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Domestic energy fact file

L D Shorrock, G Henderson and J H F Bown

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Purpose of this publication

The purpose of this publication is to gather together in one volume some of the more important data on domestic energy and the measures that have been taken to improve the efficiency with which it is used.

Most of the tables relate to national totals and will be mainly of use to Government Departments and others interested in research or planning at that level.

The present edition covers the period from 1970 (just before the first oil crisis) until 1989, the most recent year for which most of the figures are available.

This is the second edition of the *Domestic energy fact file*. The first edition appeared in 1989 and presented information covering the years from 1970 to 1986. This edition updates the data to 1989 and also introduces some new topics and expands on some of the original topics. Many of the figures for years up to 1986 have been slightly revised in the light of more recent information.

Comments which were received on the first edition have been taken into account in producing this edition. Further editions will be produced in future if there is a continuing demand for the information.

Contents

Outline of the domestic energy fact file

Introduction

The introductory section discusses the main underlying trends affecting domestic energy use and explains that the aim of the report is to highlight such trends.

There is a brief summary of the situation before 1970 followed by an overview of the period between 1970 and 1989.

The introductory section also explains the basis of the tables which appear in the report. Several of those tables rely on the results from the BREHOMES model and so a brief discussion of the model is included.

Following the introductory section there are six main sections:

Section 1

Deals with fuel prices and household expenditure on energy.

Section 2

Is concerned with basic statistics on population, households and the housing stock (age, tenure, dwelling type and regional distribution).

Section 3

Presents information on the uptake of insulation measures in the housing stock.

Section 4

Presents information on changes to the housing stock heat loss, heating systems, temperatures and energy use. This section looks at what would have happened to the energy use of the housing stock if energy efficiency improvements had not been introduced. Section 4 contains the main conclusions on the effectiveness of insulation, improvements in efficiency and the rising standards of service achieved within the housing stock.

Section 5

Draws together the topics discussed in section 4 to illustrate the individual effects of rising levels of service, external temperature variations, improved insulation and improved heating efficiency, and how these combine to determine domestic sector energy consumption.

Section 6

Considers the fuels used to meet the energy demand of the housing stock and the carbon dioxide emissions which result from this fuel use. The primary energy consumption associated with the energy delivered to the housing stock is also addressed in this section. A final energy balance diagram draws together the various topics discussed in the report by showing the main energy flows related to the housing stock.

0 Introduction

Salient trends

The tables in this report highlight certain trends which have been at work since 1970, and so afford the material for predicting their likely interaction in the future. The main underlying trends are as follows:

- Domestic energy consumption tends to increase with income and with the growth of the population.
- Domestic energy consumption tends, on the other hand, to be reduced by improvements in insulation standards and improvements to appliance efficiencies.
- The growth in demand for space heating slows down as more homes begin to approach the ultimate comfort requirements of the occupants.

To bring out these and other trends, the tables in this report show data against all the years in the period under consideration. Some interpolation and estimation has been necessary in order to achieve this. Some tables include notes to indicate where significant manipulation of data was required.

1950-70

This report is concerned with trends in energy use from 1970 onwards. 1970 marks a convenient starting point for two main reasons. Firstly, it precedes the oil crisis and, therefore, it precedes the ensuing surge of activity to improve energy efficiency. Secondly, prior to the early 1970s detailed information on energy efficiency improvements was not collected. Thus, there is very little that can be said in relation to energy efficiency for the period before 1970. Nevertheless, it is of interest to mention briefly the main features of what little is known about that period.

During the two decades up to 1970, the primary energy consumption of the United Kingdom increased in absolute terms - from approximately 6016 PJ (228.1 million tonnes of coal equivalent) in 1950 to 8878 PJ (336.6 million tonnes of coal equivalent) in 1970. *

However, even during that period, energy consumption was already beginning to decline as a proportion of the gross domestic product. The 'energy ratio' (expressed as primary energy - in tonnes of coal equivalent - per £1000 of gross domestic product at 1985 prices) had declined from 1.71 in 1950 to 1.45 in 1970. In this sense, therefore, one concludes that the energy efficiency of the United Kingdom was improving in the period leading up to 1970 - even though energy consumption was rising.

1970-89

Primary energy

In the period after 1970, United Kingdom primary energy consumption declined in absolute terms in response to the oil crises. It reached a low point of 8226 PJ (311.9 million tonnes of coal equivalent) in 1982, rising again to 8973 PJ (340.2 million tonnes of coal equivalent) in 1989 - an increase of only 1.1% on the 1970 consumption. The corresponding energy ratios in 1970, 1982 and 1989 were 1.45, 1.12 and 0.99, respectively.

The figures discussed so far have been in terms of primary energy. In order to investigate individual sectors of the economy it is necessary to consider delivered energy also. Section 6 contains further information on the relationship between primary and delivered energy.

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* In this introductory section the factor relating petajoules to million tonnes of coal has been assumed fixed at 26.375 PJ per million tonnes of coal. In reality, the factor varies slightly from year to year according to the calorific value of the primary fuels.

0 Introduction

Delivered energy

In 1970 the energy delivered to final consumers amounted to 6114 PJ (see Table a). By 1989 this had risen to 6233 PJ - an increase of only 1.9% on the 1970 consumption. A 1.9% increase in delivered energy consumption but only a 1.1% increase in primary energy consumption indicates an improvement in the ratio of delivered energy to primary energy (ie the losses associated with conversion, transmission and distribution have reduced).

The 1.9% increase in delivered energy consumption across all sectors corresponds to an average annual rate of increase of 0.1%. This increase did not take place smoothly, however, so the average annual rate is somewhat misleading (see Figure a).

Variations between sectors

Individual sectors show quite different changes to their delivered energy consumption between 1970 and 1989. In industry, for example, there was a 33% reduction, whilst the railways showed a reduction of almost 40% - mainly because of electrification. In most other sectors, including the domestic sector, delivered energy consumption increased. The rise of 9.0% in the domestic sector, however, was much less than that in other sectors where there is a more or less direct link with final consumer demand. For example, in road transport the increase was 76.5%.

Domestic energy consumption

The increase in delivered energy consumption in the domestic sector did not take place steadily (see Table a and Figure a). Although the average rate of increase over the period was 0.5% per year, up to 1984 the rate was only about 0.2% per year. Domestic energy consumption went through a peak in 1986 which was attributable to a colder than average winter.

Income and fuel prices

These increases in delivered energy consumption have to be viewed against the much higher increase in the gross domestic product at constant prices (up 51.9% at an average annual rate of 2.2%). This indicates that the demand for energy was not rising in line with increasing income. Because of the rise in incomes and the improved levels of heating, domestic energy consumption might have been expected to rise much faster than it actually did. The fact that it did not do so can be attributed to improved standards of insulation and other energy efficiency measures. Section 1 considers income and energy expenditure in greater detail.

Average household consumption

In fact, as shown in section 4, between 1970 and 1989, not only has the rise in domestic energy consumption been contained, it has actually declined slightly on a per household basis. Whilst the average rate of increase of the domestic sector energy consumption was 0.5% per year, the number of households increased at a rate of 1.0% per year.

Basis of tables

Geographical coverage

Unless otherwise stated, the figures in the tables are for Great Britain. Most of our sources are confined to Great Britain, and the relationships are clearer if the same basis is used throughout. As can be seen from Table a and Figure a, however, the difference between the domestic energy use of Great Britain and that of the United Kingdom only amounts to about 3%. Therefore, although most of the information in this report refers to Great Britain, it can, in general, be assumed to apply equally well to the United Kingdom when suitably scaled up.

The difference between the United Kingdom and Great Britain is that the former includes Northern Ireland whilst the latter does not. It should be noted that Northern Ireland does differ from the rest of the United Kingdom in one important respect with regard to domestic energy use. There is no natural gas in Northern Ireland, whereas natural gas is the dominant fuel throughout the United Kingdom. This must be kept in mind when considering scaling up numbers where the different fuel types are important.

0 Introduction

Occupied dwellings and energy use

Figures for the national housing stock are published in *Housing and Construction Statistics*[1]. Mid-year figures from that publication have been used as a source for many of the tables in this report. However, buildings do not use energy: people use energy. Consequently, it is the number of occupied dwellings which is important, rather than the total number of dwellings. For this reason, a factor has been applied to the stock figures to eliminate unoccupied dwellings. The resulting figures appear in the tables under the heading 'Total houses'.

Except where the context calls for a specific distinction to be made between houses and flats, the term 'house' is used to mean all types of dwelling.

BREHOMES

Sections 1, 2 and 3 present factual statistical information. Sections 4, 5 and 6 present some factual statistical information but also make use of estimates which have been made by using the Building Research Establishment Housing Model for Energy Studies (BREHOMES). The source for such estimates is simply quoted as being BREHOMES. It is beyond the scope of this report to explain fully the origins of such estimates because the explanations would be lengthy and they would require an understanding of the BREHOMES model itself. A very brief description follows which should help the reader appreciate, in broad terms, the essential features of the BREHOMES model. The model has been described in detail elsewhere [2].

BREHOMES is a physically based model of energy use in the housing stock which uses the Building Research Establishment Domestic Energy Model (BREDEM)[3], to calculate the energy use of individual categories of dwelling. Over 400 categories of dwelling are defined according to age, built form, tenure and the ownership of central heating. The contributions of each category are calculated and summed to produce an estimate of the housing stock energy use. The estimate is refined by small changes to the internal temperature assumptions until it exactly matches the actual housing stock energy use. When this has been achieved, the model can then be used for predictive purposes.

The information needed to run the BREHOMES model is derived from the statistical sources used for the tables in sections 1, 2 and 3 of this report, amongst others. One particular source which is not used directly for the tables in this report but which forms an important input to BREHOMES is the *English House Condition Survey*[4]. These sources contain much information related to energy use in housing but they are not sufficient individually to form a coherent picture of the energy use of the housing stock. BREHOMES provides the means to bring the information together in a form which does allow a coherent picture to be developed, as described above. As a part of this process, estimates emerge for some important quantities which can not actually be measured or be readily determined from the statistical sources alone. Examples of some of these, such as the heat loss of the average dwelling, appear in section 4 of this report.

Energy consumption 1970 to 1989

Notes

Table a and Figure a show the total United Kingdom delivered energy consumption between 1970 and 1989. Also shown is the domestic sector consumption for the United Kingdom and for Great Britain. Figures for Great Britain have been estimated using the United Kingdom figures and regional figures from the *Digest of United Kingdom Energy Statistics*[5].

Domestic sector energy consumption is defined as energy used in dwellings. It excludes petrol use for family cars (which is classified separately under transport) and energy used in residential establishments such as hotels.

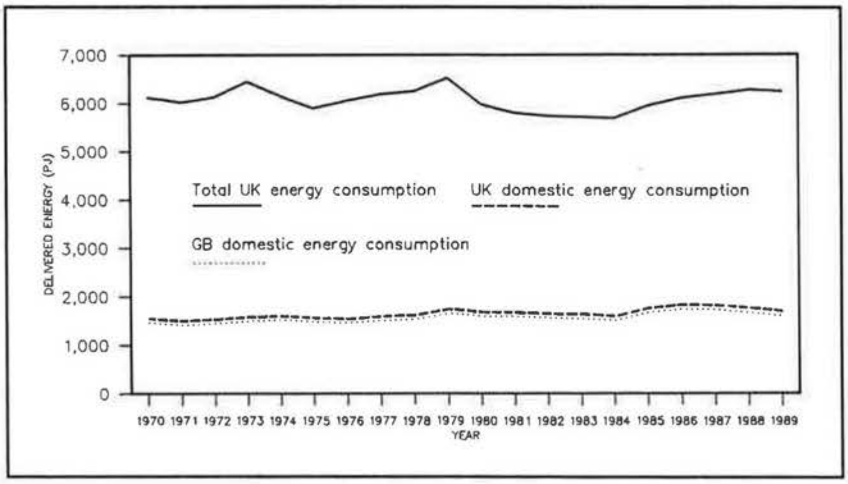
Table a: Delivered energy consumption 1970 - 89

UK/GB PJ

Year	UK Total	UK domestic	GB domestic
1970	6,114	1,545	1,502
1971	6,014	1,492	1,453
1972	6,124	1,519	1,482
1973	6,439	1,574	1,531
1974	6,149	1,592	1,544
1975	5,895	1,552	1,503
1976	6,048	1,534	1,488
1977	6,176	1,587	1,539
1978	6,238	1,620	1,572
1979	6,509	1,741	1,686
1980	5,965	1,669	1,620
1981	5,794	1,662	1,615
1982	5,727	1,643	1,592
1983	5,713	1,635	1,585
1984	5,688	1,587	1,541
1985	5,945	1,762	1,696
1986	6,103	1,830	1,768
1987	6,191	1,820	1,760
1988	6,275	1,765	1,708
1989	6,233	1,696	1,638

Source: Digest of United Kingdom Energy Statistics

Figure a: Delivered energy consumption 1970 - 89



1 Fuel prices, income and energy expenditure

Main trends

The amount of energy which households consume is determined largely by the level of service which they wish to achieve (for example, whole house heating or only partial heating). This level of service determines the energy consumption through physical factors (the insulation standard of the dwelling, the efficiency of heating, the efficiency of appliances, etc). The level of service which is chosen, in turn, depends, in part, on the cost of achieving that level. Clearly, this depends on the cost of the energy used and on the disposable income of the household.

Fuel prices, income and energy expenditure are considered in this section and it is shown that, overall, fuel price variations have not had much direct effect on domestic energy use over the past two decades. Rather, physical factors, as discussed in the following sections, offer the best explanation of the observed pattern of domestic energy use .

However, although this is true at an overall level, there can be no doubt that in many individual households this conclusion will not apply. For example, in a household which can not afford to reach its desired level of service there will be a tendency to spend any extra disposable income on getting closer to that level - particularly in cases where the existing level is very low.

Domestic fuel prices

The average domestic fuel price has not altered substantially in real terms over the period between 1970 and 1989. Although there have been occasional divergences, the domestic fuel price index has broadly kept pace with the retail price index.

It is interesting to note, however, that the real price of gas was falling at the time of both oil crises - most markedly at the time of the first oil crisis. This, undoubtedly, was a major factor in the rapid establishment of natural gas as the preferred fuel within the domestic sector (see section 6).

Average household expenditure

In real terms, the average household expenditure on fuel, light and power has remained relatively constant.

Thus, one concludes that the average energy consumption per household must have remained relatively constant. As shown in section 4, this conclusion is correct - the average energy consumption per household has actually declined very slightly.

Therefore, it would appear that, over the past two decades, fuel prices have not played a major role in determining total domestic sector energy consumption. In real terms, households have not, in general, increased their expenditure on energy as their incomes have increased.

Individual household expenditure

However, despite the overall constancy of average expenditure, there are many households who are likely to be achieving a lower level of service than they would wish. Up to a certain income level households invest a higher proportion of extra income on warmth than households earning above that level.

Notes

Table 1.i and Figure 1.i illustrate the change in the index of fuel prices as against the index of retail prices. Clearly there have been times when fuel prices were rising more rapidly than retail prices. Equally, there have been times when the opposite was true. Over the whole period, however, the two price indices have roughly kept pace with one another.

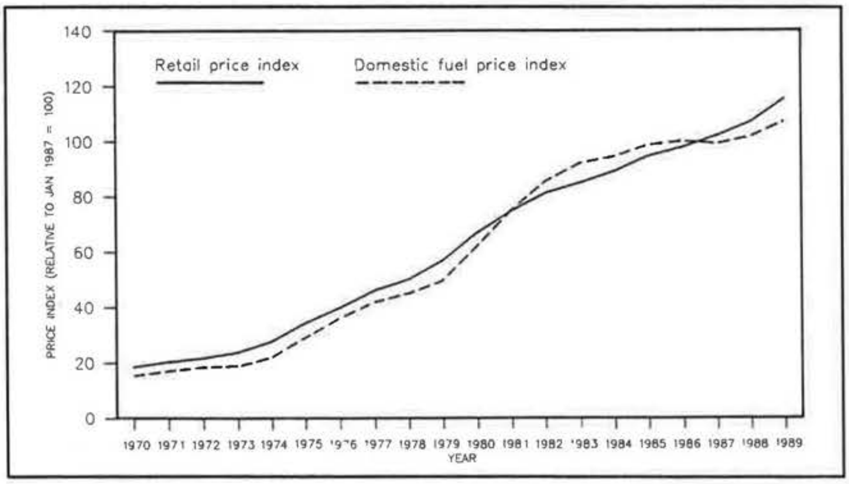
Table 1.i: Retail price index and fuel price index

UK

Year	Retail price index (Jan 87=100)	Fuel price index (Jan 87=100)
1970	18.5	15.3
1971	20.3	16.9
1972	21.7	18.2
1973	23.7	18.7
1974	27.5	21.9
1975	34.2	29.1
1976	39.8	36.0
1977	46.1	41.8
1978	50.0	45.0
1979	56.7	49.5
1980	66.8	61.9
1981	74.8	75.1
1982	81.2	85.6
1983	84.9	92.0
1984	89.2	94.6
1985	94.6	98.7
1986	97.8	100.0
1987	101.9	99.1
1988	106.9	101.6
1989	115.2	107.3

Source: Digest of United Kingdom Energy Statistics

Figure 1.i: Retail price index and fuel price index



Domestic fuel prices

Notes

Table 1.ii and Figure 1.ii show the average domestic fuel prices corrected, using the retail price index figures from Table 1.i, to 1989 money values. These prices are inclusive of any standing charges and encompass all relevant tariffs.

