4	30	6	5	44
In or out during daytime					
Out during the day	5	40	5	5	55
In during the day	4	32	5	5	47
FP Heating Pattern					
Partial	5	36	5	5	51
Standard	4	39	5	5	54
Full	4	32	6	5	47

Appendix 3 – Adjustment to the water heating algorithm in BREDEM

The current method for estimating hot water use is based on a BREDEM algorithm [1] - which is a function of the number of household occupants:

Hot water demand (litres/day) = 38 + 25 N (N = number of occupants)

All single occupant households are given the same allocation for hot water use of 63 litres per person per day. All two person households are given an allocation of 44 litres per person per day, all three person households given 38 litres and so on for larger households. When the BREDEM algorithm for hot water use is applied to EHCS 2001 data, the average hot water consumption is approximately 40 litres per person per day. This estimation of hot water use from the BREDEM algorithm per person per day decreases significantly for multiple person households. However, the results from the EFUS data show no decrease over the same range – see Figure 4 and Appendix 2.

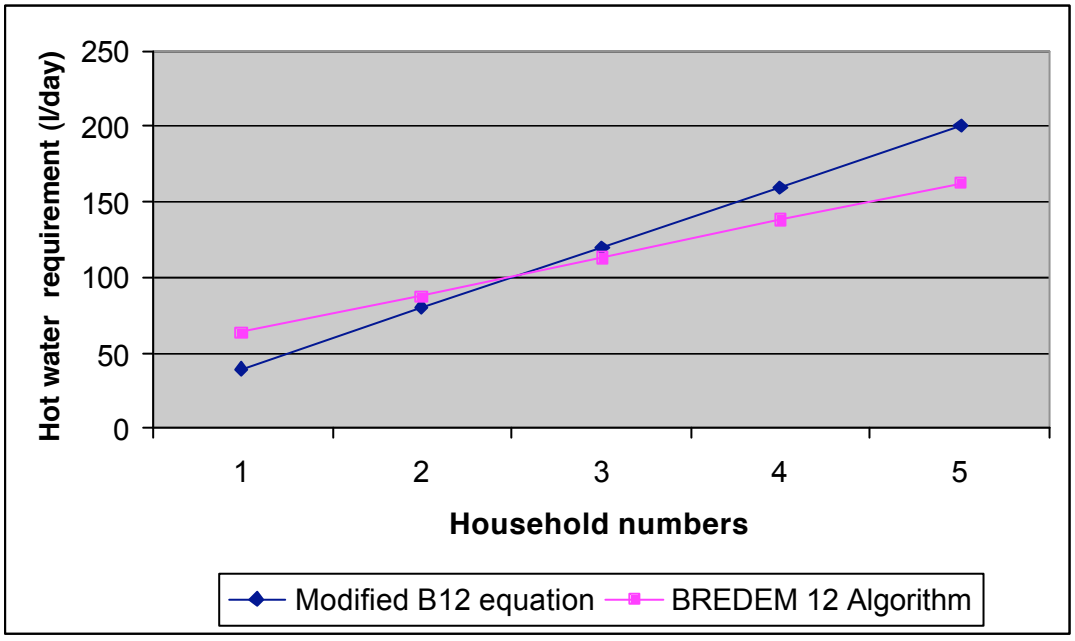

Figure 4: Variation of hot water demand for BREDEM versus modified BREDEM algorithm

The hot water energy at the tap Q_u (W) from BREDEM is given by:

$Q_u = 78 + 52\ N$

Analysis of the 1998 EFUS indicates that hot water use is directly proportional to the number of occupants. Consequently, the BREDEM 12 algorithm has been modified to determine whether the removal of the constant term in the equation (see below) has any significant effect on the number of households in fuel poverty.

Modified equation for hot water use:

$Q_u = 51.85/25 * 40\ N$

Results

The 2001, 2002 and 2003 EHCS databases were used for the analysis. Under the full income definition 2001 fuel poverty numbers decreased by approximately 60,000 households with ~ £1 reduction in average annual fuel costs when the modified hot water algorithm is applied. Basic fuel poverty numbers decreased by a similar amount. 2002 data produced a similar reduction in fuel costs and ~40,000 reduction in fuel poor households. Note that in this analysis the total hot water energy requirement is multiplied by 1.2 to incorporate the additional 20% allowable for higher than average users in BREDEM.

The reduction in fuel poverty numbers appears large when compared to the reduction in fuel bills. However, the difference between the hot water energy requirement for the B12 algorithm and the modified equation increases as occupancy levels move away from the stock mean. This can be seen in Figure 5 below. Hot water energy requirements for households with occupancy levels below the mean decrease, whereas they increase for household occupancy above the mean.

The size of reduction in fuel poverty numbers is due to the distribution of occupancy levels for fuel poor households. The average occupancy for the whole stock is ~ 2.4, however, the average for fuel poor households is closer to 1.5 (a little under 1.5 for the 2002 and 2003 data) and 2.5 for non fuel poor households. The difference in hot water costs between the two methods is almost zero for households with 2.4 occupants and hot water energy requirement decreases for the modified equation at levels below 2.4. The difference increases above 2.4 occupants per household (the non fuel poor).

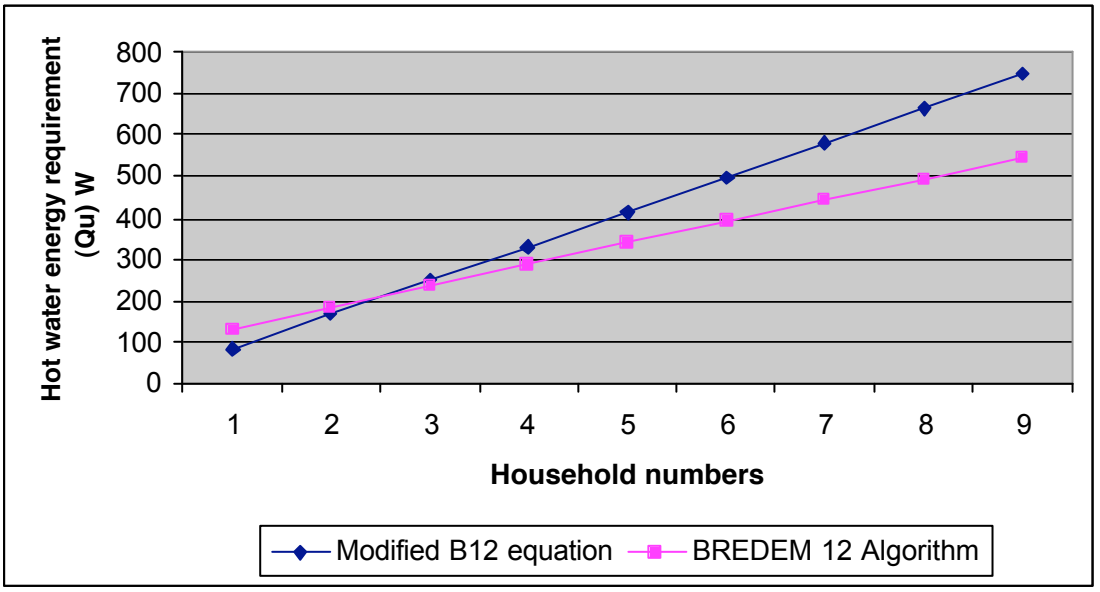

Figure 5: Variation of hot water energy requirement with household number

Summary

Modifying the BREDEM 12 hot water algorithm to remove the constant term slightly decreases BREDEM based heating costs and reduces fuel poverty numbers by ~ 50,000 households.