MURE II Project

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BEST AVAILABLE TECHNOLOGIES IN HOUSING

CASE STUDY UK

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1 INTRODUCTION

The MURE database contains data on energy efficiency measures, energy consumption and energy technologies pertaining to the Member States of the EU. The database can be used to simulate the impact of energy efficiency interventions in each of the four main sectors; households, transport, industry and tertiary. This report demonstrates the use of MURE to forecast the impact of a number of Best Available Technologies in the housing sector in the UK.

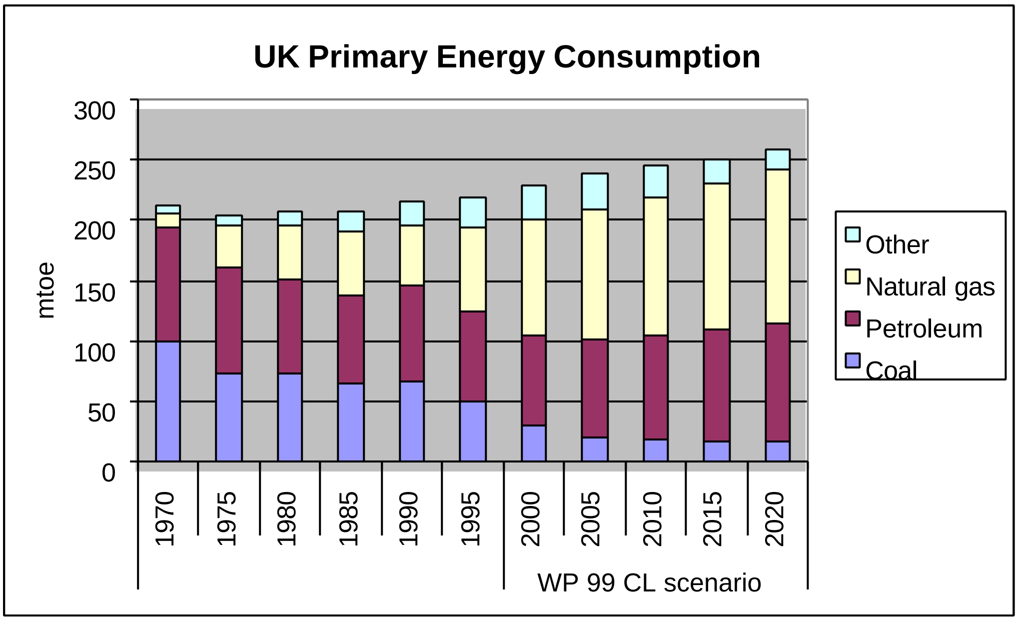
2 BACKGROUND INFORMATION

2.1 Energy Trends

2.1.1 Overall energy consumption

Total primary energy consumption in the UK in 1995 was at a similar level to the early 1970s. During the intervening years consumption fell by nearly 20% in the early 1980s due to economic and structural factors. Conversion efficiencies have remained at between 30% and 32% throughout, so delivered energy has followed the same pattern as primary energy. The main change over the years has been a significant shift from coal to gas.

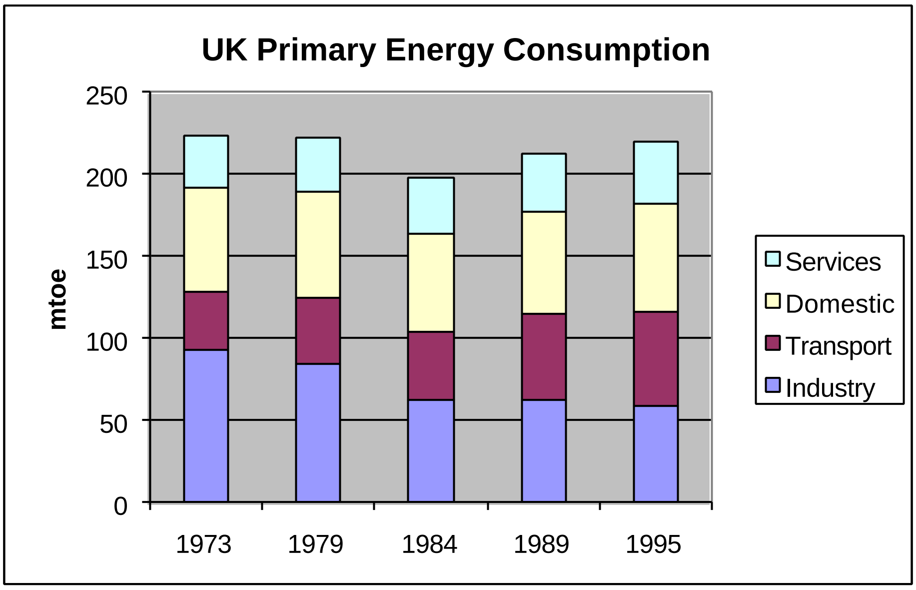
Figure 1 UK Primary Energy Consumption by Fuel 1970 - 2020



The forecasts for primary and delivered energy consumption to 2020 show a steadily increasing growth. These forecasts have only just been published and are generally lower than the last predictions published in 1995. The figures shown here are the CL scenario in which central economic growth is combined with low energy prices.

Primary energy consumption by sector shows that a step change occurred in the early 1980's when the poor state of the economy coupled with high energy prices lead to a significant structural change and a related drop in industrial energy consumption. This has remained at a lower level with the increase being mainly generated by the growth in transport sector (Figure 2).

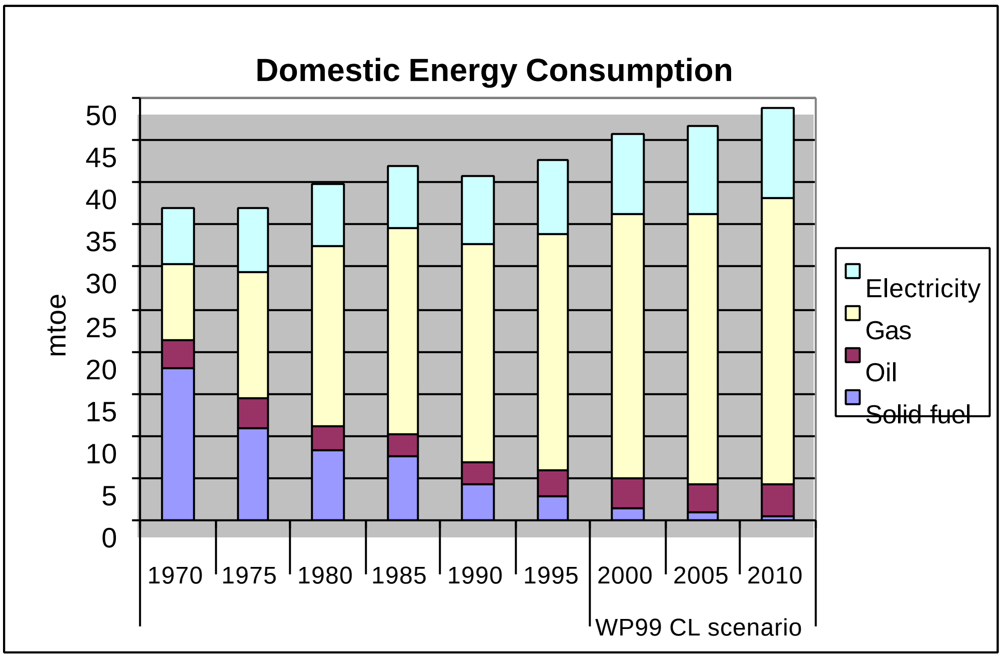
Figure 2 UK Primary Energy Consumption by Sector since 1973