Clearly, the weighted mean shows very little variation between 1970 and 1989 - confirming the conclusion reached by comparing price indices.

Individual fuels, however, have shown quite marked changes. Figure 1.ii shows quite clearly the oil price shocks and the slump in prices in the mid-1980s. To some extent, electricity prices follow a similar pattern.

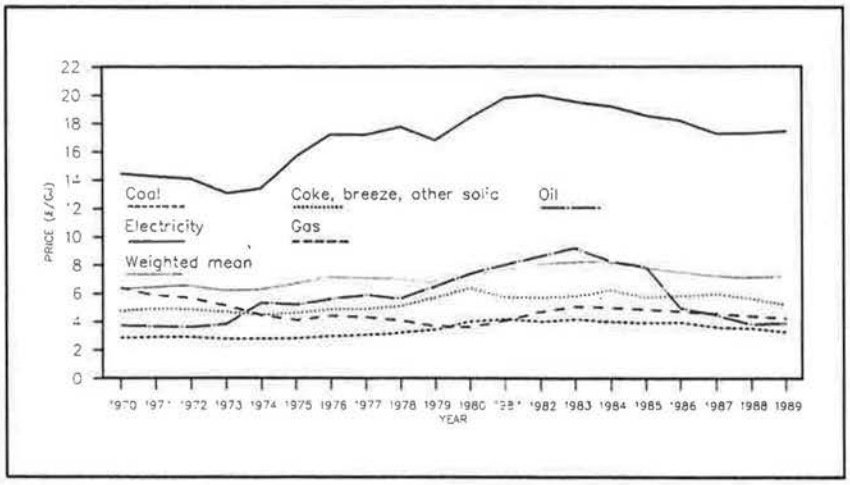
Table 1.ii: Domestic sector fuel prices corrected to 1989 money values

UK £/GJ

Year	Coal	Coke, breeze & other solid	Gas	Electricity	Oil	Weighted mean
1970	2.87	4.78	6.41	14.48	3.76	6.09
1971	2.95	4.94	5.89	14.26	3.66	6.22
1972	2.93	4.87	5.64	14.08	3.63	6.31
1973	2.80	4.71	5.12	13.08	3.87	5.96
1974	2.81	4.50	4.46	13.44	5.36	6.00
1975	2.83	4.65	4.12	15.67	5.23	6.36
1976	3.01	4.89	4.43	17.23	5.64	6.83
1977	3.08	4.91	4.33	17.25	5.88	6.76
1978	3.24	5.12	4.09	17.75	5.64	6.73
1979	3.44	5.72	3.69	16.83	6.51	6.41
1980	4.04	6.39	3.63	18.41	7.41	6.84
1981	4.23	5.74	4.10	19.78	8.06	7.31
1982	4.02	5.72	4.73	19.99	8.66	7.67
1983	4.19	5.82	5.10	19.54	9.21	7.87
1984	4.01	6.24	5.01	19.22	8.27	7.83
1985	3.95	5.74	4.88	18.56	7.88	7.41
1986	3.97	5.85	4.73	18.21	4.99	7.09
1987	3.62	5.98	4.56	17.31	4.47	6.84
1988	3.53	5.65	4.37	17.30	3.85	6.72
1989	3.26	5.22	4.26	17.46	3.89	6.75

Source: Digest of United Kingdom Energy Statistics

Figure 1.ii: Domestic sector fuel prices corrected to 1989 money values



Notes

Table 1.iii gives average household weekly expenditures on fuel, light and power and on all goods. The first two columns of Table 1.iii show the actual expenditures year by year, while the next two columns show these same expenditures deflated by the Retail Price Index from Table 1.i. These corrected expenditures are also shown graphically in Figure 1.iii.

It is clear that, in real terms, expenditure on all goods has increased noticeably as incomes have increased, whilst expenditure on fuel, light and power has remained relatively constant. Consequently, as a proportion of total expenditure, the expenditure on fuel, light and power has declined slightly from about 6% to about 5% between the early 1970s and the late 1980's (see final column of Table 1.iii).

The average fuel price, as well as the average expenditure on fuel, light and power, has remained relatively constant in real terms. Thus one concludes that the average energy consumption per household also remained relatively constant. In fact as shown in section 4, the average energy consumption per household has actually declined very slightly. In real terms, households have not, in general, increased their energy use as their incomes have increased. At the same time, it is clear that the levels of service being achieved have improved markedly (see for example, the growth in central heating illustrated in Figure 4.iii). This apparent paradox can be resolved by considering physical factors, as discussed in the following sections.

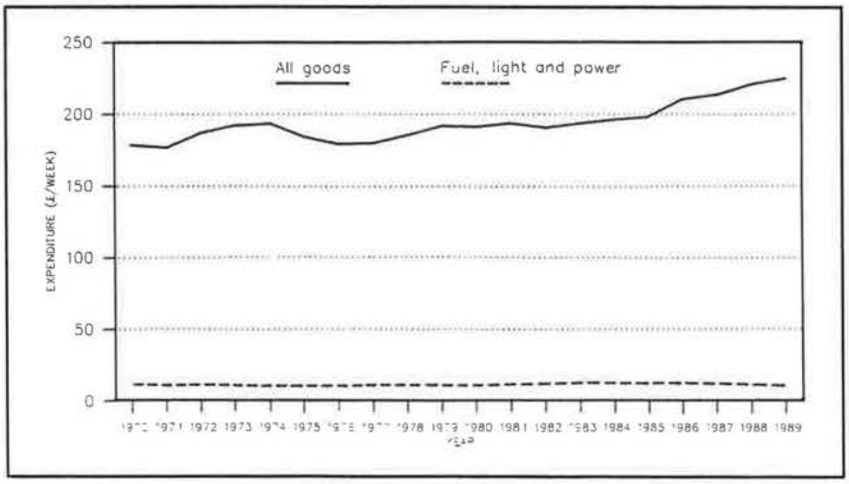
Table 1.iii: Average weekly expenditures on all goods, fuel, light and power

UK £/week

	Contemporary prices		1989 prices		
Year	All goods	Fuel, light and power	All goods	Fuel, light and power	% on fuel light and power
1970	28.57	1.79	177.91	11.15	6.3%
1971	30.99	1.85	175.86	10.50	6.0%
1972	35.06	2.06	186.12	10.94	5.9%
1973	39.43	2.17	191.66	10.55	5.5%
1974	46.13	2.42	193.24	10.14	5.2%
1975	54.58	2.99	183.85	10.07	5.5%
1976	61.70	3.53	178.59	10.22	5.7%
1977	71.84	4.38	179.52	10.95	6.1%
1978	80.26	4.76	184.92	10.97	5.9%
1979	94.17	5.25	191.33	10.67	5.6%
1980	110.60	6.15	190.74	10.61	5.6%
1981	125.41	7.46	193.14	11.49	5.9%
1982	133.92	8.35	189.99	11.85	6.2%
1983	142.59	9.22	193.48	12.51	6.5%
1984	151.92	9.42	196.20	12.17	6.2%
1985	162.50	9.95	197.89	12.12	6.1%
1986	178.10	10.43	209.79	12.29	5.9%
1987	188.62	10.55	213.24	11.93	5.6%
1988	204.41	10.48	220.28	11.29	5.1%
1989	224.32	10.58	224.32	10.58	4.7%

Source: Family Expenditure Survey [6]

Figure 1.iii: Average weekly expenditures on all goods, fuel, light and power at 1989 prices



Notes

Table 1.iv examines the effect of income on energy expenditure in more detail. This can only readily be done for a single year. Clearly, the year of greatest interest is the most recent one for which the data exists - 1989.

Table 1.iv shows average weekly expenditure on all goods and on fuel, light and power related to weekly income. The proportion of income spent on fuel, light and power varies between less than 3% for the most well off households up to about 13% for the lowest income households. The problems of the lower income groups are clear from the 'all goods' expenditure figures - many households, up to incomes of about £150 per week, have expenditures which are greater than their incomes. There are about 6 million low income households altogether and many of them are likely to be achieving a lower level of service than they would wish - ie they are more likely to be living in colder houses and be more anxious to spend any extra income they might have on warmth.

Figure 1.iv shows how expenditure on fuel, light and power varies with income. The slope of the line up to about £150 per week income implies an extra 2.1 pence spent on energy for every additional pound of income. Above £150 per week income the slope is much shallower at only 0.7 pence per additional pound of income. It is probable that these households spend all that they want to on warmth and other energy services. The shallow slope of the line is to be expected because those with higher incomes will tend to live in larger houses and so they will need to spend more on heating, lighting, etc.

Table 1.iv: Weekly expenditure on fuel, light and power by income - 1989

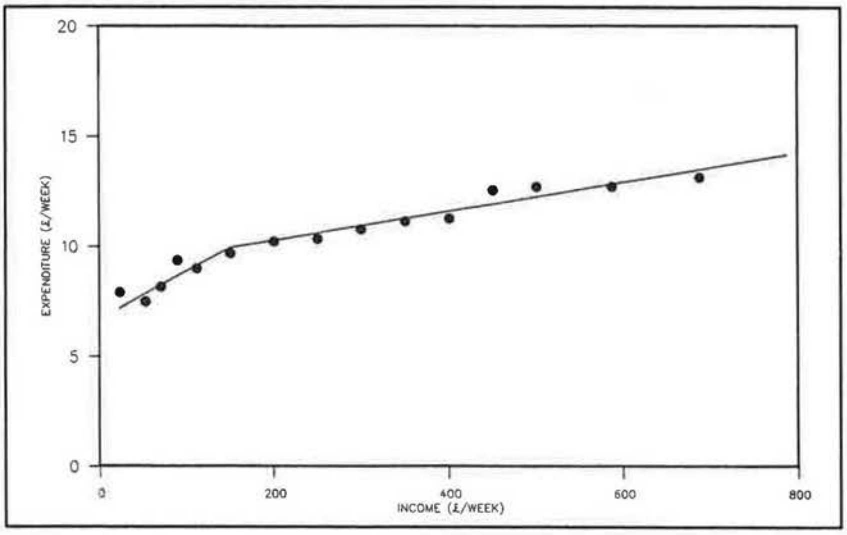
UK £/week

Weekly income*	Weekly expenditure all goods	Weekly expenditure fuel, light and power	% on fuel, light &power
0-45	67.26	7.91	11.8%
45-60	57.43	7.48	13.0%
60-80	83.05	8.12	9.8%
80-100	100.65	9.35	9.3%
100-125	123.10	8.98	7.3%
125-175	150.55	9.67	6.4%
175-225	181.57	10.21	5.6%
225-275	205.12	10.30	5.0%
275-325	253.25	10.75	4.2%
325-375	257.71	11.13	4.3%
375-425	277.50	11.27	4.1%
425-475	330.69	12.55	3.8%
475-550	352.08	12.74	3.6%
550-625	389.01	12.68	3.3%
625-750	406.06	13.14	3.2%
750+	568.76	15.24	2.7%

Source: Family Expenditure Survey

* The income ranges should be interpreted as meaning up to, but not including, the higher figure.

Figure 1.iv: Weekly expenditure on fuel, light and power by income - 1989



2 Population, households and the housing stock

Main trends

National domestic energy use is affected by the size of the population and the number of households, and by the composition of the housing stock in terms of age, building type, tenure and regional distribution.

Number and size of households The number of households has increased, while the number of occupants per household has decreased. The trend to smaller households would result, all other things being equal, in a higher consumption per capita.

Age of stock The growth of the housing stock has been subject to increasingly strict Building Regulation thermal requirements. Demolition tends to be of older, less well insulated dwellings. This tends to improve energy efficiency over time.

Effect of tenure Owner occupation has become an increasingly common form of tenure, making more occupiers directly responsible for the thermal performance of dwellings.

Dwelling types There has been a small growth in the proportion of detached dwellings tending to increase the average heat loss per dwelling.

Geographical location Climatic variations have a large effect on heating requirements. Regional distribution of the housing stock is biased towards the warmer south east of Britain; the trend is slightly to increase that bias.

Population and the number of households

Notes

Table 2.i shows figures for the total population of Great Britain and the number of households. These figures are also illustrated in Figure 2.i. The population has been growing at an average rate of about 0.15% per year, whilst the number of households has been rising at an average rate of about 1% per year.

Thus, the number of occupants per household has been declining. There has been a trend towards smaller family groups and single occupancy. Although a dwelling with fewer occupants will generally consume less energy than one with more occupants, there is, for a given level of service, a consumption which would be required regardless of the number of occupants. Thus, any trend towards smaller households would lead, all other things being equal, to a greater consumption per capita.

The last column of Table 2.i shows figures for the mean household size taken from the *General Household Survey*[7]. The figures in the column to the left have been obtained by a simple division of households into population. The figures in the last column are lower and more appropriate for assessing energy demand in dwellings. They exclude certain categories of the national population - residents of institutions, members of the armed forces and others not living in dwellings.

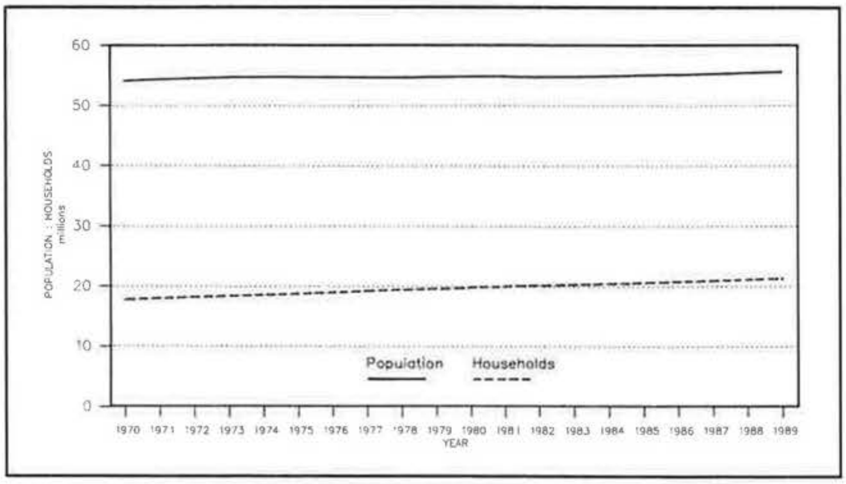
Table 2.i: Population, households, and household size

GB — Various units

Year	Population [1,000s]	Households [1,000s]	Population/ h'holds	Mean h'hold size
1970	54,105	17,759	3.05	
1971	54,369	17,990	3.02	2.91
1972	54,537	18,192	3.00	
1973	54,671	18,367	2.98	2.83
1974	54,685	18,545	2.95	
1975	54,676	18,747	2.92	2.78
1976	54,664	18,971	2.88	
1977	54,636	19,203	2.85	2.71
1978	54,621	19,401	2.82	
1979	54,675	19,575	2.79	2.67
1980	54,756	19,756	2.77	
1981	54,814	19,921	2.75	2.70
1982	54,768	20,067	2.73	
1983	54,804	20,225	2.71	2.64
1984	54,938	20,402	2.69	2.59
1985	55,061	20,580	2.68	2.56
1986	55,196	20,760	2.66	2.55
1987	55,355	20,945	2.64	2.55
1988	55,487	21,138	2.62	2.48
1989	55,653	21,340	2.61	

Sources: Population - Annual Abstract of Statistics [8].
Households - Housing and Construction Statistics (see note in Introduction)
Mean Household Size - General Household Survey

Figure 2.i: Households and population



Age of the housing stock

Notes

There are a number of age related factors which affect the energy characteristics of houses. The growth of the housing stock is accounted for by the net effect of new building and the conversion or demolition of older properties. This is illustrated in Table 2.ii and Figure 2.ii.

New building work takes place under the stricter thermal requirements of more recent Building Regulations, while the demolition is mostly of older properties built when the regulations were less strict or before any thermal regulations existed.

New standards were introduced nationally via Building Regulations in 1965, 1976, 1982 and 1990; the most significant provisions being for the U-values of roofs (1.42, 0.6, 0.35 and 0.25 W/m²°C for the four years respectively) and for the U-values of walls (1.7, 1.0, 0.6 and 0.45 W/m²°C). The 1990 revision of the Building Regulations introduced, for the first time, a provision for ground floors (U-value of 0.45 W/m²°C).

Since the beginning of the century there has been an increase in the number of houses built with cavity walls. Looking at the present stock of houses, only 19% of those built before 1918 have cavity walls, whilst over 96% of those built since 1970 have cavity walls. Un-insulated cavity walls have lower U-values than comparable un-insulated solid walls. Insulation of cavity walls to improve the U-value still further is usually relatively simple and cost-effective and can be carried out as a retro-fit measure. Improvement of solid walls is more complicated and is usually only cost-effective where the walls are in need of refurbishment anyway.