2.1.2 Domestic energy consumption

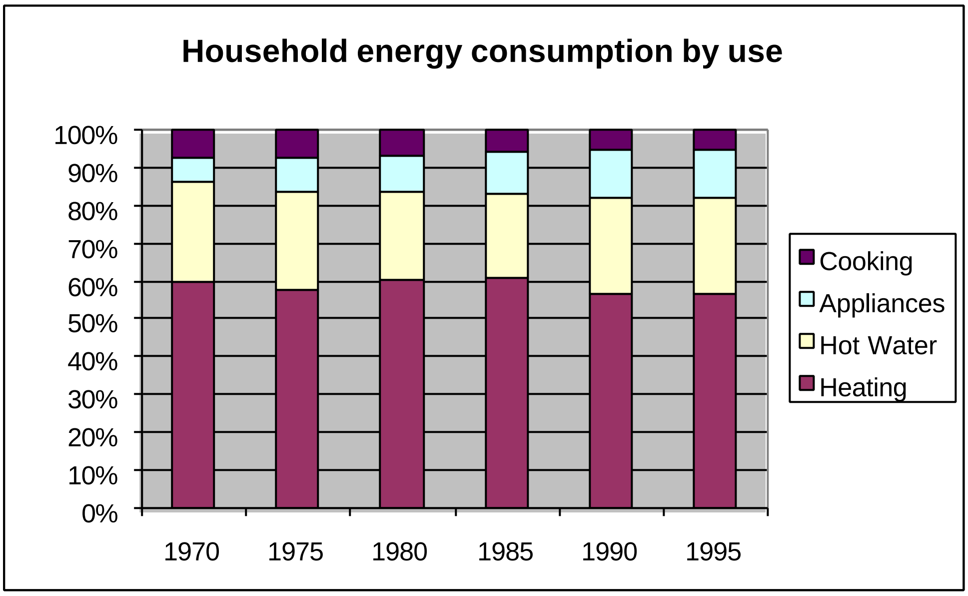
Total energy demand in the domestic sector rose by some 15% between 1970 and 1995. During this period there was a significant shift to gas due to the exploitation of the North Sea gas fields. Gas now accounts for over 65% of domestic energy use (and over 75% of heating). Conversely, solid fuel fell from being the dominant fuel in 1970 with nearly 50% of the total, to supplying less than 7% in 1995. Despite the increase in ownership of electric appliances, total electricity consumption remained fairly constant at between 18% and 20%. (Figure 3).

Figure 3 UK Domestic Energy Consumption by Fuel 1970 - 2010



As this graph shows, domestic energy consumption is expected to continue to rise to 2010, with gas maintaining its dominant share and solid fuel continuing to decline.

Figure 4 Household Energy Consumption by End Use 1970 – 1995

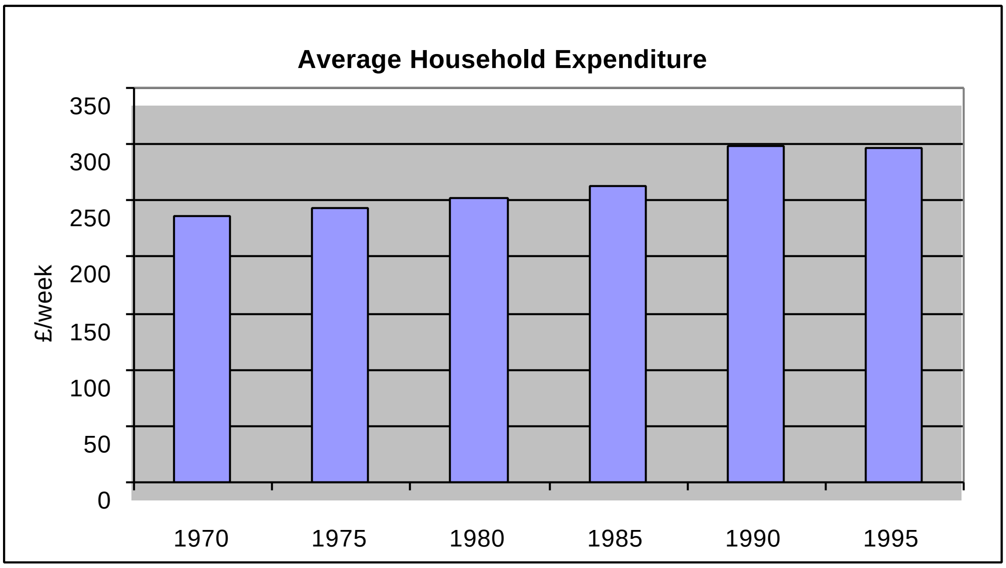


As Figure 4 shows, energy consumption for electric appliances more than doubled over the 25 year period, whereas heating and hot water use increased slightly and energy used in cooking decreased.

2.2 Socio-economic Context

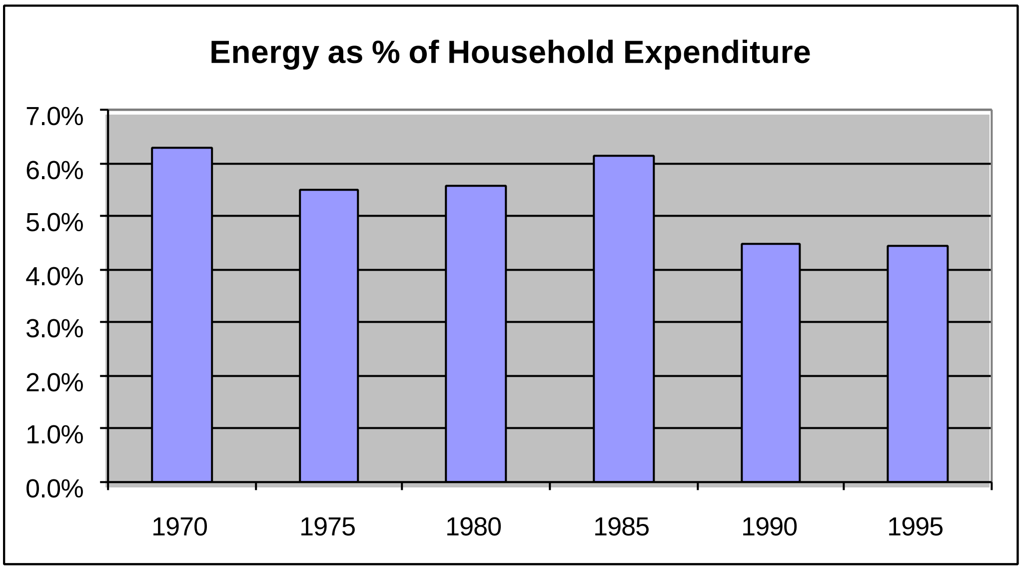
Average income and expenditure levels in real terms have been growing since 1970, with a slight levelling off in the 1990s.

Figure 5 Household Expenditure on All Goods at 1996 Prices from 1970-95.



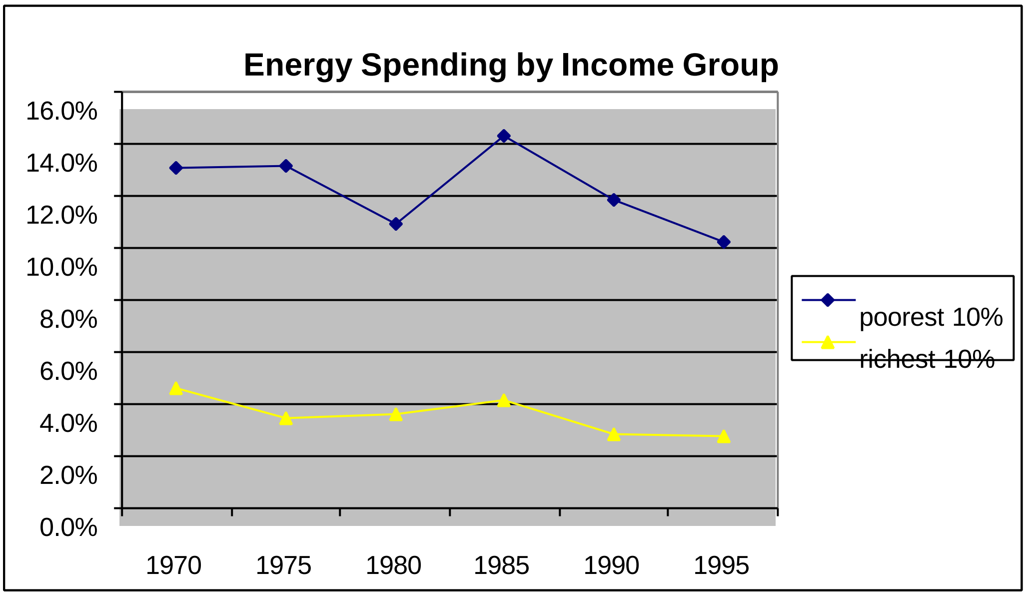
However, average spending on energy has fallen slightly over the same timescale, with the exception of a period in the mid 1980's corresponding to a time of both higher prices and colder weather. As a result, the average expenditure on energy as a proportion of all spending has fallen by over 28% since 1970.

Figure 6 Energy as a Percentage of Total Household Spending 1970-95.



Within these overall figures it is interesting to look at the importance of energy for different economic groups. The poorest tenth of the population spent 10% of their income on energy in 1995, whereas the richest tenth spend under 3%. For all economic groups, the proportion of their income spent on energy has declined in recent years. Evidence shows that it is the poorer households that have the least insulated homes.

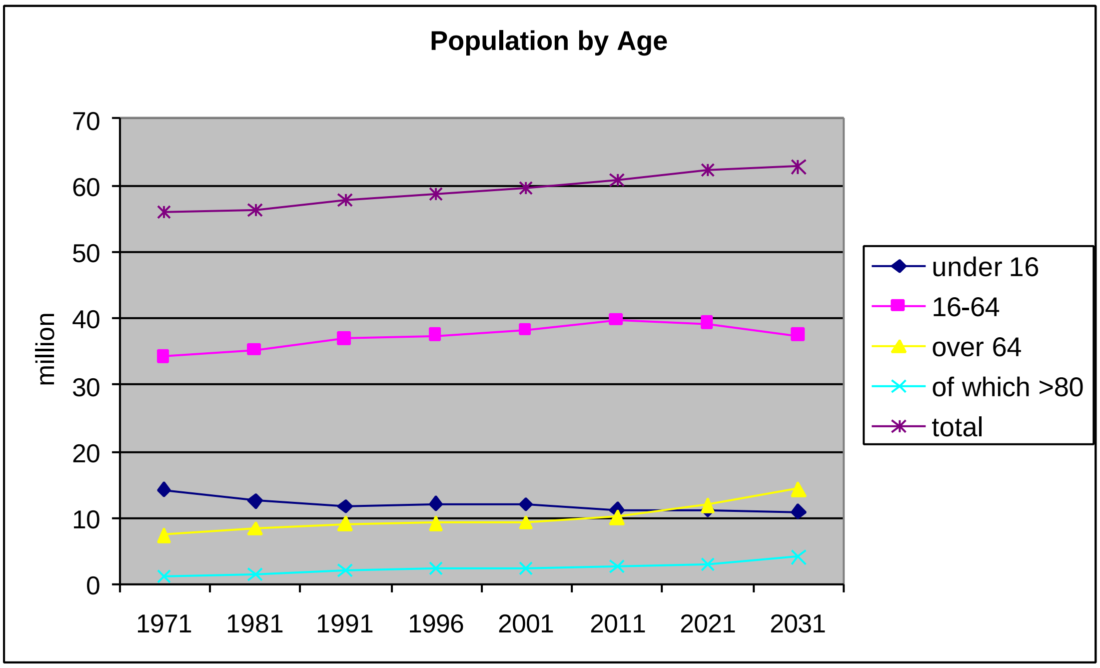
Figure 7 Energy as % of Household Expenditure by Income Group 1970-95



2.3 Demographic Trends

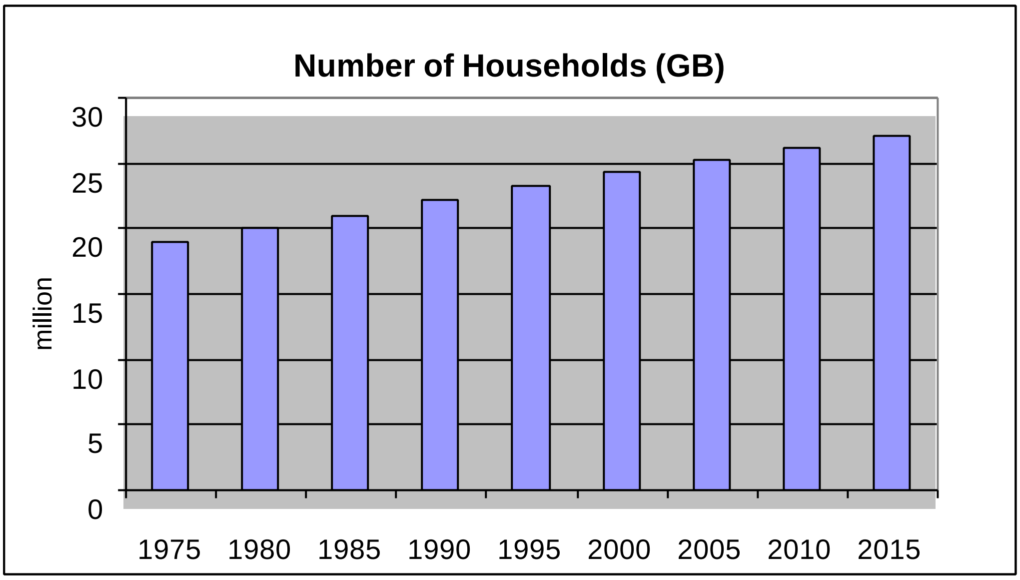
The total population of the UK has been growing steadily over the last 25 years and this trend is expected to continue. Within this overall growth there is a noticeable aging of the population. The number of people over 64 is expected to double between 1971 and 2031, while the number of children is expected to fall and the number of working-age adults is likely to begin to fall around 2015.

Figure 8 Actual and Predicted Population by Age Group 1971-2031



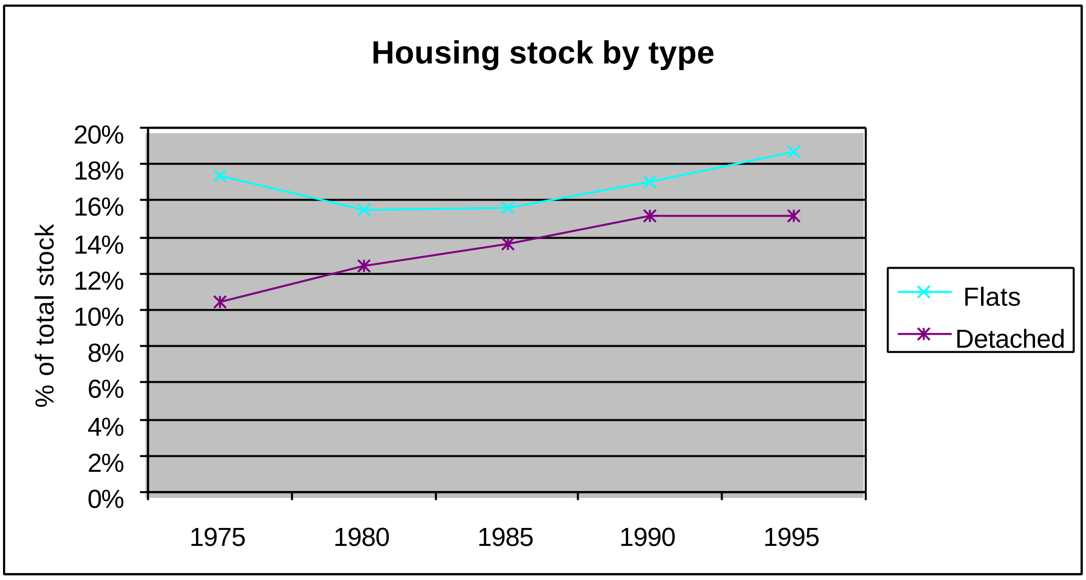
The number of households has been growing at a faster rate than population due to a trend towards smaller fewer occupants per household, from 2.8 in 1970 to 2.4 in 1995.