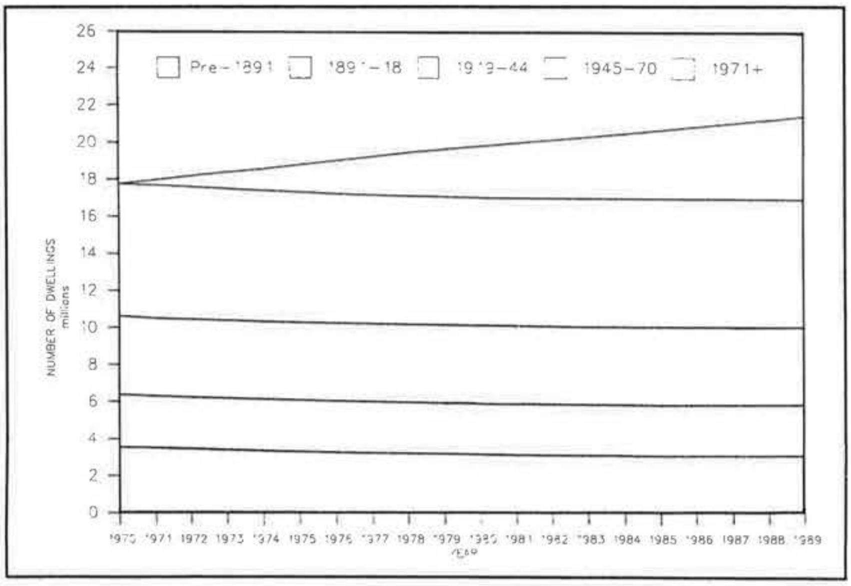
Table 2.ii: Housing stock distribution by age

GB 1,000s

Year	Pre-1891	1891-18	1919-44	1945-70	1971+	Total houses
1970	3,570	2,841	4,244	7,104	0	17,759
1971	3,524	2,798	4,196	7,189	283	17,990
1972	3,469	2,786	4,196	7,165	576	18,192
1973	3,149	2,782	4,196	7,115	855	18,367
1974	3,352	2,781	4,196	7,071	1,145	18,545
1975	3,320	2,779	4,196	7,012	1,440	18,747
1976	3,272	2,779	4,196	6,979	1,745	18,971
1977	3,245	2,779	4,196	6,940	2,043	19,203
1978	3,221	2,774	4,196	6,898	2,312	19,401
1979	3,191	2,760	4,196	6,898	2,530	19,575
1980	3,141	2,760	4,196	6,898	2,761	19,756
1981	3,128	2,760	4,196	6,898	2,939	19,921
1982	3,110	2,749	4,194	6,898	3,116	20,067
1983	3,094	2,749	4,194	6,898	3,290	20,225
1984	3,081	2,749	4,194	6,897	3,481	20,402
1985	3,081	2,735	4,194	6,897	3,673	20,580
1986	3,081	2,735	4,193	6,897	3,854	20,760
1987	3,081	2,735	4,176	6,897	4,056	20,945
1988	3,081	2,735	4,175	6,887	4,260	21,138
1989	3,081	2,735	4,175	6,887	4,462	21,340

Source: Housing and Construction Statistics.
The source for this table gives a percentage breakdown rather than absolute figures. The source percentages are quoted to the nearest 0.1% and derived from totals which differ from those used above.

Figure 2.ii: Housing stock distribution by age



Housing stock distribution by tenure

Notes

Table 2.iii shows the distribution of the housing stock by tenure. The number of owner occupied houses has grown as a proportion from 50% in 1970 to 66.5% in 1989. In contrast, private rented acommodation mirrored this change - it decreased as a proportion from 19.5% in 1970 to 7.5% in 1989.

The stock of local authority housing increased up to 1981 but it has since declined. In recent years, housing association dwellings have also become a significant part of the total stock (note: data on these is not available prior to 1981).

Figure 2.iii illustrates the changes in the distribution of the housing stock by tenure.

Owner occupiers are more likely to invest in energy efficiency measures than those in rented accomodation. The latter are not directly responsible for their homes and may be limited in what they are allowed to do. For example, 92% of owner occupiers with accessible lofts have their lofts insulated, while the proportion for tenants of private landlords is 73%. For tenants of public sector landlords the corresponding proportion is 89%.

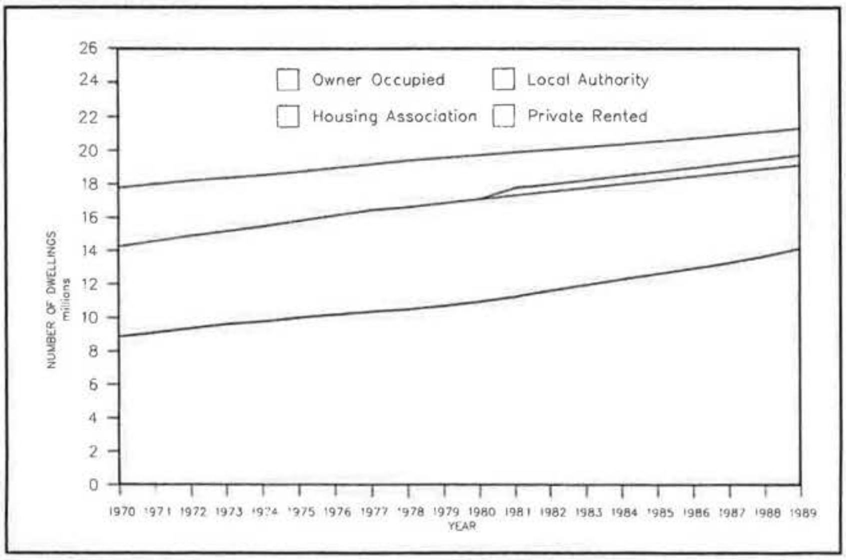
Table 2.iii: Housing stock distribution by tenure

GB 1,000s

Year	Owner occupied	Local authority	Private rented	Housing assoc.	Total houses
1970	8,871	5,402	3,486	-	17,759
1971	9,088	5,508	3,394	-	17,990
1972	9,365	5,553	3,274	-	18,192
1973	9,606	5,600	3,161	-	18,367
1974	9,770	5,720	3,055	-	18,545
1975	10,004	5,835	2,908	-	18,747
1976	10,194	5,964	2,813	-	18,971
1977	10,390	6,083	2,730	-	19,203
1978	10,502	6,126	2,773	-	19,401
1979	10,711	6,155	2,709	-	19,575
1980	10,967	6,135	2,654	-	19,756
1981	11,265	6,084	2,132	440	19,921
1982	11,661	5,904	2,051	451	20,067
1983	12,009	5,772	1,976	468	20,225
1984	12,347	5,672	1,896	487	20,402
1985	12,664	5,586	1,822	508	20,580
1986	12,980	5,502	1,755	523	20,760
1987	13,319	5,394	1,692	540	20,945
1988	13,725	5,226	1,624	563	21,138
1989	14,201	4,972	1,571	596	21,340

Source: Housing and Construction Statistics.
Figures from the above source have been adjusted pro-rata to give the same totals of occupied dwellings used elsewhere in this publication.

Figure 2.iii: Housing stock distribution by tenure



House types

Note

Semi-detached and terraced houses together account for more than half of the housing stock (30.5% and 28.9% respectively in 1989), as illustrated in Figure 2.iv.

The proportions of different dwelling types have not changed significantly since 1970, as shown in Table 2.iv.

The only appreciable change has been a rise of about 4.6% in the proportion of detached houses (from 10.4% in 1976 to 15.0% in 1989).

A detached house will have a greater surface to volume ratio and, hence, greater heat loss than any other dwelling type built to the same standard using the same materials. Detached houses are also likely to have greater floor areas than other types of dwelling.

Such considerations mean that the characteristic heat losses of different house types are appreciably different. For example, typical heat losses of existing, recently (post 1976) constructed dwellings would be as follows: detached 345 W/°C, semi-detached 260 W/°C, end terrace 260 W/°C, mid terrace 220 W/°C, bungalow 255 W/°C, flats 185 W/°C.

The overall average heat loss for dwellings of this age would be about 260W/°C, compared with an average for the whole stock of 293W/°C (see Table 4.ii).

Clearly, the slight shift towards more detached houses will tend to have the effect of increasing the energy consumption of the housing stock other things being equal.

Table 2.iv: Housing stock distribution by type of dwelling

GB | 1.000s

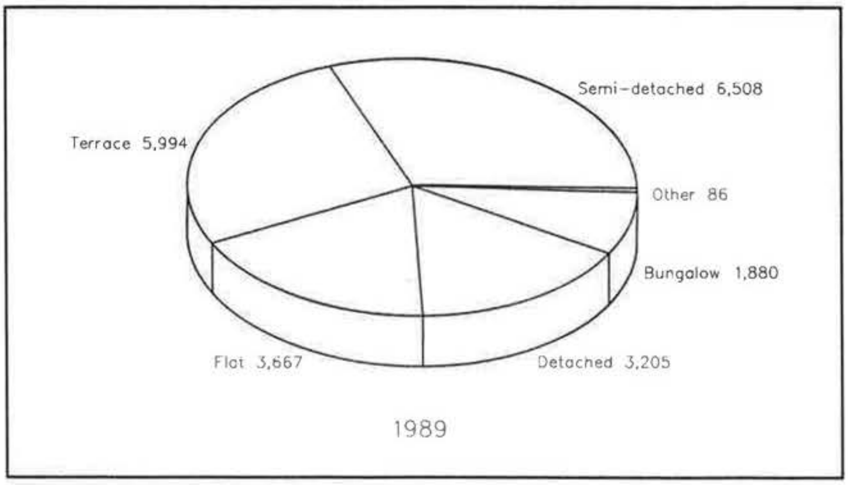
Year	Semi-detached	Terrace	Flat	Detached	Bungalow	Other	Total houses
1970	6,061	5,538	2,789	1,848	1,344	179	17.759
1971	6,116	5,577	2,879	1,871	1,368	179	17.990
1972	6,234	5,555	3,151	1,721	1,356	175	18.192
1973	6,304	5,550	3,327	1,654	1,359	173	18.367
1974	6,337	5,570	3,413	1,672	1,380	173	18.545
1975	6,342	5,621	3,413	1,776	1,419	176	18.747
1976	6,316	5,702	3,327	1,967	1,477	182	18.971
1977	6,278	5,804	3,185	2,203	1,544	189	19.203
1978	6,213	5,679	3,235	2,347	1,622	305	19,401
1979	6,419	5,845	3,013	2,520	1,589	189	19,575
1980	6,265	6,213	3,064	2,459	1,550	205	19,756
1981	6,280	6,061	3,053	2,653	1,675	199	19,921
1982	6,330	6,106	3,075	2,670	1,686	200	20,067
1983	6,347	6,148	3,114	2,715	1,759	142	20.225
1984	6,404	6,203	3,143	2,734	1,774	144	20.402
1985	6,446	6,202	3,207	2,811	1,791	123	20.580
1986	6,517	6,270	3,218	2,824	1,806	125	20.760
1987	6,452	6,201	3,346	2,954	1,887	105	20.945
1988	6,447	6,173	3,444	3,046	1,901	127	21.138
1989	6,508	5,994	3,667	3,205	1,880	86	21,340

Source: G&A Home Audit[9].

Figures have been available from the above source covering the years 1976 to 1989.

Figures for previous years have been estimated by extrapolation.

Figure 2.iv: Housing stock distribution by type of dwelling



Regional distribution of the housing stock

Notes

Because of climatic differences, the space heating energy requirement of houses differs from region to region. For example, in an average year it would require nearly 45% more energy to maintain a given temperature in a house in Scotland than it would for the same house in the South West. Large variations within any one region are also possible.

In Table 2.v the housing stock is shown region by region. The order of the columns is from the warmest region to the coldest.

Almost one third of the housing stock is in the South Eastern region of the country, as illustrated in Figure 2.v. This proportion has not changed significantly over the years.

Over the period under consideration there has been very little change in the regional distribution of the housing stock. What change there has been has generally involved movements from colder into warmer regions. The proportion of dwellings in Scotland has decreased by 0.3% and the proportion of homes in the North, North West and Yorkshire/ Humberside has fallen, for all three regions together, by 2.2%. The proportion of the housing stock in the South West, on the other hand, has risen by 1.5%.

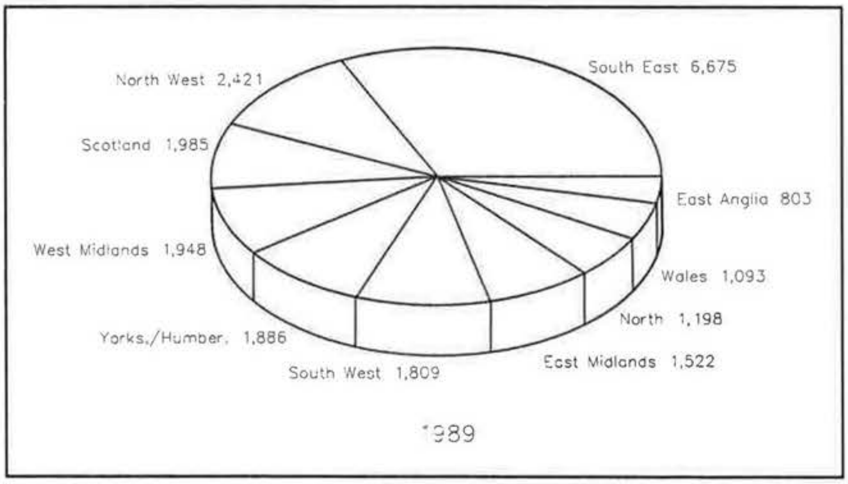
Table 2.v: Housing stock distribution by region

GB 1,000s

Year	South West	Wales	South East	East Anglia	Yorks Humber	East Mids	West Mids	North West	North	Scot -land	Total houses
1970	1,267	905	5.586	576	1,641	1.127	1,623	2,226	1,096	1,703	17,759
1971	1,398	916	5.578	587	1,659	1.226	1,654	2,199	1,048	1,725	17,990
1972	1,418	925	5.631	645	1,664	1.241	1,666	2,212	1,055	1,735	18,192
1973	1,447	938	5.703	611	1,679	1.261	1,683	2,229	1,065	1,751	18,367
1974	1,466	947	5.766	623	1,690	1.276	1,697	2,239	1,076	1,765	18,545
1975	1,487	960	5.837	635	1,701	1.293	1,714	2,251	1,084	1,785	18,747
1976	1,508	970	5,914	648	1,715	1.310	1,736	2,263	1,096	1,811	18,971
1977	1,533	983	5,998	660	1,729	1.332	1,757	2,277	1,104	1,830	19,203
1978	1,548	988	6.102	670	1,736	1.345	1,772	2,287	1,109	1,844	19,401
1979	1,572	998	6.132	681	1,752	1.361	1,794	2,302	1,118	1,865	19,575
1980	1,614	1,006	6,147	700	1,779	1.381	1,809	2,312	1,132	1,876	19,756
1981	1,633	1,025	6,210	709	1,790	1.395	1,826	2,325	1,140	1,868	19,921
1982	1,651	1,030	6,269	717	1,799	1.406	1,839	2,334	1,144	1,878	20,067
1983	1,670	1,036	6,326	726	1,807	1.420	1,853	2,345	1,151	1,891	20,225
1984	1,690	1,044	6,391	738	1,817	1.433	1,868	2,357	1,157	1,907	20,402
1985	1,714	1,053	6,458	748	1,828	1.445	1,883	2,366	1,163	1,922	20,580
1986	1,738	1,064	6,472	763	1,845	1.469	1,904	2,383	1,177	1,945	20,760
1987	1,760	1,072	6,536	775	1,857	1.487	1,918	2,396	1,184	1,960	20,945
1988	1,783	1,083	6,603	787	1,871	1.505	1,933	2,408	1,189	1,976	21,138
1989	1,809	1,093	6,675	803	1,886	1,522	1,948	2,421	1,198	1,985	21,340

Source: Housing and Construction Statistics.
Figures from the above source have been adjusted pro-rata to give the same totals of occupied dwellings used elsewhere in this publication.

Figure 2.v: Housing stock distribution by region



3 Insulation

Main trends

Figures on the acquisition and ownership of insulation have been gathered since 1974 by the market research organisation G & A Marketing Services Ltd (formerly AGB) as part of the *G & A Home Audit*. Figures from this source have been adjusted pro-rata to those used elsewhere in this report for total number of occupied dwellings.

Uptake of insulation measures

The measures covered have been loft insulation, cavity insulation, double glazing, draught stripping and hot water tank lagging.

There has been an increase in the proportion of houses in which insulation measures have been installed, and a saturation level is now being reached for the two most obviously cost-effective - hot water tank lagging and loft insulation. These are also the two measures for which grants were made available under the Homes Insulation Scheme. This scheme ran from 1978 to 1990 and has now been superseded by new schemes aimed particularly at those on low incomes.

Ownership of cavity wall insulation, a measure which can save more energy than loft or tank insulation, but which has a longer payback period for its capital cost, has now reached 20% of its potential.

Potential for take-up

The tables covering insulation measures include a column labelled 'potential'. For loft insulation the 'potential' is the number of houses with accessible lofts. For cavity insulation the 'potential' is the number of houses with cavity walls - although it must be recognised that a proportion of these could not actually have the cavity filled because their location is such that there would then be a risk of rain penetration. For other measures that are not limited to any particular category of house the potential is equivalent to the whole of the housing stock.

Influences on take-up

There is evidence of higher proportions of insulated houses where the householder is in a better position to pay for insulation or where consumption levels are high so that the incentive to save is greater. There is proportionally more insulation in owner occupied houses, houses owned by the higher income groups, and houses with central heating.

Loft insulation

Notes

In 1974 there was some loft insulation in 42% of houses which had accessible lofts (see Table 3.i and Figure 3.i). By 1989 the proportion had risen to 88.8%.

Among those houses which had loft insulation, the average depth had gone up from 2.2 inches in 1976 to 3.6 inches in 1989.

The figures given in Table 3.i relate to houses with accessible lofts. There are other houses in which the loft space is not now accessible, but which could have been insulated at the time of construction. These would number approximately 476,000 in 1989. Both the latter figure and those for accessible lofts apply strictly to lofts - ie flat roofs are excluded from the figures.