Figure 9 Actual and Predicted Numbers of Households



For energy consumption, it is also interesting to note the trends in type of building. The proportion of detached houses, which have an average heat loss of 411 W/K, has been growing steadily. However, as Figure 10 shows, since the early 1980s, this has been compensated by a similar growth in the proportion of flats, which have an average heat loss of only 188 W/K.

Figure 10 Housing Stock by Type 1975-1995



Overall the average size of dwellings has been decreasing. Table 1 shows the average floor area of housing in 1996 by date of construction.

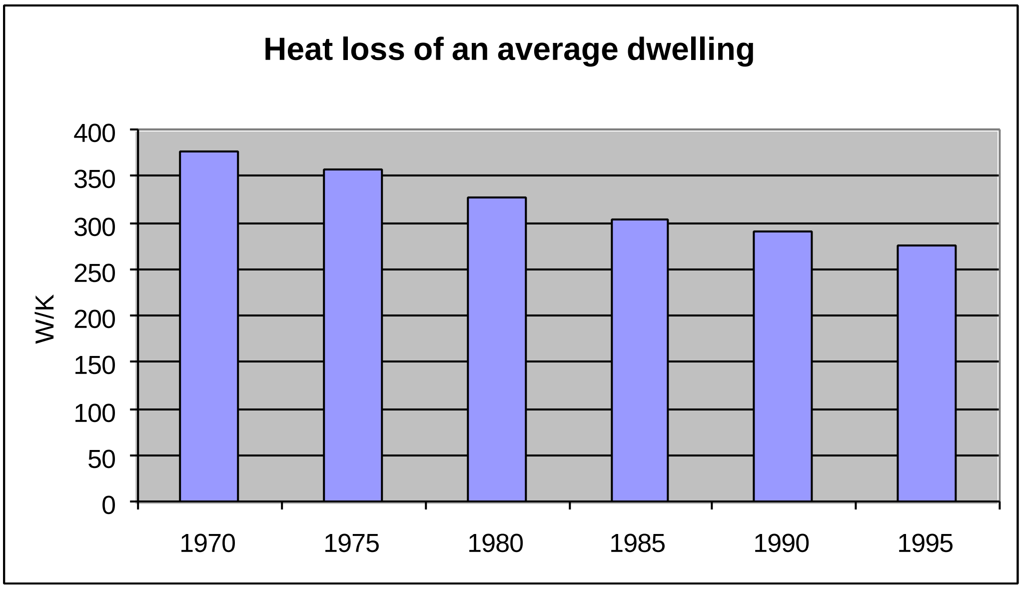
Table 1 Average dwelling size by date of construction

Date of construction	pre-1850	1850-99	1900-18	1919-44	1945-64	1965-80	post 1980
Ave dwelling size m2	140	84	87	85	80	82	76

2.4 Energy Efficiency in Housing

There is no doubt that the energy performance of dwellings has improved since the 1970s. Energy conservation requirements were first introduced in the building regulations in 1965 and have been tightened at regular intervals since. As a result of both rising energy prices and government support programmes, the energy performance of homes built prior to the more stringent regulations has also improved markedly.

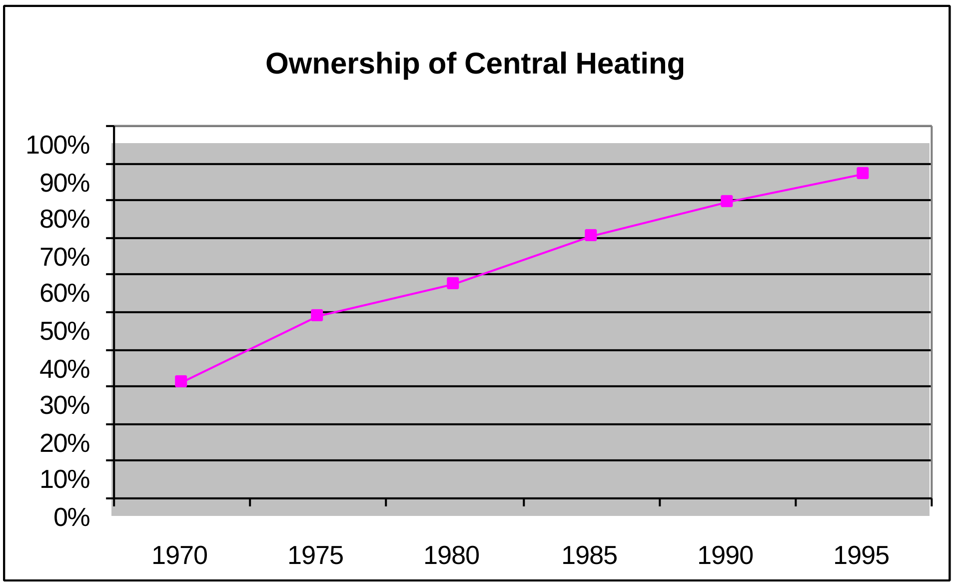
Figure 11 Heat Loss of an Average Dwelling 1970-1995



Figures for the ownership of a number of insulation measures have been collected since 1974. Saturation levels have practically been reached for the number of dwellings having the two most cost effective measures; loft insulation and hot water tank insulation. However, in 25% - 40% of homes, more loft insulation could still be cost-effectively installed. Ownership of other insulation such as double glazing and cavity wall insulation has also been growing steadily. By 1995, just over 10% of dwellings could be classed as fully insulated, but almost 15% had no insulation. These figures are considered in more detail in Chapter 3.

In parallel with this improved efficiency of the building fabric has been an increase in ownership of central heating (predominantly gas) from 31% in 1970 to 87% in 1995.

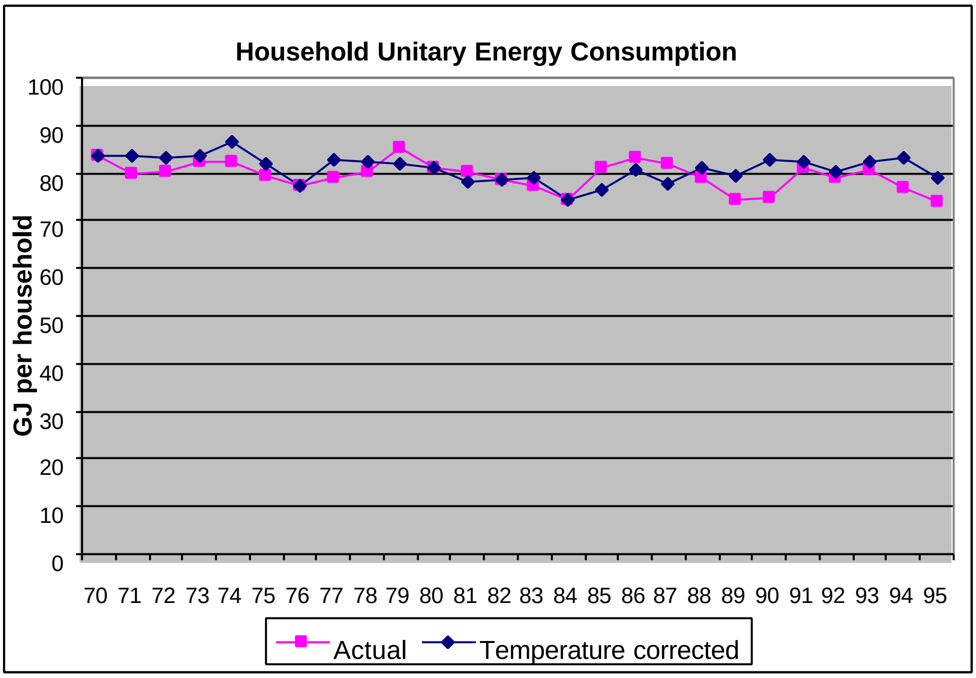
Figure 12 % of Housing with Central Heating 1970-1995



The average efficiency of central heating systems has remained roughly constant over the period, whilst the efficiency of non-central heating appliances has improved largely due to the shift away from solid fuel. The installation of central heating tends to lead to an increase in comfort levels, as more rooms are heated. The average internal temperature has risen from 12.8°C in 1970 to 16.8°C in 1995. It is expected that the saturation comfort level would be around 19°C, which could take a further 25 years to achieve.

As a result of both the fabric improvements and increased levels of comfort, the average energy consumption per dwelling has remained roughly constant over the 25 year period.

Figure 13 Household Unitary Energy Consumption 1970-95



Thus it has been reasonable to assume that the overall energy consumption in housing is proportional to the number of dwellings. However, as saturation levels are approached in terms of standards of comfort and appliance use, improvements to building insulation and energy supply efficiency may begin to result in a decrease in unitary consumption.

3 BEST AVAILABLE TECHNOLOGIES IN HOUSING

3.1 Energy Supply Technologies

Gas central heating is the predominant form of space and water heating in the UK, being installed in 68% of homes. The other main means of heating are electrical (12.7%) and individual gas heaters (8.7%). The remainder are heated by solid fuel (which has been declining steadily) and oil, whose share has declined but is starting to show signs of growing due to the price advantage over gas. It is interesting to note that while the average annual efficiency of non-central heating systems improved by 15% between 1970 and 1995, that of central heating systems remained at around 70% throughout that period.

This dominance of gas central heating leads to two important points for the potential to improve energy efficiency in heating;

1. Any significant improvement in the average efficiency of gas boilers on the market will have a strong impact on energy savings over a relatively short period (15-20 years).

2. New technologies that do not appear to the consumer as similar to gas central heating face substantial structural and behavioural barriers.

Electricity is supplied to practically all homes from the national grid. Only in a few isolated areas is electricity supplied from generators, wind turbines or photovoltaics. Until recently it was impossible for very small generators to sell excess electricity to the grid.

3.1.1 Improved boiler efficiency

The average annual efficiency of a central heating boiler is around 76% for gas and 73% for oil, although the efficiency of older boilers still in service can be as low as 55%. The best condensing boilers on the market currently achieve efficiencies of 91%, while the best non-condensing boilers reach 83%. Under the new Boiler Directive it is expected that the average efficiency of boilers on the market could reach 85%.

3.1.2 Heat pumps

Despite the technology having been developed for some time, there are very few applications of electric heat pumps in domestic dwellings in the UK. Of these, only a very small number in remote areas are used as the main heat source. The majority are used for swimming pools and conservatory heating/cooling. There is a small but growing market for air conditioning using heat pumps in the more expensive new housing in the south of England.

The greatest potential for energy conservation is through the use of gas engine heat pumps, which could save up to 50% of the cost of heating a gas centrally-heated home, and be viable in up to 20% of new homes.

3.1.3 Micro-CHP

Micro-cogeneration systems for domestic use are under development and expected to reach the market by 2005. Demonstration models have been able to generate between 20% and 40% of electricity demand for a 10% increase in gas demand. They are particularly economic in dwellings with a high heat-power ratio. The units are intended to be a straight replacement for a gas central heating boiler in terms of size, noise and cost, so as to maximise their potential market.

3.1.4 CHP-based district heating

There are very few applications of CHP-based district heating in the UK; approximately 1% of dwellings are connected to DH and only about 5% of these are CHP-based. It is estimated that there is an economic potential for 1 million homes to be connected to CHP-based district heating by 2010, of which half will come from new buildings, 35% from converting existing DH to CHP and the remainder through connecting existing homes to DH networks. CHP-based district heating schemes can provide homes with electricity and heat with an overall conversion efficiency of 70-80%.

3.1.5 Solar hot water collectors

In the UK, solar systems can provide up to 60% of a household's hot water during the year. However, these systems have been on the market for over 25 years but have only achieved a tiny proportion of the heating market in that time. Whilst the cost of the solar panels has reduced dramatically over time, the relatively high maintenance costs can outweigh the savings achieved. It is unlikely that there will be any further significant reduction in system costs and more financial support is not expected in this technology. The total market is likely to remain low, with growth in a few niche areas such as swimming pool heating. Hence the use of solar hot water heating has not been included in the simulations.

3.1.6 Photovoltaics

The number of applications of photovoltaics in domestic dwellings in the UK is tiny (83kW installed by 1997), and limited to homes in very remote areas. Peak domestic electricity consumption does not coincide with peak generating time and therefore either storage components or the potential to export to the grid is required. Current PV technology is too expensive for most applications, although it is expected that the cost of a module could be halved by 2010. However, in order to be economically viable for grid-connected domestic applications, the cost would need to reduce by a factor of 7-8.

It is estimated that the technical potential for domestic PV systems could be 2,600 GWh/year generated by 2010 and over 13,000 GWh/year by 2025. However, a realistic market potential would be less than 0.5% of this.

3.2 Insulation Technologies

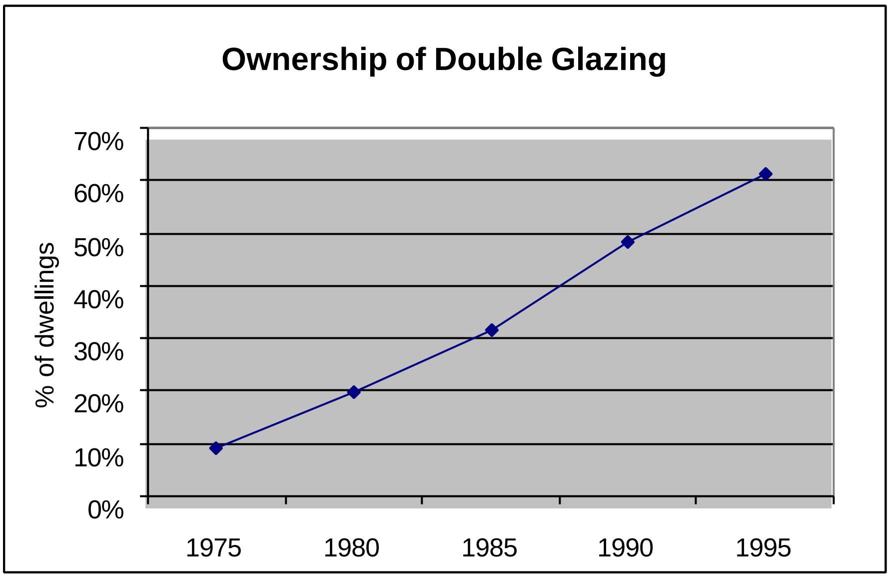
The energy performance of the average dwelling has improved substantially since the early 1970s. An estimate of the recently applied Standard Assessment Procedure for an average house in 1970 would be a rating of 12 (out of 100), compared to an average performance of 41.5 in 1995. Improved insulation has been a major factor in this improvement.

3.2.1 Insulation of existing buildings

There is an autonomous trend to install two main types of insulation in existing dwellings; cavity wall insulation and double glazing. The former is installed predominantly for reasons of energy saving and/or comfort, and there is currently a grant available to assist with this. The latter is often installed for other reasons such as a cosmetic improvement, to increase the value of the property or to reduce noise.

Figures 14 and 15 show the percentage of homes with double glazing and cavity wall insulation since 1975.

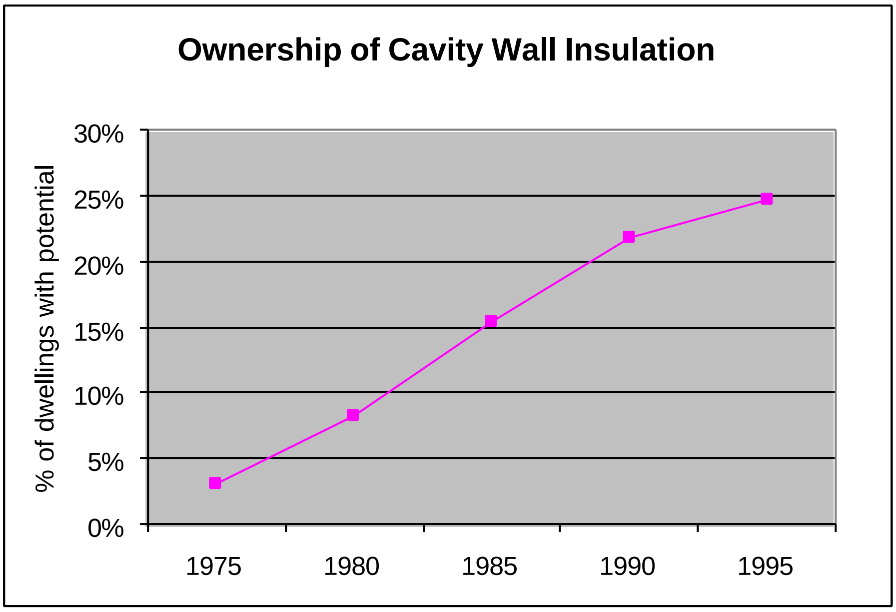
Figure 14 Ownership of double glazing 1975-95



The graph above includes all dwellings which have any double glazing. When the proportion of double glazed rooms in a house was first counted in 1983 only 9% of all homes had full double glazing, but this figure has now risen to 38%. The number of homes with less than 60% double glazing has begun to fall.