Table 3.i: Ownership and depth of loft insulation

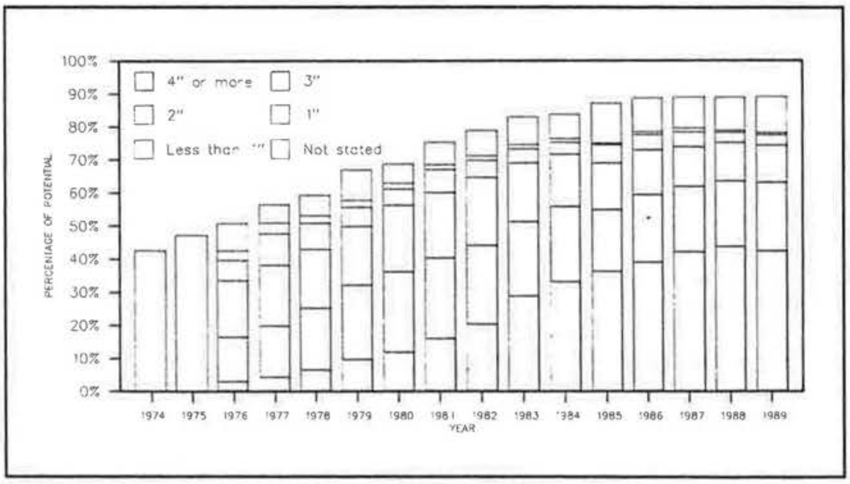
GB — 1,000s

Year	<1"	1"	2"	3"	4" +	Not stated	Total with	Potential	Total houses
1974	-	-	-	-	-	5,870	5,870	13,828	18,545
1975	-	-	-	-	-	6,648	6,648	14,127	18,747
1976	419	866	2,415	1,885	417	1,151	7,153	14,146	18,971
1977	489	1,378	2,636	2,224	616	780	8,123	14,441	19,203
1978	387	1,170	2,610	2,738	967	851	8,723	14,756	19,401
1979	344	888	2,676	3,369	1,456	1,330	10,063	15,071	19,575
1980	305	751	3,131	3,752	1,849	858	10,646	15,549	19,756
1981	292	1,050	3,116	3,792	2,494	1,020	11,764	15,657	19,921
1982	288	787	3,284	3,804	3,219	1,182	12,564	15,982	20,067
1983	266	670	2,877	3,662	4,634	1,308	13,417	16,228	20,225
1984	219	595	2,634	3,759	5,469	1,168	13,844	16,585	20,402
1985	139	897	2,364	3,105	6,084	1,967	14,556	16,777	20,580
1986	175	796	2,311	3,486	6,656	1,674	15,098	17,094	20,760
1987	261	793	2,023	3,373	7,167	1,529	15,146	17,090	20,945
1988*	132	559	1,951	3,375	7,484	1,675	15,176	17,109	21,138
1989	136	549	1,913	3,514	7,272	1,821	15,205	17,128	21,340

Source: G&A Home Audit

The 1988 figure for 'potential' has been obtained by interpolation.

Figure 3.i: Ownership and depth of loft insulation



Cavity wall insulation

Notes

In 1974 about 2.5% of cavity walled houses had cavity insulation (see Table 3.ii and Figure 3.ii). By 1989 this had risen to about 20.3%.

Timber framed houses are, in this context, included under the definition of cavity walls.

The 1986 figure and later figures for houses with cavity walls have been derived directly from the *G & A Home Audit* data. The earlier figures for 'potential' have been estimated by back projection from the 1986 figure.

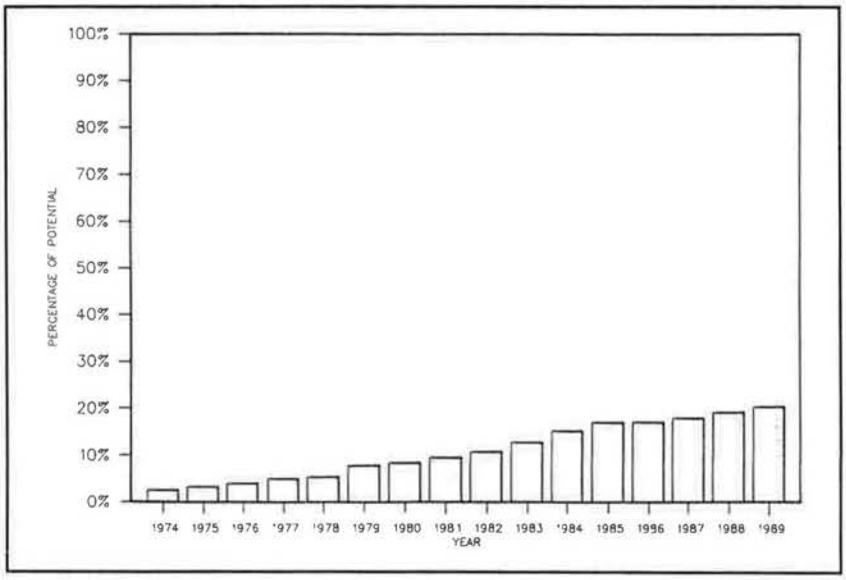
Table 3.ii: Ownership of cavity wall insulation

GB — 1,000s

Year	Houses with cavity insulation	Potential	Total houses
1970	-	10,565	17,759
1971	-	10,852	17,990
1972	-	11,141	18,192
1973	-	11,428	18,367
1974	292	11,713	18,545
1975	385	11,993	18,747
1976	479	12,289	18,971
1977	618	12,623	19,203
1978	666	12,884	19,401
1979	1,016	13,086	19,575
1980	1,100	13,302	19,756
1981	1,259	13,482	19,921
1982	1,445	13,636	20,067
1983	1,747	13,824	20,225
1984	2,118	14,034	20,402
1985	2,412	14,192	20,580
1986	2,442	14,352	20,760
1987	2,605	14,575	20,945
1988	2,841	14,835	21,138
1989	3,064	15,076	21,340

Source: G&A Home Audit

Figure 3.ii: Ownership of cavity wall insulation



Double glazing

Notes

Double glazing ownership has grown from 7.8% in 1974 to 45.6% in 1989 (see Table 3.iii and Figure 3.iii). This uptake is roughly twice that for cavity insulation even though double glazing is a considerably more expensive measure.

Purely in terms of energy saving, double glazing is rarely cost-effective. It does have other benefits, however, which have proved attractive to householders and encouraged take-up.

When windows have deteriorated to the point where replacement is necessary then the extra expense of installing double glazing rather than single glazing can often be small enough to make the measure cost-effective.

Figures for households owning some double glazing have been collected since 1974. Since 1984 there has been additional information on the number of rooms in which double glazing has been installed. For households with some double glazing in 1989, about two fifths had full double glazing (80% or more of the rooms with double glazing). Over half had double glazing in at least 60% of rooms.

('Double glazing' in this section includes both sealed units and windows with secondary glazing).

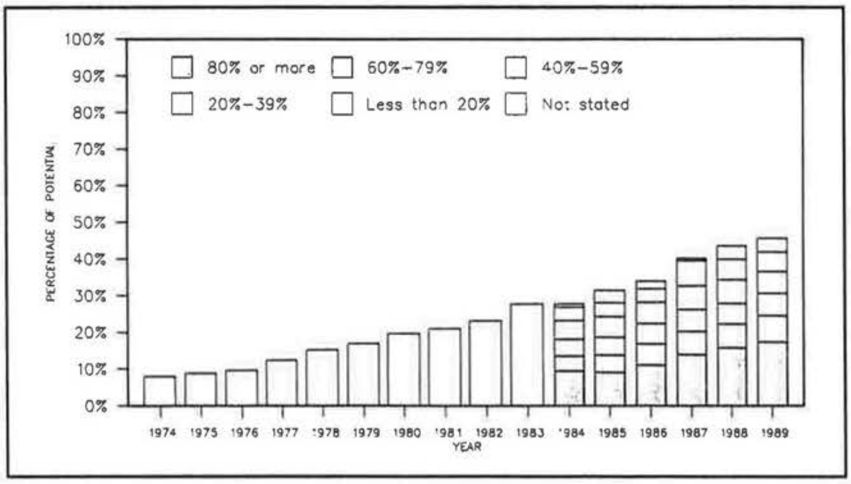
Table 3.iii: Ownership of double glazing

GB 1,000s

Year	Percentage of rooms treated					Not stated	Total with	Potential
	<20%	20-39%	40-59%	60-79%	80%+			
1974	-	-	-	-	-	1,455	1,455	18,545
1975	-	-	-	-	-	1,653	1,653	18,747
1976	-	-	-	-	-	1,832	1,832	18,971
1977	-	-	-	-	-	2,383	2,383	19,203
1978	-	-	-	-	-	2,943	2,943	19,401
1979	-	-	-	-	-	3,296	3,296	19,575
1980	-	-	-	-	-	3,876	3,876	19,756
1981	-	-	-	-	-	4,168	4,168	19,921
1982	-	-	-	-	-	4,635	4,635	20,067
1983	-	-	-	-	-	5,592	5,592	20,225
1984	816	1,024	936	834	1,927	127	5,664	20,402
1985	787	1,160	1,011	950	1,880	678	6,466	20,580
1986	800	1,206	1,142	1,210	2,304	369	7,031	20,760
1987	1,461	1,345	1,227	1,352	2,912	87	8,384	20,945
1988	1,219	1,371	1,164	1,389	3,345	682	9,170	21,138
1989	1,166	1,263	1,276	1,546	3,741	748	9,740	21,340

Source: G&A Home Audit

Figure 3.iii: Ownership of double glazing



Draught stripping

Notes

Figures for the ownership of draught stripping have been collected since 1983 (see Table 3.iv and Figure 3.iv).

By 1989 35% of houses had some draught stripping although, in the majority of cases, under 40% of the rooms were treated.

Draught stripping of windows is not likely to be necessary in rooms which have been fitted with good quality double glazing. Thus, although the potential for draught stripping has been quoted in Table 3.iv as the total number of households, this is unlikely to correspond to the true potential. The true potential for draught stripping is probably more reliably related to the number of windows which are still single glazed (which, of course, has been steadily falling as double glazing has been taken up by households). For these reasons the figures quoted in Table 3.iv should be viewed with caution. Bearing this in mind, it is no surprise that Figure 3.iv shows no obvious trends.

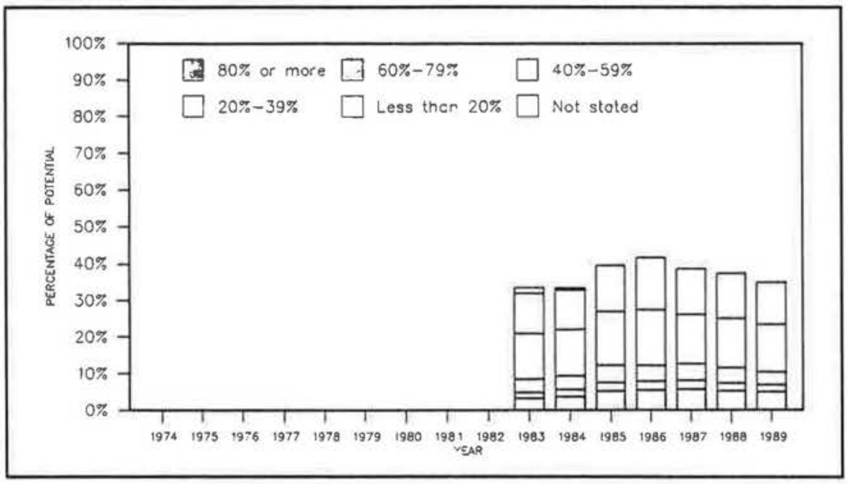
Table 3.iv: Ownership of draught stripping

GB 1,000s

Year	Percentage of rooms treated					Not stated	Total with	Potential
	<20%	20-39%	40-59%	60-79%	80%+			
1983	2,286	2,519	751	307	647	241	6,751	20,225
1984	2,286	2,566	780	372	756	5	6,765	20,402
1985	2,606	3,037	977	482	1,065	0	8,167	20,580
1986	2,950	3,139	890	512	1,145	0	8,636	20,760
1987	2,636	2,840	942	507	1,202	0	8,127	20,945
1988	2,634	2,838	899	445	1,119	0	7,935	21,138
1989	2,474	2,748	775	411	1,071	0	7,479	21,340

Source: G&A Home Audit

Figure 3.iv: Ownership of draught stripping



Hot water tank insulation

Notes

The energy efficiency measures considered so far are all measures which affect the heat loss through the building envelope. The insulation of hot water tanks is different in that it produces a saving in the cost of supplying domestic hot water rather than a saving in supplying space heating. In fact, this measure reduces the amount of heat lost from the tank to the house and so it actually results in a slight increase in the energy required for space heating.

Insulation of the hot water tank is a particularly cost-effective measure. It is cheap and simple to install and usually pays back in less than a year. In 1976 74% of hot water storage tanks had been insulated (see Table 3.v and Figure 3.v). By 1989 the proportion had risen to almost 94%. The average thickness of insulation was 2.13 inches in 1976, and had gone up only slightly to 2.33 inches by 1989. It should be noted, however, that it is not easy to accurately determine or define the thickness of tank insulation - cylinder jackets have a nominal thickness as sold but the insulation is often compacted somewhat when fitted to the tank.

In 1989 the number of houses with hot water tanks is quoted in Table 3.v as 19,338,000. The total number of occupied dwellings at that date was 21,340,000. The difference of 2,002,000 is largely accounted for by houses with instantaneous water heaters.

Table 3.v: Ownership of hot water tank insulation

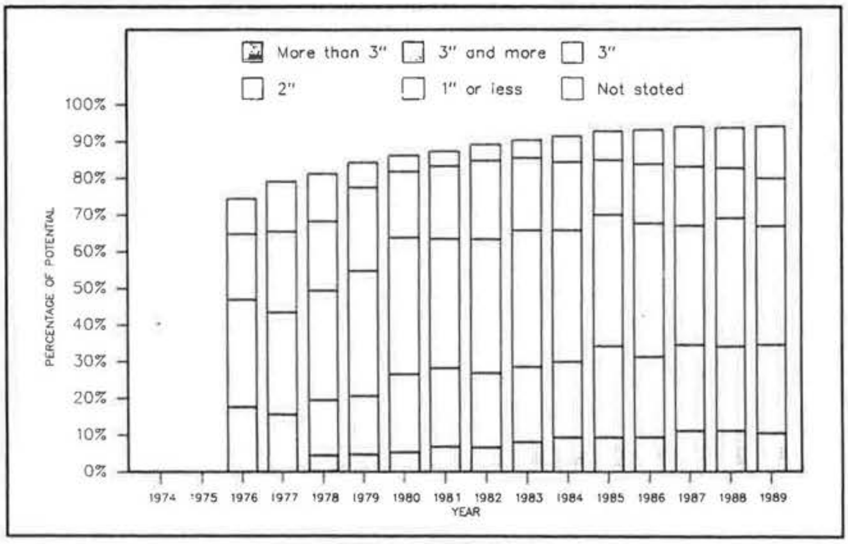
GB 1,000s

Year	1" or less	2"	3"	3" or more	>3"	Not stated	Total with	Potential	Total homes
1976	2,950	4,808	-	2,881	-	1,532	12,171	16,377	18,971
1977	3,703	4,603	-	2,592	-	2,212	13,110	16,590	19,203
1978	3,170	4,962	2,473	-	741	2,097	13,443	16,571	19,401
1979	3,931	5,817	2,719	-	799	1,112	14,378	17,085	19,575
1980	3,142	6,471	3,695	-	907	709	14,924	17,356	19,756
1981	3,440	6,087	3,694	-	1,161	668	15,050	17,250	19,921
1982	3,736	6,346	3,547	-	1,139	732	15,500	17,413	20,067
1983	3,541	6,646	3,652	-	1,439	831	16,109	17,851	20,225
1984	3,432	6,508	3,748	-	1,686	1,205	16,579	18,162	20,402
1985	2,810	6,734	4,644	-	1,754	1,427	17,369	18,742	20,580
1986	3,085	6,862	4,105	-	1,780	1,715	17,547	18,858	20,760
1987	3,079	6,216	4,463	-	2,131	2,028	17,917	19,089	20,945
1988	2,711	6,813	4,446	-	2,162	2,046	18,178	19,427	21,138
1989	2,567	6,240	4,654	-	2,020	2,690	18,171	19,338	21,340

Source: G & A Home Audit

G & A Home Audit figures for ownership of hot water tank insulation in 1974 and 1975 have been found to be inconsistent with later data and so have been ignored.

Figure 3.v: Ownership of hot water tank insulation



4 Energy consumption

Main trends

This section presents overall trends in energy consumption in the context of the variables which affect it. Their effects are summed up in Table 4.vii and Figure 4.vii, 'the effect of energy efficiency improvements'.

External temperatures, heat loss, and energy consumption

Space heating accounts for the major part of energy used in the average home.The strength of the relationship between domestic energy consumption and external temperature depends on the proportion of energy use which is for space heating. This, in turn, depends on the heat loss of the average dwelling. As the heat loss reduces, a greater proportion of the total energy use goes towards end uses which are not related (or, at least, not strongly related) to external temperature.

The quantity of energy required for space heating is related to external temperature. The insulation measures covered in section 3 will have affected only space heating and water heating consumptions. Tank insulation acts to reduce water heating consumption whilst the other insulation measures reduce space heating consumption. A large part of the improvement in average house heat loss is attributable to loft insulation. Since loft insulation is now reaching a saturation level, it is not surprising to see that the rate of improvement has declined in recent years. There is, however, considerable scope for future acceleration of the rate of improvement through other insulation measures - particularly cavity wall insulation and double glazing.

Central heating and increased comfort levels

Other things being equal, space heating would have increased with the increasing proportion of houses having central heating (see Table 4.iii and Figure 4.iii) and with growing expectations of comfort in both centrally heated and non-centrally heated homes (see Table 4.vi and Figure 4.vi). The trends towards more central heating and higher comfort levels will continue until such time as a saturation level is reached, corresponding to the attainment of desired levels of comfort by all households.

Despite the growth in the ownership of central heating and increasing standards of comfort, space heating energy consumption per household is estimated to have gone down over the period under consideration (see Table 4.v).

Efficiency of appliances

The rising trends have been offset by better standards of insulation (detailed in section 3 and summarised in Table 4.ii and Figure 4.ii) and improved heating appliance efficiencies (see Figure 4.iv). There has also been an increase in the incidental gains from appliances which has further helped to offset space heating energy requirements.

Total energy consumption figures include energy that has been used for space heating, water heating, cooking, lighting and the running of electrical appliances. All these categories of energy consumption will have been affected by the increasing numbers of households and by improvements in the efficiencies of appliances. Increasing numbers of households will have tended to raise consumption but improving efficiencies will have acted to reduce consumption.

The delivered energy requirement of houses has undoubtedly been reduced by improvements in the efficiencies of heating appliances. It is difficult to quantify precisely this improvement in terms of an average efficiency in 1970 compared with an average efficiency calculated on the same basis in 1989. Table 4.iv.c attempts to do this. However, before considering this table, it is necessary to look briefly at what is known about improvements to heating appliance efficiencies. The discussion focuses on gas appliances because gas is the most used fuel for heating and so has the greatest influence on overall changes to heating efficiency. Also, detailed data on some other forms of heating is rather sparse.

Efficiency of appliances *(continued)*

British Gas have published data on the full load efficiencies of central heating boilers submitted for approval[10]. Although there is considerable scatter in such measurements there has been a clear trend towards improving efficiencies. The average full load efficiency of boilers assessed in 1970 was about 73%. By 1984 this had risen to about 78%. A modern conventional boiler might achieve a full load efficiency of about 80% - which is close to the ultimate limit for such a boiler. Although modern conventional boiler full load efficiencies are probably near their limit now it seems likely that the trend towards improving efficiencies will continue through the introduction of condensing boilers which have full load efficiencies of about 90%.

There have been similar improvements in the full load efficiencies of gas fires which have risen at an average rate of about 0.7% per annum between 1977 and 1986. Here too, the improvement looks likely to continue with the introduction of condensing appliances.

The full load efficiencies of new appliances are, of course, not properly representative of the average efficiencies achieved by existing appliances in use in the housing stock now. These efficiencies will be lower because, in general, the existing appliances will have somewhat lower full load efficiencies than new appliances and because the operation of the appliances is necessarily at part load. The efficiency of a conventional boiler decreases quite substantially as the load is progressively reduced. Unlike conventional boilers, however, condensing boilers have part load efficiencies which are close to their full load efficiencies.

Basis of calculations - BREHOMES

To investigate the interaction between the above factors the Building Research Establishment Housing Model for Energy Studies (BREHOMES) has been used. Some of the tables in this section rely on the analyses of that model. The BREHOMES model has been used to calculate the heat losses of different types of dwelling for eight of the years between 1976 and 1989. These calculations have used the same information that was presented in section 3. The BREHOMES calculations of heat loss rely on factual statistical data where it exists but, inevitably, some assumptions have to be made where the available data is less robust. In future, it is possible that such data will be improved upon, which might lead to slight revisions of the calculated heat loss figures.

Although the detailed calculations have only been done for eight of the years between 1970 and 1989, this is sufficient to be able to make good estimates for all years, thereby forming a continuous series.

End uses

Among the following tables there is one (Table 4.v) which gives a breakdown of domestic energy consumption between the categories of end use mentioned above - space heating, water heating, cooking and lighting and appliances. This table is a little more tentative than some of the others for a number of reasons. Firstly, there is no factual statistical source on which one can base such figures. By using BREHOMES, however, it is possible to make informed estimates.

Even so, it has to be recognised that the categorisation of end uses is not unequivocal. For example, because space and water heating are often supplied using the same appliance, there is no uniquely correct way of allocating the total consumption of that appliance between space heating and water heating. Any such allocation is largely a matter of definition or convention. The numbers in Table 4.v need to be viewed with this in mind - they are indicative rather than definitive figures.

Energy consumption and external temperatures

Notes

The total delivered energy consumption of the housing stock of Great Britain is shown in Table 4.i.

Between 1970 and 1989 domestic energy consumption rose by 9% from 1,502 PJ to 1,638 PJ. The number of households rose by more than 20% over the same period so that the average energy consumption per household in 1989 was actually less than in 1970 (see Table 4.i). However, 1989 was an unusual year because the winter was noticeably warmer than normal.

Table 4.i and Figure 4.i also show the relationship between domestic energy consumption and external temperature. Although there are some anomolies, the low points in the winter temperature generally correspond, as would be expected, with peaks in energy consumption. For example, the effect of the cold winter of 1979 shows up very clearly, as does the effect of the very cold successive winters of 1985, 1986 and 1987.

Table 4.i: Domestic energy consumption and external temperatures

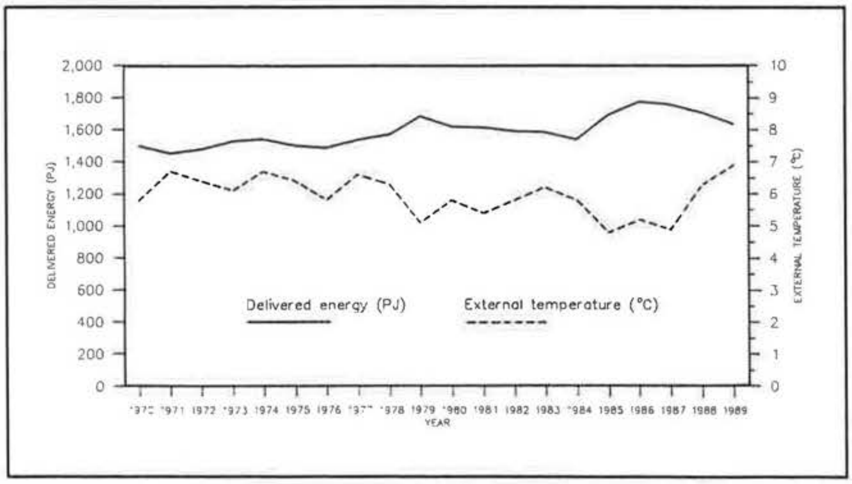
GB — Various units

Year	Total houses [1,000s]	Total delivered energy [PJ]	Average external temperature [°C]	Average consumption per dwelling [GJ]
1970	17,759	1,502	5.8	84.6
1971	17,990	1,453	6.7	80.8
1972	18,192	1,482	6.4	81.5
1973	18,367	1,531	6.1	83.4
1974	18,545	1,544	6.7	83.3
1975	18,747	1,503	6.4	80.2
1976	18,971	1,488	5.8	78.4
1977	19,203	1,539	6.6	80.1
1978	19,401	1,572	6.3	81.0
1979	19,575	1,686	5.1	86.1
1980	19,756	1,620	5.8	82.0
1981	19,921	1,615	5.4	81.1
1982	20,067	1,592	5.8	79.3
1983	20,225	1,585	6.2	78.4
1984	20,402	1,541	5.8	75.5
1985	20,580	1,696	4.8	82.4
1986	20,760	1,779	5.2	85.7
1987	20,945	1,760	4.9	84.0
1988	21,138	1,708	6.3	80.8
1989	21,340	1,638	6.9	76.8

Source: Digest of United Kingdom Energy Statistics.

First quarter and fourth quarter figures for mean air temperatures are given in the Digest of Energy Statistics. The figure shown here is the average of the two quarters.

Figure 4.i: Domestic energy consumption and external temperatures



Heat loss of the average dwelling

Notes

Values for the heat loss of the average dwelling are presented in Table 4.ii and Figure 4.ii. They show how the heat loss of the average dwelling has improved considerably over the years.

The rate of heat loss of a dwelling is usually expressed as the specific rate in Watts per degree Celsius of difference in temperature between the internal and external environments. Hence the notation W/°C in Table 4.ii and Figure 4.ii. As indicated in the table and figure, the specific heat loss rate includes both losses through the fabric of the dwelling and losses by ventilation. The term 'specific heat loss rate' is commonly replaced, for the sake of brevity, by 'heat loss'. This practice has been adopted throughout the *Domestic energy factfile*.

The heat loss of the average dwelling has been calculated using the BREHOMES model for the years 1976, 1982, and 1984 to 1989 inclusive. Using these figures it is possible to make good estimates of the heat loss of the average dwelling for the missing intermediate years. Some slightly more speculative estimates can also be made for the years immediately preceding 1976 - thereby allowing a continuous series to be produced from 1970 to 1989.

The heat losses in Table 4.ii and Figure 4.ii are for the average dwelling. For comparison, for dwellings with loft insulation but without cavity insulation (typical of the present stock) the heat loss would range from about 550 W/°C (for a large detached house) to between 100 W/°C and 200 W/°C (for a flat). A typical value for a semi-detached house would be about 290 W/°C - so that this house type corresponds quite closely to the average dwelling.

Space heating energy consumption is not directly proportional to the heat loss. This is mainly because of the contribution which is made to meeting the space heating requirement by other sources of heat. These sources of heat consist of the free gains from other energy uses (heat from electrical appliances, cookers, etc) and natural gains (heat from the dwelling occupants themselves and from the solar energy which enters the dwelling). If these free gains were to remain constant then a given reduction in dwelling heat loss would result in a more than proportionate decrease in the heat supplied by the space heating system. The BREHOMES model suggests that a 1% reduction in dwelling heat loss typically results in a 1.5% reduction in the heat supplied by the space heating system.

The final column in Table 4.ii gives the heat loss of the entire housing stock. This figure is equal to the heat loss of the average dwelling multiplied by the number of occupied dwellings (and divided by a factor of 10^9 to convert W/°C to gigawatts/°C). The stock heat loss begins to fall from the early 1970s, but in recent years it has changed little - implying that the rate of improvement to the insulation standards of the stock is only just keeping pace with the tendency towards a larger heat loss due to the growth of the stock.

Table 4.ii: Heat loss of the average dwelling and the whole stock

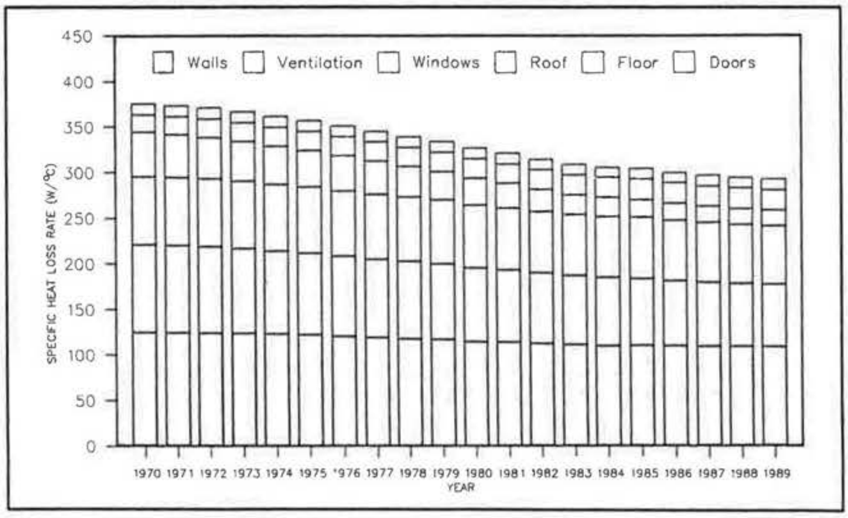
GB — Various units

Year	Average dwelling heat loss [W/°C]	Heat losses by building element [W/°C]						Total houses [1,000s]	Stock heat loss [GW/°C]
		Walls	Ventilation	Windows	Roofs	Floors	Doors		
1970	376.0	124.9	96.4	74.3	48.4	19.7	12.2	17,759	6.68
1971	374.0	128.8	95.6	74.3	46.9	20.0	12.3	17,990	6.73
1972	371.0	124.4	94.5	74.2	45.3	20.3	12.4	18,192	6.75
1973	367.0	123.7	93.2	73.8	43.5	20.5	12.4	18,367	6.74
1974	362.0	122.9	91.1	72.7	42.1	20.9	12.3	18,545	6.71
1975	357.0	121.9	89.7	72.3	40.1	20.8	12.3	18,747	6.69
1976*	351.2	120.1	88.0	71.7	38.5	20.7	12.2	18,971	6.66
1977	345.0	118.5	86.1	71.0	36.5	20.8	12.2	19,203	6.63
1978	339.0	117.7	84.6	70.5	33.4	20.6	12.2	19,401	6.58
1979	334.0	116.4	83.2	70.1	30.9	21.3	12.1	19,575	6.54
1980	327.0	114.3	80.6	68.8	29.8	21.5	12.0	19,756	6.46
1981	321.0	113.4	79.3	68.4	26.5	21.4	12.0	19,921	6.39
1982 *	314.7	111.8	77.4	67.5	24.5	21.5	11.9	20,067	6.32
1983	309.0	111.0	75.7	66.8	21.9	21.7	11.9	20,225	6.25
1984 *	306.1	109.6	75.2	66.5	21.1	21.9	11.8	20,402	6.25
1985 *	304.3	110.4	73.3	66.9	19.5	22.3	12.0	20,580	6.26
1986 *	300.4	109.8	71.6	66.0	18.6	22.4	12.0	20,760	6.24
1987 *	296.9	109.2	70.3	65.3	17.8	22.3	12.0	20,945	6.22
1988 *	294.7	108.8	69.1	64.6	17.4	22.7	12.1	21,138	6.23
1989 *	292.6	108.3	68.6	64.2	17.4	22.1	12.1	21,340	6.24

Source: BREHOMES

* Full calculation has been made for the years marked with an asterisk. Figures for other years have been arrived at by interpolation and extrapolation.

Figure 4.ii: Heat loss of the average dwelling



Central heating ownership

Notes

In 1970 34% of homes had central heating. By 1989 the proportion had risen to 78% (see Table 4.iii and Figure 4.iii).

Central heating appliances are generally more efficient than individual room heating appliances so, for any given requirement for useful space heat in a dwelling, they would be expected to use less delivered energy.

However, installation of central heating is usually associated with a considerable increase in the occupants' comfort expectation, particularly in respect of the number of rooms heated - and, hence, an increase in the useful heat requirement. As a result, unless there is a concurrent improvement in insulation, an average centrally heated house would require about twice as much delivered energy for space heating as would a similar house in which only the living room is heated.

This proportion would be higher for a house with poor levels of insulation. On the other hand, it would be lower for a well insulated house where heat transfer from the living room can often achieve comfort temperatures throughout the house. In a very well insulated house, therefore, it may only be necessary to install a simple system of one or two room heaters instead of a full central heating system.

Table 4.iii: Central heating ownership

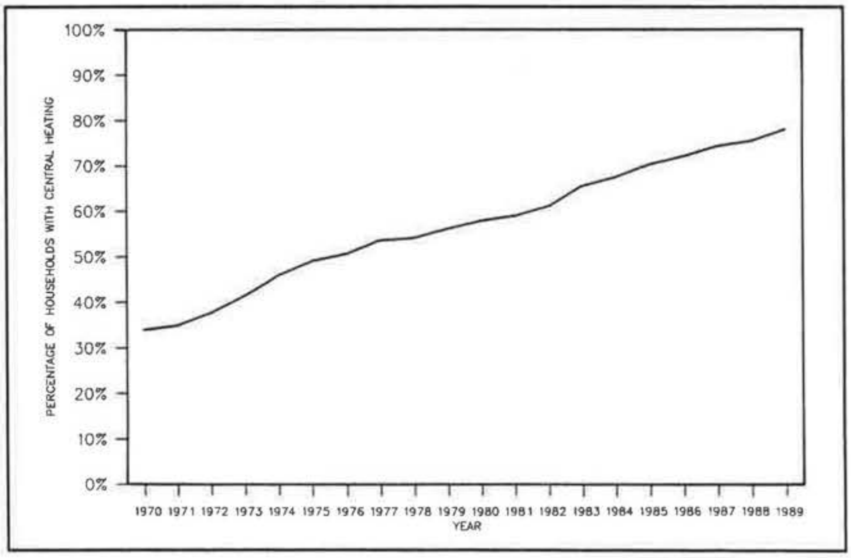
GB 1,000s

Year	No central heating	Central heating	Total houses
1970	11,721	6,038	17,759
1971	11,693	6,297	17,990
1972	11,329	6,863	18,192
1973	10,750	7,617	18,367
1974	10,026	8,519	18,545
1975	9,550	9,197	18,747
1976	9,371	9,600	18,971
1977	8,927	10,276	19,203
1978	8,915	10,486	19,401
1979	8,598	10,977	19,575
1980	8,326	11,430	19,756
1981	8,174	11,747	19,921
1982	7,812	12,255	20,067
1983	6,979	13,246	20,225
1984	6,630	13,772	20,402
1985	6,110	14,470	20,580
1986	5,788	14,972	20,760
1987	5,365	15,580	20,945
1988	5,174	15,964	21,138
1989	4,703	16,637	21,340

Source: G&A Home Audit

Figures from the above source have been adjusted pro rata to give the same totals of occupied houses as those used elsewhere in this publication.

Figure 4.iii: Central heating ownership



Notes

Tables 4.iv.a and 4.iv.b give the main form of heating in winter, between 1970 and 1989, for centrally heated and non-centrally heated houses.