The graph for cavity wall insulation shows only the proportion of dwellings in which it would be possible to install the insulation i.e. where a cavity exists. In 1995 there were some 7 million homes without cavity walls.

Figure 15 Ownership of Cavity Wall Insulation 1975-95



Loft insulation has been installed in most dwellings over the last 25 years, but saturation point is being reached for, although in a large number of these it would be economic to increase the depth of insulation.

3.2.2 Insulation of future buildings

The Building Regulations have contained a requirement to install energy conservation measures since 1965. Subsequent issues have steadily tightened these requirements. Until 1995, the regulations stipulated the thermal characteristics of each of the main building elements (ground, walls, roof, windows and doors). However, in 1995 a new system was introduced which allows the architect or builder to vary the performance of any element provided that an overall energy rating is achieved, which takes into account the building fabric, the heating system and any other heat gains.

Table 2 shows the improvements in elemental u-values for each regulation.

Table 2 Elemental u-values (W/m2K) of Building Regulations

	Year of Regulation			
Element	1976	1985	1991	1995
Ground	1.00	0.60	0.45	0.35
Roof	0.60	0.35	0.20	0.20
Walls	1.00	0.60	0.45	0.45
Windows	N/a	5.70	5.70	3.00

It is expected that a revision to the regulation will be introduced in 2001, following an extensive consultation period to identify the maximum possible contribution to energy savings from new Building Regulations. Further revisions are expected to continue the downward trend in the average u-value of new buildings.

3.3 Appliance Technologies

The energy consumption of domestic electric appliances has been rising steadily since 1970 through a combination of increased ownership and increased usage patterns. With no improvement in the efficiency of products on the market, appliances energy consumption could increase by over 25% by 2025. In recent years however, the labelling and minimum standards introduced across the EU have lead to a reduction in some unitary consumptions, notably cold appliances. Further reductions are expected as a result of voluntary agreements among manufacturers. In the UK, a comprehensive study of this field has been carried out by the Oxford University Environmental Change Unit, and the majority of figures used in this report have been provided by their DECADE model.

3.3.1 Cold appliances

Cold appliances include refrigerators, fridge-freezers and freezers, which together consume around 24% of domestic appliance electricity. Between 1970 and 1987 the total electricity consumption of cold appliances increased fourfold, but since then this growth has virtually stopped due to a significant improvement in efficiency of new devices. As table 3 shows, there is still a considerable potential for further savings largely through the introduction of vacuum insulation panels.

Table 3 Annual Consumption of Cold Appliances

Appliance	Average annual consumption kWh/yr		
	In Stock	New	Best (2010)
Refrigerator	320	270	40
Fridge-freezer	640	590	120
Freezer	500	420	90

3.3.2 Wet appliances

Wet appliances includes washing machines, tumble driers and dishwashers. The energy consumption of this group has risen dramatically over the last 25 years due mainly to increased ownership, but also to patterns of increased usage per household. Together they account for 16% of electric appliance energy consumption.

However, ownership of washing machines and tumble dryers is reaching saturation levels although dishwasher ownership is expected to increase by around 50% by 2010.

A number of factors determine the annual energy consumption of wet appliances; number of cycles and the temperature of the cycle used can play a more significant role than the technological performance of the machine. The average wash temperature has been decreasing and this trend is expected to continue.

Table 4 Annual Consumption of Wet Appliances

Appliance	Average annual consumption kWh/yr	
	In Stock	Best (2010)
Washing machine	225	162
Tumble dryer	380	257
Dishwasher	415	220

3.3.3 Cooking appliances

The major cooking appliances are ovens, hobs, microwaves and kettles. Together they account for 18% of electric appliance energy consumption. Unlike for most other appliances, this has increased only slightly over the 25 year period. A decline in the consumption of ovens and hobs is related to both the decrease in household size and an increased use of microwaves.

Improvements in the energy efficiency of ovens are possible through better insulation, controls and the use of low emissivity surfaces. For hobs savings are possible from greater introduction of induction hobs, and for microwaves, a reduction in stand-by power. Some savings are possible through increased insulation of kettles, although the greatest potential is by changing the habits of use (reducing boiled volumes).

Table 5 Annual Consumption of Cooking Appliances

Appliance	Average annual consumption kWh/yr	
	In Stock	Best (2010)
Oven	277	158
Hob	270	160
Microwave	84	69
Kettle	170	142

3.3.4 Recreational appliances

This category includes televisions, videos and home office equipment. Ownership of recreational appliances has increased enormously over the last 25 years, which has had a related impact on energy consumption, despite improving efficiency. The trend in ownership is likely to continue as saturation levels are unlikely to be reached for some time. In addition, increasing ownership of satellite and digital decoders will tend to add to the energy consumption in this group.

The greatest potential for savings comes from a reduction in stand-by power, which could be reduced by as much as 90%.

Table 6 Annual Consumption of Recreational Appliances

Appliance	Average annual consumption kWh/yr	
	In Stock	Best (2010)
TV	121	81
Video	108	13
Office equipment	62	34

3.3.5 Lighting

Lighting is the largest single energy consuming appliance, accounting for 23% of the appliances total. Lighting energy consumption is directly related to comfort factors, and the number of light fittings per household has been steadily increasing. Almost no efficiency improvements were possible until the introduction of compact fluorescent lightbulbs (CFLs) in the early 1990s. The very high cost of these has been a major barrier to market penetration, but it is now estimated that around 23% of household own at least one.

The energy savings predicted are based on the assumption that by 2010 80% of lightbulbs will have been replaced with CFLs, which consume 25% of the energy of a conventional bulb.

3.3.6 Electric water heating

Around 18% of households use electricity as their main energy source for water heating. A further 30% will use direct electric water heating in the summer months when the central heating is not in use. Together this accounts for some 11% of domestic electricity consumption. Electricity used for water heating has halved since 1975 due to the growth in central heating and this decline is expected to continue, although more slowly.

While the heating element can be considered as 100% efficient, over 25% of the energy consumed is lost during storage and distribution of the hot water. The technologies available to reduce these standing losses are improved insulation, intelligent controls and the use of dual-element heaters.

4 DEVELOPMENT OF THE SIMULATION SCENARIOS

Three scenarios have been developed as reference cases against which the new technologies were applied:

- Scenario 1 represents the continuation of current autonomous trends with no additional support in terms of legislation, grants or information campaigns.
- Scenario 2 represents the case in which energy efficient policies are pursued at the level at which they have been applied historically.
- Scenario 3 represents the best possible future case in which existing technologies are heavily promoted through both legislation and other campaigns.

In order to standardise the reference cases across the three countries involved in the study, these scenarios were further defined by level of technology, as is summarised in the following table.