Although it is difficult to quantify precisely the actual average seasonal efficiencies of appliances in use in the housing stock, some indication can be given, based on the available data. Tables 4.iv.a and 4.iv.b include typical efficiencies in use for each type of appliance. Figures are given for both the start and end of the period under consideration.

Electric systems have been shown as having an efficiency of 100%. This is physically correct because 100% of the energy delivered is converted into heat within the dwelling. There are no flue/chimney losses as with fossil fuel based heating. However, some of the heat which is delivered by an electric storage system may be released into the dwelling at times when it is not required. This effect is sometimes allowed for by reducing the heater efficiency - and so some authors quote efficiencies below 100%. It is better allowed for by calculating the temperature within the dwelling according to how the heater releases the stored heat - but keeping the efficiency at the physically correct value of 100%.

The equivalent figures in the previous edition of this report were derived from the *General Household Survey*, rather than the *G & A Home Audit*. The relevant figures are no longer available from the former source and so the latter has been used to revise all figures. There are some differences between the figures derived from these different sources - in particular, the *G & A Home Audit* data suggests a higher proportion of homes heating with electric storage systems. This may be due to different conventions in deciding how many storage heaters are required before a system would be classified as equivalent to central heating.

Table 4.iv.a: Main form of heating - centrally heated dwellings

GB 1,000s

Year	Solid Fuel	Electric Storage	Other Electric	Gas	Oil	Other	Total houses
1970	1,304	1,246	496	2,254	571	167	6,038
1971	1,360	1,299	517	2,351	596	174	6,297
1972	1,483	1,416	564	2,562	649	189	6,836
1973	1,425	1,566	636	3,087	680	223	7,617
1974	1,443	1,711	694	3,699	680	292	8,519
1975	1,377	1,846	791	4,161	667	355	9,197
1976	1,406	1,636	793	4,799	660	306	9,600
1977	1,362	1,533	805	5,530	769	277	10,276
1978	1,064	1,458	921	6,002	770	271	10,486
1979	985	1,355	743	6,962	680	252	10,977
1980	1,168	1,204	866	7,429	600	163	11,430
1981	1,094	1,181	778	7,956	470	268	11,747
1982	1,159	1,131	715	8,572	425	253	12,255
1983	1,232	1,242	754	9,242	522	254	13,246
1984	1,234	1,279	750	9,675	535	299	13,772
1985	1,486	1,283	644	10,187	516	354	14,470
1986	1,487	1,126	455	11,142	478	284	14,972
1987	1,455	1,229	464	11,520	548	364	15,580
1988	1,475	1,347	463	11,732	585	362	15,964
1989	1,250	1,473	531	12,481	521	381	16,637
Typical seasonal efficiencies of the above [%]							
Beginning	64	100	100	64	62		
End	64	100	100	66	64		

Table 4.iv.b: Main form of heating - non-centrally heated dwellings

GB 1,000s

Year	Solid fuel fire	Solid fuel stove	Electric	Gas	Oil	Other	Total houses
1970	3,055	587	2,230	5,166	445	238	11,721
1971	3,048	586	2,225	5,153	444	237	11,693
1972	2,953	568	2,155	4,993	430	230	11,329
1973	2,802	539	2,045	4,738	408	218	10,750
1974	2,613	502	1,907	4,420	381	203	10,026
1975	2,489	479	1,817	4,208	363	194	9,550
1976	2,443	470	1,783	4,129	356	190	9,371
1977	2,327	447	1,698	3,935	339	181	8,927
1978	2,324	447	1,696	3,928	339	181	8,915
1979	1,730	579	1,735	4,067	301	186	8,598
1980	1,545	606	1,595	4,083	297	200	8,326
1981	1,405	521	1,573	4,211	208	256	8,174
1982	1,250	555	1,428	4,134	179	266	7,812
1983	1,002	595	1,121	3,928	100	233	6,979
1984	957	548	1,089	3,807	60	169	6,630
1985	873	483	959	3,626	34	135	6,110
1986	793	427	685	3,700	21	162	5,788
1987	654	351	693	3,514	24	129	5,365
1988	597	321	729	3,359	22	146	5,174
1989	580	312	612	3,049	16	134	4,703
Typical seasonal efficiencies of the above [%]							
Beginning	30	65	100	51	85		
End	30	70	100	57	85		

Source: G&A Home Audit

Notes

In estimating the average level of heating appliance efficiency more confidence can be placed in the improvement over the years than in the absolute values. In the past, average efficiencies have been influenced more by changes from one fuel to another (ie largely from solid fuel to gas) and from individual fires to central heating, rather than through improvements in the efficiency of particular appliances. In the future, the latter effect would be expected to play the dominant role now that gas is firmly established as the preferred fuel for heating and substantial improvements are possible through the introduction of condensing appliances.

From the mix of appliances it is possible to calculate values for the weighted average efficiencies of all heating appliances (see Table 4.iv.c and Figure 4.iv). For central heating systems the average efficiency actually goes down because of the diminishing proportion represented by electric systems. Overall, however, there has been a substantial improvement in heating efficiency.

Table 4.iv.c: Weighted average space heating efficiencies

GB — Per cent

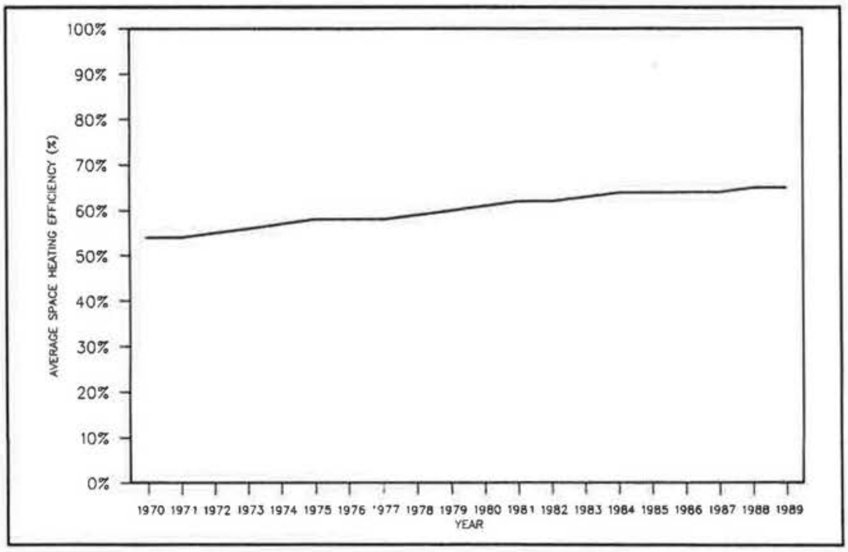
Year	Central heating efficiency	Non-central heating efficiency	Average efficiency
1970	70	48	54
1971	70	48	54
1972	70	49	55
1973	70	49	56
1974	70	49	57
1975	70	49	58
1976	70	49	58
1977	70	49	58
1978	70	50	59
1979	69	52	60
1980	69	53	61
1981	69	54	62
1982	68	55	62
1983	69	55	63
1984	69	55	64
1985	69	55	64
1986	68	54	64
1987	68	55	64
1988	68	56	65
1989	69	55	65

Source: BREHOMES

These are average efficiencies, weighted in accordance with the number of appliances of different types.

Variations between years reflect changes between fuels and appliances.

Figure 4.iv: Weighted average space heating efficiencies



Energy consumption by end use

Notes

Table 4.v and Figure 4.v show the breakdown of domestic energy use between different end uses. As noted earlier, these figures are a little more tentative than some of the others in this report (see page 24.).

It is beyond the scope of this report to give exact details of how the estimates in Table 4.v have been obtained. The following is a brief summary of the methodology.

The figures in Table 4.v show total delivered energy for each end use. Although it is not evident from the table, the figures were actually calculated fuel by fuel and then totalled. For electricity the breakdown between end uses follows estimates which have been made by the former Electricity Council for all years up to 1986/7. The figures have been extrapolated slightly to provide estimates up to 1989.

The electricity estimates have then been used to derive figures for the consumptions of other fuels. For example, knowing the number of households using different fuels for cooking, together with the cooker efficiencies relative to electric cookers, it is possible to deduce the total delivered energy for cooking.

For lights and appliances, it has been assumed that this is all accounted for by electricity (not quite correct, but gas appliances are so rare that it is a reasonable assumption). It is interesting to note that the consumption for lights and appliances has risen considerably over the years - although this end use still represents a relatively small part of the total delivered energy.

Water heating consumption by fuels other than electricity has been based on an estimate of average volume of hot water used per person together with figures on the proportions of households heating water using different fuels. The volume of hot water used per person has been assumed to rise in proportion to household incomes. The overall efficiencies of water heating appliances include an element to adjust for the loss from the hot water tank and this reduces according to the level of tank insulation.

Having estimated the delivered energy by fuel for each of the above mentioned end uses, and knowing the total domestic energy consumption by fuel, the space heating energy use is obtained as the difference.

In all years the space heating consumption is estimated to be slightly more than half of the total consumption. This proportion is entirely in line with what would be expected for an average dwelling. The amount of heat provided by the space heating system is always less than the space heating requirement of a dwelling. Heat is also released into the house from appliances, lighting, cooking, etc. A large part of these free gains make a useful contribution towards meeting the space heating requirement. This, in turn, means that, should there be a slightly incorrect allocation between space heating and other end uses, it will not have as great an effect on calculated internal temperatures, or on estimates of potential energy savings through insulation, as might be expected.

Table 4.v. Domestic energy consumption by end use

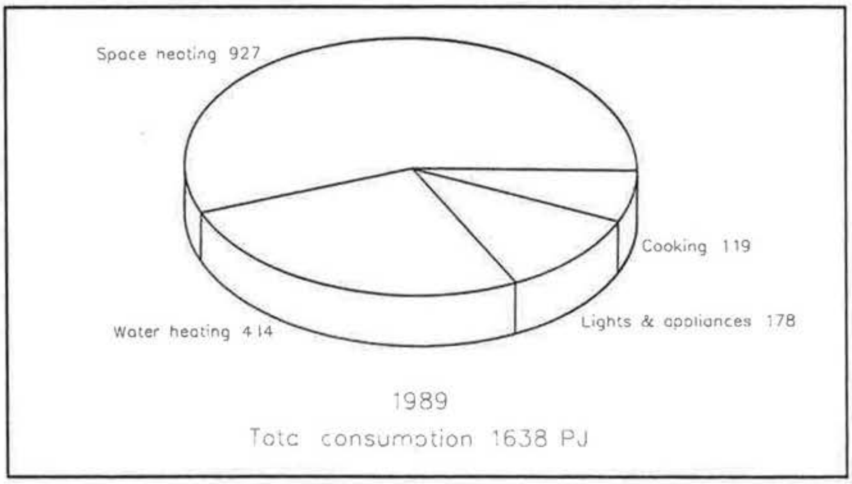
GB — PJ and GJ

Year	Space heating [PJ]	Water heating [PJ]	Lights & appliances [PJ]	Cooking [PJ]	All energy [PJ]	Space heating per household [GJ]
1970	906.9	403.2	84.1	107.8	1,502	51.1
1971	849.9	403.4	89.8	109.8	1,453	47.2
1972	873.7	401.8	95.6	110.9	1,482	48.0
1973	896.1	423.2	100.1	111.5	1,531	48.8
1974	912.2	411.8	107.8	112.2	1,544	49.2
1975	893.4	392.2	110.0	107.4	1,503	47.7
1976	866.2	394.6	118.4	108.8	1,488	45.7
1977	903.2	389.2	131.0	115.6	1,539	47.0
1978	933.5	389.3	135.3	113.9	1,572	48.1
1979	1,049.0	383.8	140.4	112.9	1,686	53.6
1980	993.6	370.5	144.0	111.9	1,620	50.3
1981	996.8	357.5	149.4	111.3	1,615	50.0
1982	976.8	358.7	150.1	106.4	1,592	48.7
1983	947.1	368.7	158.8	110.5	1,585	46.8
1984	906.3	364.0	160.5	110.2	1,541	44.4
1985	1,038.5	373.6	170.0	114.0	1,696	50.5
1986	1,087.3	384.8	177.1	118.8	1,768	52.4
1987	1,065.6	394.0	179.8	120.7	1,760	50.9
1988	1,003.3	406.9	178.2	119.6	1,708	47.5
1989	926.6	414.6	177.6	119.2	1,638	43.4

Source: BREHOMES

The breakdown of electricity consumption figures is based on the Electricity Council's Domestic Sector Analysis [11].

Figure 4.v: Domestic energy consumption by end use



Standards of comfort

Notes

The average household used 84.6 GJ of energy in 1970. In 1989 the figure was actually lower at 76.8 GJ. However, 1989 was a warmer than average year. The corresponding space heating figures were 51.1 GJ in 1970 and 43.4 GJ in 1989 (see Table 4.v). For the colder years of 1985 to 1987 the average space heating consumptions were all slightly above 50 GJ.

The space heating energy consumption per house, therefore, appears to have remained very stable between 1970 and 1989 despite the large growth in the ownership of central heating from 34% to 78%.

The effect of the increase in central heating must have been to raise average dwelling temperatures. Broad estimates can be made of the magnitude of this rise. By running heat balance equations for all the years in question it is possible to deduce a 24 hour average internal temperature during the six 'winter' months. The results of these calculations are shown in Table 4.vi and Figure 4.vi.

The absolute values of these temperatures can not be quoted with as much confidence as estimates of the extent of the rise. However, the general level of temperatures in houses has been suggested by a number of surveys. One such survey, carried out in February and March 1978 [12] gave the average daytime temperature of occupied dwellings as approximately 17°C and 14°C for centrally heated and non-centrally heated houses respectively. The 24 hour averages would be slightly lower than these values.

The temperature rise over the period for both centrally heated and non-centrally heated houses is estimated to be 2.25°C. Due to the move towards more central heating, however, the rise in the average temperature across all houses is estimated to be higher at nearly 3.4°C. Table 4.vi indicates how much scope there is for further increases in mean internal temperatures.

It would be expected that, eventually, the average temperature will stabilise as more and more households achieve their desired comfort levels. For most people, a living room temperature during occupied periods of about 21°C would be regarded as comfortable. A temperature perhaps 2°C below this would generally be considered adequate elsewhere in the dwelling, so that a whole house average comfort level might be around 19-20°C. Achieving this temperature throughout a dwelling for 24 hours per day, therefore, could be taken to be an ultimate comfort level beyond which most people would not wish to go. At current rates of increase this level could be reached in perhaps 30 years time.

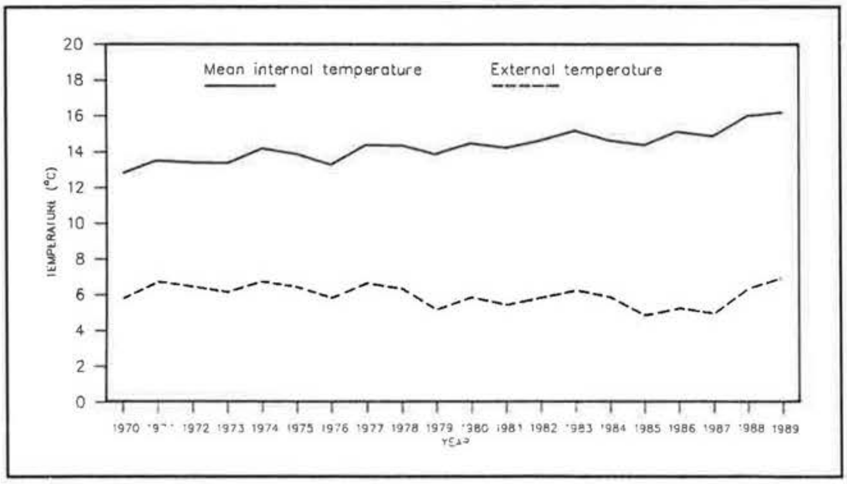
Table 4.vi: Standards of comfort - mean internal and average winter external temperatures

GB | Various units

Year	% of dwellings with central heating [%]	Calculated internal temperatures: Centrally heated [°C]	Non-centrally heated [°C]	Average [°C]	External temperature [°C]	Total houses [1,000's]
1970	34.0	14.44	11.94	12.79	5.8	17,759
1971	35.0	15.11	12.61	13.49	6.7	17,990
1972	37.7	14.92	12.42	13.36	6.4	18,192
1973	41.5	14.78	12.28	13.32	6.1	18,367
1974	45.9	15.49	12.99	14.14	6.7	18,545
1975	49.1	15.10	12.60	13.83	6.4	18,747
1976	50.6	14.44	11.94	13.21	5.8	18,971
1977	53.5	15.50	13.00	14.34	6.6	19,203
1978	54.1	15.43	12.93	14.28	6.3	19,401
1979	56.1	14.88	12.38	13.78	5.1	19,575
1980	57.9	15.43	12.93	14.38	5.8	19,756
1981	59.0	15.15	12.65	14.12	5.4	19,921
1982	61.1	15.53	13.03	14.56	5.8	20,067
1983	65.5	15.95	13.45	15.09	6.2	20,225
1984	67.5	15.34	12.84	14.53	5.8	20,402
1985	70.3	15.01	12.51	14.27	4.8	20,580
1986	72.1	15.75	13.25	15.05	5.2	20,760
1987	74.4	15.42	12.92	14.78	4.9	20,945
1988	75.5	16.52	14.02	15.91	6.3	21,138
1989	78.0	16.69	14.19	16.14	6.9	21,340

Source: BREHOMES

Figure 4.vi: Standards of comfort - mean internal and average winter external temperatures



Notes

Table 4.vi suggests that an average 24 hour temperature of 12.8°C was achieved in 1970 when the national domestic energy consumption was 1,502 PJ and that an average temperature of 16.1°C was achieved in 1989 when consumption was 1,638 PJ.