	Scenario 1	**Scenario 2**	**Scenario 3**
Building shell			
New houses	Building codes as they are (including planned building codes already fairly advanced)	Introduction of building codes as suggested by the sequence of historical introduction of building codes	As Scenario 2
Existing houses	Existing autonomous trends continued (e.g. double glazing, cavity wall insulation)	Existing autonomous trends continued (e.g. double glazing, cavity wall insulation)	Insulation of existing buildings in the renovation cycle (windows, roofs, cavity walls etc,)
Heating equipment (space and water)	Development according to European Boiler Directive	Only low-temperature boilers or better admitted	Enhanced introduction of condensing boilers
Electric appliances	Improvement only for appliances with minimum standards (cold appliances). Little impact of energy labels	Minimum standards for all appliances or equivalent through ambitious voluntary agreements and active strategy to promote energy consumption labels.	Best available technology for all appliances

The following energy supply technologies were then applied to each reference case to assess their potential impact;

- Micro-Cogeneration
- Cogeneration-based district heating.
- Heat pumps
- Photovoltaics

These technologies have very low market penetration in the UK despite being, in some cases, very well developed products. In the business-as-usual scenario it is unlikely that they would make any significant impact. The penetration rates used have therefore been based on the best potential market with the strong backing of energy conservation policies.

5 THE MURE SIMULATIONS

In order to simulate the impact of the technologies discussed it is necessary to set up the MURE Household database with the corresponding technical parameters (energy performance characteristics of insulation, heating system efficiencies, unitary consumptions of appliances). During the simulation it is then necessary to input expected penetration rates of the new technologies over five time-periods to 2025. The following sections detail the data that was used to set up the three reference scenarios. The technical parameters were derived from studies of the technologies. The penetration rates, which are somewhat more subjective, were calculated from the following principles;

- new building codes will apply to all new buildings from the date of their introduction
- the autonomous trends seen in double glazing and cavity wall insulation will continue at the same rate until the maximum potential is reached
- minimum standards/ directives will apply to new products and hence will have an impact over the normal replacement cycle of the product
- enhanced introduction of measures (scenario 3) will apply for the period up to 2010.

5.1 Scenario 1

Scenario 1 was set up using the following parameters.

5.1.1 Space Heating (insulation)

New Building Regulations applied to New buildings from 2001

Average u-value of new buildings;	Individual housing	0.66
	Collective housing	1.1
% stock involved;	100%	

Annual Penetration rates

1995-2005	2005-2010	2010-2015	2015-2020	2020-2025
0.2*	0.8	0.8	0.9	0.9

*Lower than the stock growth rate to take account of the expected date of introduction

Cavity Wall Insulation applied to Old and Intermediate Individual Dwellings

Average u-value of walls;	Old dwellings	0.58 W/m2K
	Intermediate dwellings	0.49 W/m2K
% stock involved;	100%	

Annual Penetration rates

1995-2005	2005-2010	2010-2015	2015-2020	2020-2025
0.2	0.2	0.1	0.1	0.1

Double glazing applied to Old and Intermediate Dwellings

Average u-value of windows;	Old dwellings	3.17 W/m2K
	Intermediate dwellings	3.04 W/m2K
% stock involved;	31.5%	
Annual Penetration rates;	Individual dwellings	8% all periods
	Collective dwellings	4% all periods

5.1.2 Equipment Replacement/Maintenance

Gas and oil boilers replaced with new ones at 85% average efficiency in 100% of stock.

Annual Penetration rates;	Individual dwellings	8% all periods
	Collective dwellings	4% all periods

5.1.3 Sanitary Hot Water

Gas and oil water heating equipment replaced with new with the following average seasonal efficiencies;

		Reference	New
Combined system	Gas	60%	70%
Combined system	Oil	55%	70%
Separated system	Gas	75%	85%

Penetration rates all 6.7% based on an average lifetime of 15 years.

5.1.4 Appliances

Cold appliances only replaced to minimum standards using the following data;

Appliance	Annual Unitary Consumption (kWh/year)	Annual Penetration Rate
Refrigerators	270	8%
Freezers	420	6%
Fridge-freezers	663	6%

5.1.5 Reference Scenario 1

The predicted energy consumption to 2025 for scenario 1 is shown in the following table. The baseline figure projects the current unitary energy consumption onto the predicted growth in housing and appliance ownership. The scenario consumption is derived by deducting the savings made in each energy end use.

Derivation of Scenario 1 Energy Consumption (ktoe)

	1995	2005	2010	2015	2020	2025
Baseline	41346	45202	47310	49528	51609	53941
Heating	0	2025	2752	3345	3896	4415
Sanitary Hot Water	0	702	914	1069	1179	1258
Appliances	0	54	94	124	146	162
Scenario 1 Consumption	41346	42421	43550	44990	46389	48106

5.2 Scenario 2

Scenario 2 was set up using the following parameters.

5.2.1 Space Heating (insulation)

New Building Regulations applied to New buildings in 2001 and 2015

Figures to 2015 taken from Scenario 1, then the following applied

Average u-value of new buildings;	Individual housing	0.54
	Collective housing	0.95
% stock involved;	100%	

Annual Penetration rates

1995-2005	2005-2010	2010-2015	2015-2020	2020-2025
0.5	0.8	0.8	0.9	0.9

Cavity Wall Insulation applied to Old and Intermediate Individual Dwellings (as scenario 1)

Average u-value of walls;	Old dwellings	0.58 W/m2K
	Intermediate dwellings	0.49 W/m2K
% stock involved;	100%	

Annual Penetration rates

1995-2005	2005-2010	2010-2015	2015-2020	2020-2025
0.2	0.2	0.1	0.1	0.1

Double glazing applied to Old and Intermediate Dwellings (as scenario 1)

Average u-value of windows;	Old dwellings	3.17 W/m2K
	Intermediate dwellings	3.04 W/m2K
% stock involved;	31.5%	
Annual Penetration rates;	Individual dwellings	8% all periods
	Collective dwellings	4% all periods

5.2.2 Equipment Replacement/Maintenance

Gas and oil boilers replaced with new ones at 90% average efficiency in 100% of stock.

Annual Penetration rates;	Individual dwellings	8% all periods
	Collective dwellings	4% all periods

5.2.3 Sanitary Hot Water

Gas and oil water heating equipment replaced with new with the following average seasonal efficiencies (as scenario 1);

		Reference	New
Combined system	Gas	60%	70%
Combined system	Oil	55%	70%
Separated system	Gas	75%	85%

Penetration rates all 6.7% based on an average lifetime of 15 years.

5.2.4 Appliances

Minimum standards applied to cold appliances as in scenario 1 and to all other appliances on the assumption that this would be at 20% of the difference between the current average and the best technically possible.

Appliance	Annual Unitary Consumption (kWh/year)	Annual Penetration Rate
Refrigerators	270	8%
Freezers	420	6%
Washing machines	235	14%
Dishwashers	374	7%
Clothes dryers	357	7%
Electric ovens	290	5%
Televisions	113	13%
Kettles	164	20%
Lighting	639	33%
Other	250	10%
Fridge-freezers	663	6%
Electric hobs	264	5%
Microwaves	91	17%
Videos	89	13%
Office equipment	56	20%
Water heaters	1914	5%

5.2.5 Reference Scenario 2

The predicted energy consumption to 2025 for scenario 2 is shown in the following table.

Derivation of Scenario 2 Energy Consumption (ktoe)

	1995	2005	2010	2015	2020	2025
Baseline	41346	45202	47310	49528	51609	53941
Heating	0	2553	3450	4297	4997	5658
Sanitary Hot Water	0	702	914	1069	1179	1258
Appliances	0	54	364	499	582	643
Scenario 2 Consumption	41346	41893	42582	43663	44851	46383

5.3 Scenario 3

Scenario 3 was set up using the following parameters.

5.3.1 Space Heating (insulation)

New Building Regulations applied to New buildings in 2001 and 2015 (as scenario 2)

Figures to 2015 taken from Scenario 1, then the following applied

Average u-value of new buildings;	Individual housing	0.54
	Collective housing	0.95
% stock involved;	100%	

Annual Penetration rates

1995-2005	2005-2010	2010-2015	2015-2020	2020-2025
0.5	0.8	0.8	0.9	0.9

Insulation applied to Old and Intermediate Individual Dwellings to reach the level of the 1995 Building Regulations

Average u-values achieved (W/m2K)

	Individual Housing	Collective Housing
Old dwellings	0.73	1.24
Intermediate dwellings	0.67	1.17

% stock involved; 35%

Annual Penetration rates

	1995-2005	2005-2010	2010-2015	2015-2020	2020-2025
Individual	10	20	8	8	8
Collective	5	10	4	4	4

5.3.2 Equipment Replacement/Maintenance

Gas and oil boilers replaced with new ones at 90% average efficiency in 100% of stock.