If insulation and efficiency levels had remained as they were in 1970, how much more energy would now be required to maintain the average 1989 internal temperatures?

In Table 4.vi internal temperatures were calculated from a given consumption of energy. In Table 4.vii the calculation is reversed. Energy consumption is calculated from a given level of temperature. The table shows the consumptions calculated for each year using the temperatures from Table 4.vi but assuming that the insulation and efficiency levels are those for 1970. Figure 4.vii illustrates the results graphically.

The 1989 consumption is calculated to be 2,405.1 PJ, which is 767.1 PJ more than the actual consumption of 1,638.0 PJ. Of this difference, 508.4 PJ would be ascribed to improvements in insulation and 258.7 PJ to improved heating efficiency. Thus, it may be concluded that energy efficiency measures applied to housing have resulted in a saving of roughly 32% relative to what the consumption would have been without those measures.

Readers should be aware, however, that there are a number of conceptual difficulties in the definition of savings achieved by energy efficiency measures. For example, it has been assumed that 1989 households would maintain 1989 temperatures despite having 1970 insulation standards. In reality, the temperature would probably be allowed to drop from the 1989 level both by deliberate choice and for reasons of building physics (the 24 hour temperature in a dwelling, for any given intermittent heating pattern, depends on the insulation standard - it is lower in a poorly insulated dwelling than in a well insulated dwelling). The problem is, of course, that there is no way of knowing by how much the temperature would have been allowed to fall in practice.

The calculated figure of 767.1 PJ is, therefore, hypothetical but it does give a good indication of the quantity of energy that has been saved by energy efficiency measures. The definition used is actually a measure of two things - the energy saved and the energy value of improved comfort standards.

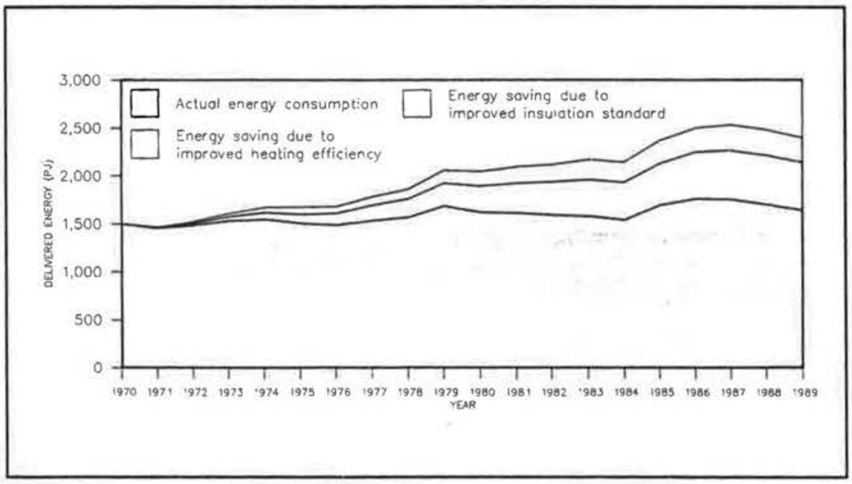
Table 4.vii: The effect of energy efficiency improvements on energy consumption

GB PJ

Year	Total houses	Actual energy used	Energy use if 1970 insulation standard	Energy use if 1970 insulation & efficiency standard	Saving due to improved insulation	Saving due to improved efficiency	Total saving
1970	17,759	1,502.0	1,502.0	1,502.0	0.0	0.0	0.0
1971	17,990	1,453.0	1,461.7	1,465.0	8.7	3.3	12.0
1972	18,192	1,482.0	1,505.0	1,522.0	23.0	17.0	40.0
1973	18,367	1,531.0	1,574.3	1,605.5	43.3	31.2	74.5
1974	18,545	1,544.0	1,612.6	1,668.7	68.6	56.1	124.7
1975	18,747	1,503.0	1,594.9	1,668.6	91.9	73.7	165.6
1976	18,971	1,488.0	1,607.8	1,680.5	119.8	72.7	192.5
1977	19,203	1,539.0	1,695.9	1,782.1	156.9	86.2	243.1
1978	19,401	1,572.0	1,765.0	1,862.4	193.0	97.4	290.4
1979	19,575	1,686.0	1,921.7	2,057.0	235.7	135.3	371.0
1980	19,756	1,620.0	1,890.2	2,041.4	270.2	151.2	421.4
1981	19,921	1,615.0	1,922.9	2,092.5	307.9	169.6	477.5
1982	20,067	1,592.0	1,937.2	2,115.3	345.2	178.1	523.3
1983	20,225	1,585.0	1,963.9	2,170.8	378.9	206.9	585.8
1984	20,402	1,541.0	1,930.3	2,140.9	389.3	210.6	599.9
1985	20,580	1,696.0	2,131.1	2,372.0	435.1	240.9	676.0
1986	20,760	1,768.0	2,255.1	2,501.9	487.1	246.8	733.9
1987	20,945	1,760.0	2,271.5	2,535.1	511.5	263.6	775.1
1988	21,138	1,708.0	2,220.6	2,484.6	512.6	264.0	776.6
1989	21,340	1,638.0	2,146.4	2,405.1	508.4	258.7	767.1

Source: BREHOMES

Figure 4.vii: The effect of energy efficiency improvements on energy consumption



5 How domestic sector energy consumption is determined

Main trends

It should be clear to the reader by now that there are many interacting factors which determine the energy consumption of the housing stock. For space heating these can be summarised as follows:

- there is a natural variation due to changes in the external temperature.
- there is a trend towards lower heat losses due to insulation, which tends to reduce energy consumption.
- there is a trend towards improved comfort linked to the growth of central heating, which tends to increase consumption.
- there is a trend towards improved space heating efficiencies due to change of fuel, more central heating and better heating appliance efficiencies, which tends to reduce energy consumption.

In addition, there is a continuing growth in the size of the housing stock which tends to increase energy consumption across all end uses.

The improvement in comfort standards is just one aspect of an improvement in the general level of service required by households. Another clear example is the increasing electricity consumption for lights and appliances (see Table 4.v). Although there may be several individual level of service effects, they are all ultimately related to a general improvement in standard of living, so it is convenient to consider them all together. The dominant level of service effect over the past two decades has been improving comfort standards. This is linked to the ownership of central heating which is, therefore, a convenient factor to use to characterise level of service effects.

Predicting housing stock energy use

The above considerations suggest that it should be possible to derive an equation which describes the changes in the energy consumption of the housing stock since 1970. Following the discussion above it is clear that suitable variables for such an equation are central heating ownership, the external temperature, the improvement in the average dwelling heat loss, the improvement in the average heating efficiency and the number of households.

Using regression techniques, together with the figures in several tables in section 4, the following equation has been derived:

$$Q = N \times [82.32 + (0.82 \times CH\%) - (4.77 \times Te) - (0.29 \times \Delta H) - (1.12 \times \Delta E\%)]$$

Where:

Q	is the housing stock consumption (PJ)
N	is the number of households (millions)
CH%	is the ownership level of central heating.
Te	is the winter external temperature (°C)
ΔH	is the improvement in the average dwelling heat loss relative to 1970 (for 1989 this is 376.0 - 294.7 = 81.3 W/°C. See Table 4.ii)
ΔE%	is the improvement in the average heating efficiency relative to 1970 (for 1989 this is 65% - 54% = 11%. See Table 4.iv.c)

The predictions of this equation are in good agreement with actual consumptions, as shown in Table 5.i and Figure 5.i.

Predicting domestic energy consumption

Notes

Table 5.i illustrates how the changes in each variable have combined to produce the overall housing stock energy consumption.

- CH% - In the first column is the consumption of the average dwelling increasing by 0.82 GJ per 1% growth in the ownership of central heating. It assumes no improvements in heat loss or heating efficiency and that the external temperature is the long term average.
- Te - In the next column the variations to be expected from fluctuating external temperature are introduced. The temperature variation alters the consumption by 4.77 GJ per °C change.
- ΔH - In the third column, the effect of improving heat loss is added in. For each 1 W/°C improvement the consumption falls by 0.29 GJ.
- ΔE - In the fourth column the effect of improving heating efficiency is added in. For each percentage point improvement in the efficiency the consumption falls by 1.12 GJ.
- N - In the fifth column the figure in the fourth column (which is an estimate of the average dwelling consumption) is multiplied up by the number of households. It can be seen that the figures in the fifth column are in quite good agreement with the actual housing stock consumptions shown in the final column. In fact, the difference between the predictions and the actual consumptions has a standard deviation of only 43 PJ, ie the predictions are generally within about 2.5% to 3% of the actual consumptions.

The level of agreement between the predictions and the actual consumptions can also be gauged from Figure 5.i. It is clear that the equation which has been derived describes the observed changes to the housing stock energy consumption quite well.

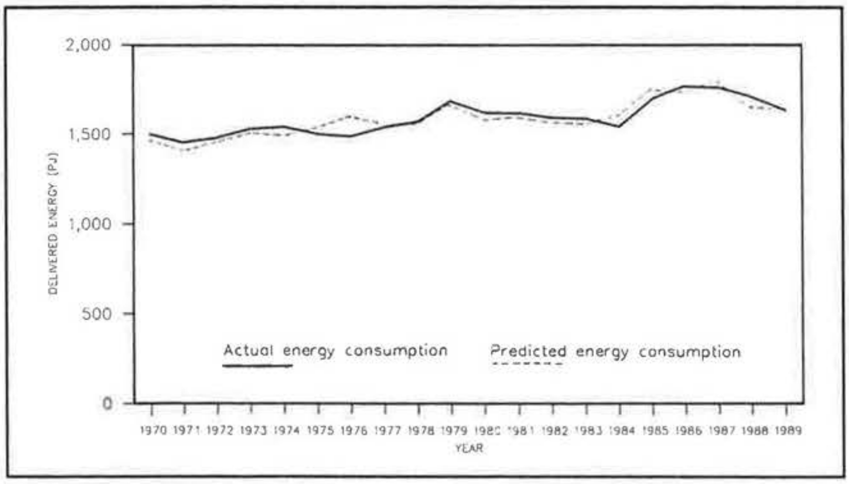
In principle, this equation could also be used to predict future housing stock consumption, given estimates of the relevant variables for the years under consideration. Such projections would probably be reasonably robust in the short term (timescales of less than 10 years) but would be expected to be less reliable beyond that - because central heating ownership would then be close to saturation and so other level of service effects would become dominant. Even so, it would be expected that many levels of service would have saturated or would be nearing saturation at about the same time as central heating. In other words, the fairly steady historical growth due to improving levels of service, which is illustrated in the first column of Table 5.i, would not be expected to continue indefinitely.

Table 5.i: How domestic energy consumption is determined

GB — PJ or GJ

Year	CH% Predicted 1970 standard [GJ]	Te Corrected for temps [GJ]	ΔH Effect of improved insulation [GJ]	ΔE Effect of improved efficiency [GJ]	N Grossed up to stock [PJ]	Q Actual energy use [PJ]
1970	81.79	82.51	82.51	82.51	1,465.23	1,502.0
1971	82.61	79.03	78.45	78.45	1,411.40	1,453.0
1972	84.84	82.70	81.25	80.13	1,457.65	1,482.0
1973	87.91	87.20	84.59	82.35	1,512.45	1,531.0
1974	91.57	87.99	83.94	80.57	1,494.21	1,544.0
1975	94.13	91.98	86.49	81.99	1,537.10	1,503.0
1976	95.40	96.11	88.94	84.44	1,601.96	1,488.0
1977	97.78	94.68	85.71	81.22	1,559.58	1,539.0
1978	98.22	96.55	85.84	80.23	1,556.48	1,572.0
1979	99.88	103.94	91.79	85.04	1,664.75	1,686.0
1980	101.34	102.06	87.88	80.01	1,580.74	1,620.0
1981	102.25	104.88	88.96	79.97	1,593.16	1,615.0
1982	103.97	104.69	86.95	77.97	1,564.53	1,592.0
1983	107.60	106.41	87.02	76.91	1,555.46	1,585.0
1984	109.25	109.96	89.74	78.50	1,601.58	1,541.0
1985	111.55	117.03	96.29	85.05	1,750.40	1,696.0
1986	113.03	116.61	94.73	83.50	1,733.42	1,768.0
1987	114.89	119.90	97.01	85.77	1,796.53	1,760.0
1988	115.82	114.15	90.63	78.27	1,654.37	1,708.0
1989	117.82	113.28	89.15	76.79	1,638.76	1,638.0

Figure 5.i: Predicted and actual domestic energy use



6 Types of fuel, CO_2 emissions and primary energy use

Main trends

Up to this point, energy has been treated as though it were a single homogeneous entity. Apart from mention of ownership and efficiency of different heating systems, the different forms of delivered energy (ie different fuels, including electricity) have not been discussed.

Delivered fuel type is an important consideration because each fuel has different primary sources associated with it, and different losses in conversion, transmission and distribution. This also means that the environmental implications of consumption of each delivered fuel are different.

In this section the delivered fuels used by the housing stock, and the changes to these in the past two decades, are examined. The delivered fuel consumptions are translated into both carbon dioxide emissions and primary energy consumptions. Finally, a simplified energy balance for the housing stock is presented which illustrates the relationships between primary energy and delivered energy and how the delivered energy for space heating and other uses, together with natural gains, meets the useful heat requirement of the housing stock.

Domestic consumption by fuel

While overall delivered energy consumption has remained relatively stable, the proportion of different fuels used for space heating has shifted steadily towards natural gas.

Carbon dioxide emissions

Whenever a fossil fuel is burnt to extract energy, carbon dioxide is produced. Carbon dioxide plays an important role in regulating the climate of the Earth, even though it is present in the atmosphere only in small concentrations - because it absorbs infra-red radiation emitted by the Earth's surface, causing a warming of the lower atmosphere. This 'greenhouse effect' is responsible for maintaining temperatures at the Earth's surface which make life possible. In recent times there has been growing concern, however, that the burning of fossil fuels and other human activities are increasing the concentration of carbon dioxide and other greenhouse gases, which is leading to an additional warming at the Earth's surface. Carbon dioxide is believed to be the most important contributor to this additional warming because of the large quantities which are emitted. Energy efficiency is now seen as one of the most promising means of substantially reducing carbon dioxide emissions whilst maintaining, or improving, the levels of service achieved.

Since 1970 the carbon dioxide emission which can be attributed to domestic energy use has fallen substantially.

Primary consumption

Each delivered fuel has associated with it an equivalent in terms of primary energy, and this equivalence can be expressed as a primary energy ratio. This ratio indicates the size of the losses involved in conversion, transmission and distribution as well as the amount of energy used by the energy industries themselves. The primary energy ratio differs considerably between different delivered fuels. For a fuel where there are few losses the primary energy ratio is close to unity. As the size of the losses increases, so the primary energy ratio increases.

The domestic sector primary energy ratio has shown a substantial improvement between 1977 and 1989 because of efficiency improvements to the supply of energy. Consequently, the domestic sector now makes better use of natural resources.

Notes

During the period 1970 - 1989 there has been a dramatic change in the proportions of different fuels delivered to the housing stock (see Table 6.i and Figure 6.i). This is in marked contrast to the relative stability in the total delivered energy use of the housing stock.

The main feature of the changes is the rapid penetration of natural gas. Natural gas supplied less than 5% of the total energy delivered to the housing stock in 1970. By 1989 this proportion had risen to 64%. Town gas, on the other hand, has almost completely disappeared. In 1970 it supplied 20% of the total housing stock demand. Similarly, solid fuel use has declined from 48% of the total to only 11%, and oil has declined from 9% to 5%. Electricity, on the other hand, has remained at an almost constant proportion of the total - 18% in 1970 and 20% in 1989.

Although the proportion of delivered energy represented by electricity has remained roughly constant, in absolute terms electricity use has risen by almost 20%. This is despite the fact that electricity use for space heating has declined - from about 87 PJ in 1970 to 58 PJ in 1989. Clearly, the considerable increase in electricity use for lights and appliances (see Table 4.v) is the driving force behind the net increase in total housing stock electricity use.

Table 6.i: Energy use of the housing stock by fuel type

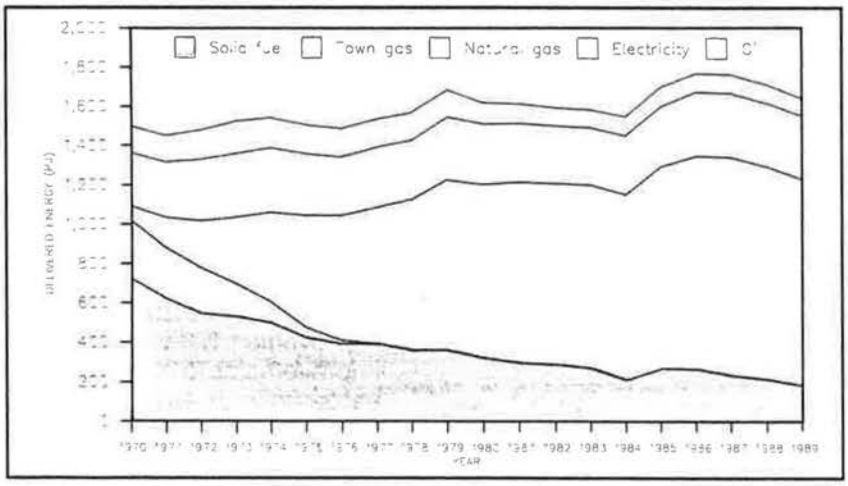
GB PJ

Year	Solid fuels	Gas (natural)	Gas (town)	Gas (total)	Electric	Oil	All fuels
1970	721	65.9	305.1	371	272	138	1,502
1971	619	149.4	263.6	413	285	136	1,453
1972	545	241.4	232.6	474	307	156	1,482
1973	532	337.9	167.1	505	323	171	1,531
1974	500	455.8	109.2	565	327	152	1,544
1975	423	567.0	52.0	619	315	146	1,503
1976	391	635.8	15.2	651	300	146	1,488
1977	396	689.4	4.6	694	302	147	1,539
1978	361	762.0	2.0	764	302	145	1,572
1979	364	863.1	1.9	865	316	141	1,686
1980	315	887.2	1.8	889	303	113	1,620
1981	293	921.3	1.7	923	298	101	1,615
1982	288	916.5	1.5	918	292	94	1,592
1983	268	933.8	1.2	935	292	90	1,585
1984	211	939.9	1.1	941	295	94	1,541
1985	270	1,018.9	1.1	1,020	310	96	1,696
1986	266	1,079.2	0.8	1,080	323	99	1,768
1987	231	1,106.5	0.5	1,107	328	94	1,760
1988	210	1,081.9	0.1	1,082	325	91	1,708
1989	180	1,046.0	0.0	1,046	324	88	1,638

Source: Digest of United Kingdom Energy Statistics

Figures for Great Britain have been deduced from the United Kingdom figures published in the Digest of United Kingdom Energy Statistics. For each of the four categories of fuel in the table (solid, gas, electricity and oil) a factor has been applied to give the proportion of that fuel which is consumed in Great Britain. A separate set of factors has been determined for each year.

Figure 6.i: Energy use of the housing stock by fuel type



Notes

Table 6.ii and Figure 6.ii show that, in 1970 the carbon dioxide emission associated with the housing stock was about 200 million tonnes. By 1989 this had been reduced to about 150 million tonnes.

These figures include the carbon dioxide emitted at power stations to meet the domestic electricity demand.

The reduction between 1970 and 1989 is due to a number of things:

Firstly, the energy efficiency measures discussed in this report have held domestic energy consumption down and avoided the increase in carbon dioxide emissions which would otherwise have occured. Assuming the same fuel mix as actually applied in 1989, without energy efficiency improvements total domestic consumption would have been about 47% higher (see Table 4.vii) and so carbon dioxide emissions would have been roughly 47% higher than 150 million tonnes, ie about 220 million tonnes.

Secondly, the change in the fuel types used has been important. Burning solid fuel produces roughly twice as much carbon dioxide per unit of delivered energy obtained as does gas, whilst oil is intermediate between the two. Clearly, therefore, the move towards gas and away from solid fuel and oil has had a beneficial effect.

Thirdly, although the electricity use has increased, the emission associated with that electricity use has declined. This has occured because the efficiency of generation, transmission and distribution has improved and because of an increasing proportion of non-fossil fuel derived electricity.

Clearly, however, although electricity use only accounts for about 20% of the housing stock energy use, it contributes a much greater proportion of the carbon dioxide emission. This is because electricity generation in this country is heavily reliant on coal and because conventional thermal power stations are necessarily limited to relatively low efficiencies (about 35% being typical).

Partially compensating for this, of course, is the fact that electricity has a very high end use efficiency - as indicated by the 100% space heating efficiencies quoted in Tables 4.iv.a and 4.iv.b.

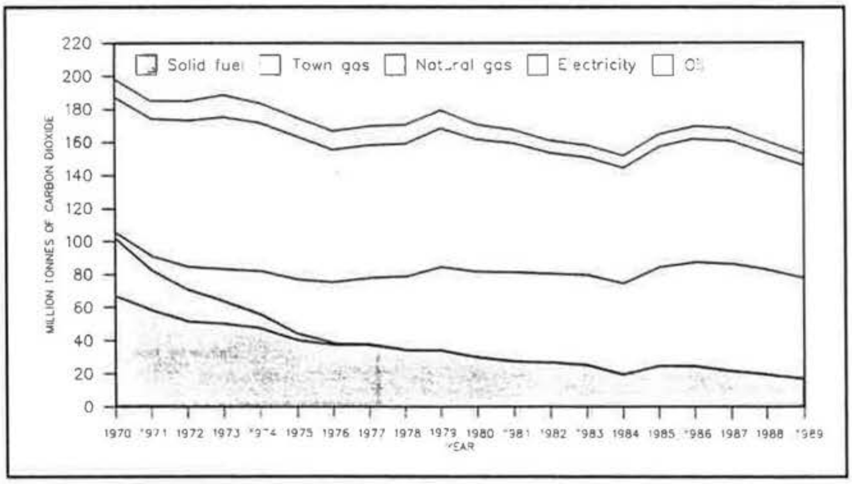
Table 6.ii: Carbon dioxide emissions due to domestic energy consumption

GB — Million tonnes CO_2

Year	Solid fuels	Gas (natural)	Gas (town)	Electric	Oil	All fuels
1970	67.0	3.8	34.7	81.7	10.9	198.1
1971	58.0	8.7	24.3	83.0	10.7	184.8
1972	51.4	14.1	19.0	88.2	12.3	185.1
1973	50.0	19.7	13.3	92.0	13.5	188.5
1974	47.1	26.6	8.2	89.4	12.0	183.2
1975	39.9	33.1	3.9	86.2	11.5	174.7
1976	36.9	37.1	1.1	79.7	11.5	166.4
1977	37.2	40.3	0.3	80.2	11.6	169.6
1978	33.9	44.5	0.1	80.2	11.4	170.2
1979	34.0	50.4	0.1	83.3	11.1	179.5
1980	29.7	51.8	0.1	79.8	8.9	170.4
1981	27.5	53.8	0.1	77.7	8.0	167.0
1982	26.9	53.5	0.1	72.6	7.4	160.6
1983	25.1	54.5	0.1	70.9	7.1	157.7
1984	19.5	54.9	0.1	69.6	7.4	151.5
1985	24.9	59.5	0.1	72.5	7.6	164.6
1986	24.6	63.0	0.1	74.1	7.8	169.6
1987	21.7	64.6	0.0	74.2	7.4	168.0
1988	19.7	63.2	0.0	70.0	7.2	160.0
1989	16.9	61.1	0.0	67.5	6.9	152.4

Source: BRE estimates of emission factors applied to Table 6.i figures.

Figure 6.ii: Carbon dioxide emissions due to domestic energy consumption



Notes

As should be clear from the discussion on carbon dioxide emissions, a saving of one petajoule of one delivered fuel may not necessarily be as beneficial as a similar saving of another fuel. If there were an ideal price structure then price might be a good measure of the relative value of different forms of energy. Clearly, the prices do, at least partially, reflect the values of different fuels - particularly the value of electricity relative to other fuels (see Figure 1.ii). A better measure, however, is one which is related to the amount of primary energy consumed.

For 1989 the primary energy ratio for coal was about 1.02 (secondary solid fuels such as coke and breeze have a much higher primary energy ratio). For gas and oil the ratio was about 1.05 and 1.17 respectively. For electricity the ratio was 3.07 (as noted earlier, the losses have been reducing and so the primary energy ratio for electricity has improved over the years).

The overall average primary energy ratio depends on the losses associated with the individual delivered fuels and the proportions of those fuels actually used. For the domestic sector the 1989 average primary energy ratio was 1.46. For comparison, the ratio in 1977 was 1.53 (see Table 6.iii and Figure 6.iii), so there has been a substantial improvement since then. It is difficult to derive an entirely comparable figure for earlier years because of the different format of the information presented in the *Digest of United Kingdom Energy Statistics* for these earlier years. However, the picture for consumption as a whole in 1970 is characterised by the predominance of coal and the relative unimportance of natural gas (as previously indicated by Figure 6.i). In 1970, coal accounted for 47% of the total available primary energy, petroleum 44%, natural gas and colliery methane between them 5%, nuclear electricity 3% and hydro-electricity less than 1%.

It should be noted that there are several complications involved in relating delivered energy to primary energy for electricity. For some end uses it is possible for consumers to save money by switching from using on-peak electricity to off-peak electricity. Such a switch may not involve either an increase or a saving of delivered energy. However, using more off-peak electricity and less on-peak electricity helps to even out the daily demand variations. This means that power stations are able to run more continuously which, in turn, means that the conversion process becomes more efficient. The net effect, therefore, is that primary energy consumption is reduced.

Table 6.iii. Primary and delivered energy figures, 1977 and 1989

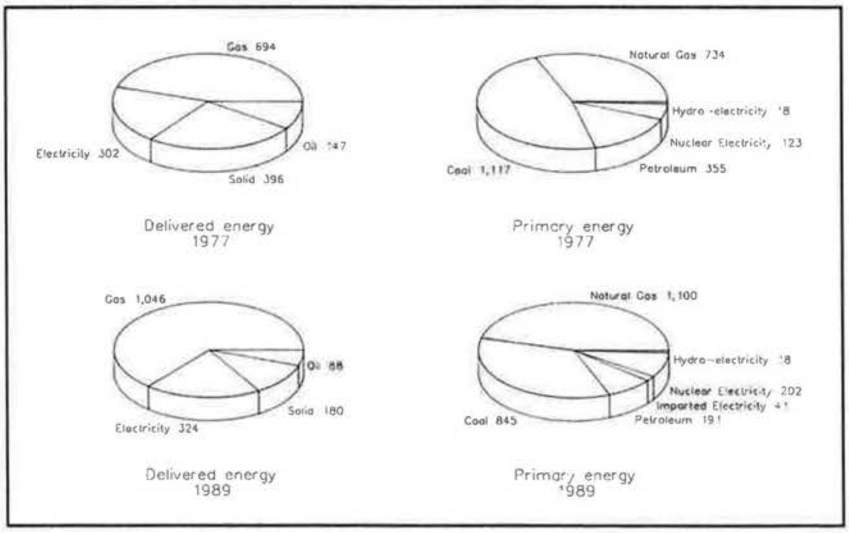
GB PJ

Fuel	1977	1989
Domestic sector delivered energy		
Gas	694	1,046
Electricity	302	324
Solid	396	180
Oil	147	88
Total	1,539	1,638
Primary energy equivalent to the above		
Natural gas	734	1,100
Coal	1,117	845
Petroleum	355	191
Imported electricity	0	41
Nuclear electricity	123	202
Hydro-electricity	18	18
Total	2,347	2,397
Primary energy ratio	1.53	1.46

Source: Digest of United Kingdom Energy Statistics

Note: There are complications in the definition of primary electricity (nuclear and hydro). These are noted in the Digest of United Kingdom Energy Statistics.

Figure 6.iii. Primary and delivered energy figures, 1977 and 1989



Energy balance of the housing stock

Notes

Figure 6.iv illustrates the scale of the housing stock related energy flows for 1989. The figure shows the relationships between primary energy, delivered energy, useful heat and the housing stock heat losses.Some of the figures in the energy balance are known quite accurately (eg delivered gas) while others are necessarily more uncertain (eg useful heat gains). All numbers are undoubtedly of the right order however.

There are five blocks in the diagram.

The first block shows that part of the national primary energy consumption which is related to the housing stock.

The amount of energy, and the fuels, actually delivered are shown in the second block. The difference between the first and the second block is the losses associated with conversion, transmission and distribution, as well as the energy used by the energy industries themselves.

The third block shows the same delivered energy as the second, augmented by natural gains (solar and metabolic). This block illustrates the end uses of the delivered energy rather than the fuels delivered.

The fourth block shows that part of the total delivered energy which supplies useful heat. A part of the useful heat is supplied directly by the energy delivered for space heating (reduced according to the average efficiency of heating systems). The rest is supplied as incidental heat gains from lights, appliances, cookers, hot water systems and from natural gains. Only a part of the potential incidental heat gains are useful. In summer, for example, a large proportion of incidental gains are deliberately rejected because they would otherwise cause overheating. Even in winter, part of the potential incidental gains are lost. For example, a large part of the potential gains from hot water are lost as water flows away through the drains. Similarly, much of the heat produced by cooking is often lost through extraction to the outside.

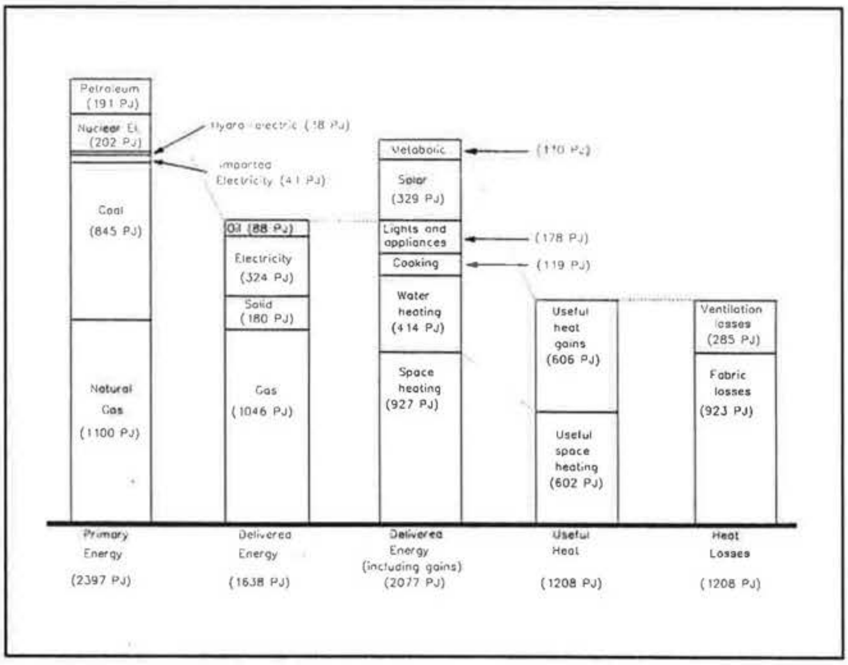
The fifth block shows how the useful heat is lost to the external environment through the fabric and ventilation losses associated with the national housing stock. By reducing the losses at the fifth block - through improved insulation - the primary energy input shown in the first block can be reduced. This can also be achieved, however, through improvements to other parts of the overall energy balance:

- The losses between the third and fourth block can be reduced through improvements to the efficiencies of heating systems and by recovery of incidental gains which are lost.

- The solar heat gains can be increased by solar design features and by appropriate orientation. Such 'passive solar' techniques result in a reduced proportion of the useful heat being supplied by the heating system - and, hence, a reduced amount of fuel has to be delivered for space heating.

- A given delivered energy requirement can be supplied from a reduced amount of primary energy by reducing the losses between the first and second block. This can be done, for example, by improving conversion efficiency or by the energy industries reducing the amount of energy which they themselves use.

Figure 6.iv: Energy balance of the housing stock - 1989



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References and sources

The following is a list of publications and sources of information which have been referred to within this report. Those marked with a * were referred to so that the reader would know where to find out more about particular topics which, of necessity, were only briefly touched upon in this report. The rest are statistical sources which have been used in compiling this report (and which are quoted below the individual tables) and in the development of the BREHOMES model. In most cases, several editions of these statistical sources have been consulted in preparing the tables for this report.

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Also available from BRE

BREDEM — BRE Domestic Energy Model: background, philosophy and description

B R Anderson, A J Clark, R Baldwin and N O Milbank
Ref BR66 £9 BRE Report 1985
Describes a procedure for calculating the annual energy requirements of houses. It is designed to be relatively simple to operate, using a calculator or computer, providing realistic results. BREDEM is based on many years' practical experience of what happens in buildings, and represents a synthesis of up-to-date information.

An economic assessment of some energy conservation measures in housing and other buildings

J Pezzey
Ref BR58 £12 BRE Report 1984
Provides a framework for economic advice and decisions on energy conservation in housing and other buildings. It also describes the various measures and assesses their effectiveness in a range of applications.

Energy assessment for dwellings using BREDEM worksheets

B R Anderson
BRE Information Paper IP13/88 £2.50
Data are given for a worksheet calculation of energy-use in dwellings using a simplified BREDEM methodology. The worksheet — one copy is included with the Paper — is constructed for use with a hand-held calculator and IBM-compatible microcomputers.

Building Regulations: conservation of fuel and power — the 'energy target' method of compliance for dwellings

B R Anderson
Ref BR150 £10 BRE Report 1989
Details of the Regulations effective in 1990 are presented in worksheet form. The data needed for calculations, sample calculation and blank worksheet are provided. Additional worksheets, packed in 50s, are available under *Ref AP47*.

Energy efficiency in dwellings

BRE Digest 355 £3.50
Identifies which factors determine the energy requirements of a dwelling, and describes the methods used to assess energy efficiency. Also looks at levels required by Building Regulations for new dwellings, and improvements to the energy efficiency of existing buildings, including opportunities that arise in major refurbishment.

Energy use in buildings and carbon dioxide emissions

L D Shorrock and G Henderson
Ref BR170 £25 BRE Report 1990
About half the UK's emission of the major greenhouse gas carbon dioxide can be attributed to buildings, and about 60% of this to dwellings. This Report analyses and reviews evidence of UK emissions, looking also to some extent at the world as a whole, and considers the potential for reducing them.

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Explores the relationship between building energy use and the emission of carbon dioxide and other greenhouse gases. Also considers the scope for reducing carbon dioxide emissions through applying energy efficiency measures in existing buildings.

Thermal insulation: avoiding risks

Ref BR143 £10 BRE Report 1989
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