Annual Penetration rates

	1995-2005	2005-2010	2010-2015	2015-2020	2020-2025
Individual	10	20	8	8	8
Collective	5	10	4	4	4

5.3.3 Sanitary Hot Water

Gas and oil water heating equipment replaced with new with the following average seasonal efficiencies:

		Reference	New
Combined system	Gas	60%	75%
Combined system	Oil	55%	75%
Separated system	Gas	75%	90%

Annual Penetration rates

1995-2005	2005-2010	2010-2015	2015-2020	2020-2025
10	10	6.7	6.7	6.7

5.3.4 Appliances

Best available technology applied to all appliances, with annual consumption and penetration rates as shown below.

Appliance	Annual Unitary Consumption (kWh/year)	Annual Penetration Rate
Refrigerators	44	8%
Freezers	96	6%
Washing machines	162	14%
Dishwashers	220	7%
Clothes dryers	257	7%
Electric ovens	160	5%
Televisions	81	13%
Kettles	136	20%
Lighting	336	33%
Other	250	10%
Fridge-freezers	139	6%
Electric hobs	113	5%
Microwaves	48	17%
Videos	13	13%
Office equipment	34	20%
Water heaters	1585	5%

5.3.5 Reference Scenario 3

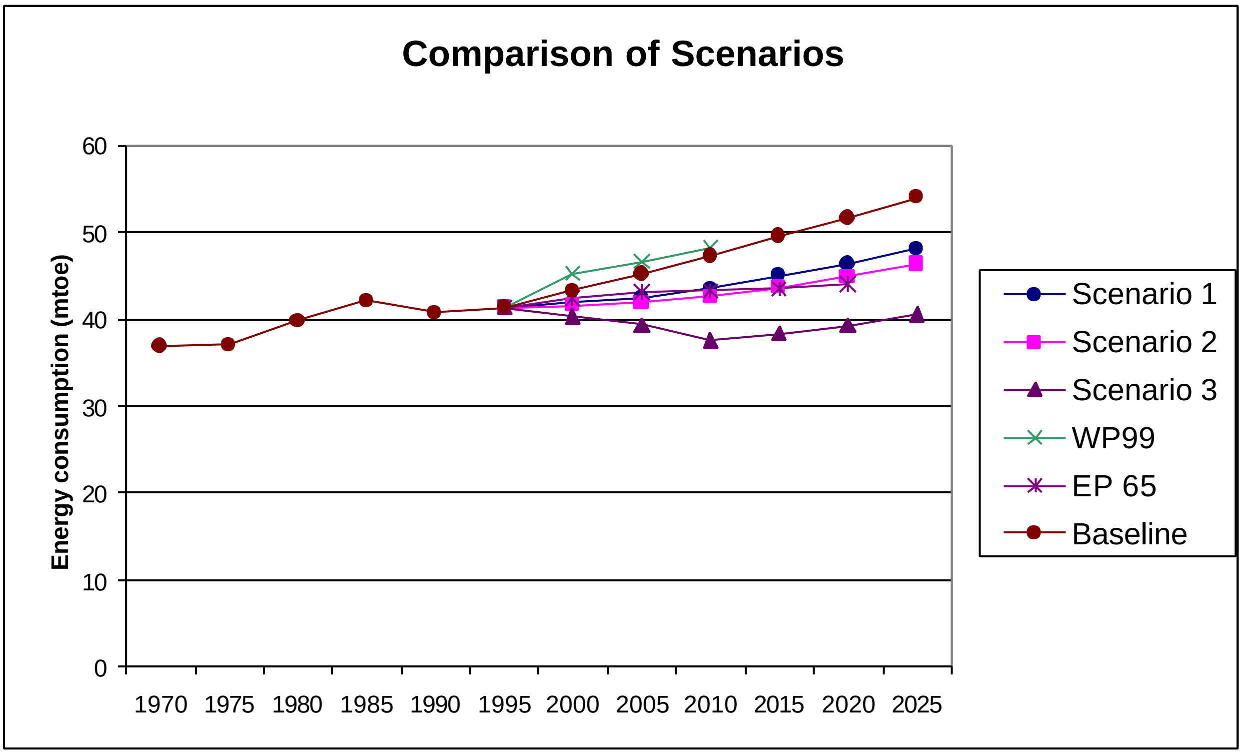
The predicted energy consumption to 2025 for scenario 3 is shown in the following table.

Derivation of Scenario 3 Energy Consumption (ktoe)

	1995	2005	2010	2015	2020	2025
Baseline	41346	45202	47310	49528	51609	53941
Heating	0	4182	6017	6647	7196	7750
Sanitary Hot Water	0	1260	1549	1678	1770	1836
Appliances	0	388	2154	2916	3395	3755
Scenario 2 Consumption	41346	39372	37590	38287	39247	40601

5.4 Summary of Scenarios

The predicted energy consumption to 2025 for the three scenarios is shown graphically below. For comparison, the trend from 1970 and the UK government's predictions (EP65 from 1995 and the draft WP99 from 1999) are also shown.



Scenarios 1 and 2 show a rising total energy consumption in the domestic sector, as the efficiency improvements fail to counter the expected growth in number of houses and appliance ownership. In scenario 3, energy consumption falls to 2010 as a result of the very high penetration rates used for those years (accelerated programmes). At penetration rates which reflect the average investment cycles in energy saving products used in the later stages, the total consumption begins to rise again. However, the figures for 2020-2025 are highly speculative and do not include the impact of technologies not yet developed which may have reached the market by that stage.

For all 3 scenarios the greatest savings are expected to come from a significant improvement in the average efficiency of boilers, although the technical potential is as great from improved insulation and the highest efficiency appliances.

The first 2 scenarios represent what may be economically feasible, given sufficient backing of policies to ensure that energy efficient equipment makes up the majority of products on the market. To achieve scenario 3 would take both a huge investment and a great leap in the perceived importance of energy conservation across all sectors of the population.

It is interesting to note that EP65 is similar to Scenario 2 but falling slightly to 2020, whereas the draft figures just produced (WP99) are considerably higher than all the scenarios and more in line with the baseline in which the total energy consumption is directly proportional to the number of dwellings.

6 THE ENERGY SUPPLY TECHNOLOGIES

Each scenario was run again including the energy supply technologies. In the case of the heat supply technologies (district heating, heat pump and micro CHP) the installation of the technology directly competes with the growth of higher efficiency boilers predicted in the baseline scenarios. For micro CHP and photovoltaics, the electricity generated is used to reduce the total demand of appliances.

The parameters used for the simulations are given below.

District Heating

CHP-based district heating with an average efficiency of 80% and a primary energy coefficient of 80% was applied to 5.5% of individual housing and 10% of collective housing in order to reach 1 million homes by 2010. Improved boiler technology was applied to the remaining gas/oil heating systems.

Gas Heat Pumps

Gas heat pumps with a coefficient of performance of 1.5 were applied to 3% of all dwellings. Improved boiler technology was applied to the remaining gas/oil heating systems.

Micro CHP

Micro CHP with an average efficiency of 69% was applied to 25% of all dwellings. Improved boiler technology was applied to the remaining gas/oil heating systems. Electricity savings of 40% were applied to 25% of dwellings.

Annual Penetration Rates

Annual penetration rates for the technologies above were the same as used in the baseline scenarios for improved boiler efficiencies.

Scenarios1 and 2;	Individual dwellings	8% all periods
	Collective dwellings	4% all periods

Scenario 3;

	1995-2005	2005-2010	2010-2015	2015-2020	2020-2025
Individual	10	20	8	8	8
Collective	5	10	4	4	4

Photovoltaics

It was assumed that where PV is installed it would provide all the electricity requirements of the dwelling. The technology was not expected to have any measurable impact on the market before 2010 and thereafter would have a penetration rate of 0.1% per year of the total number of dwellings.

7 SIMULATION RESULTS – ENERGY SAVINGS

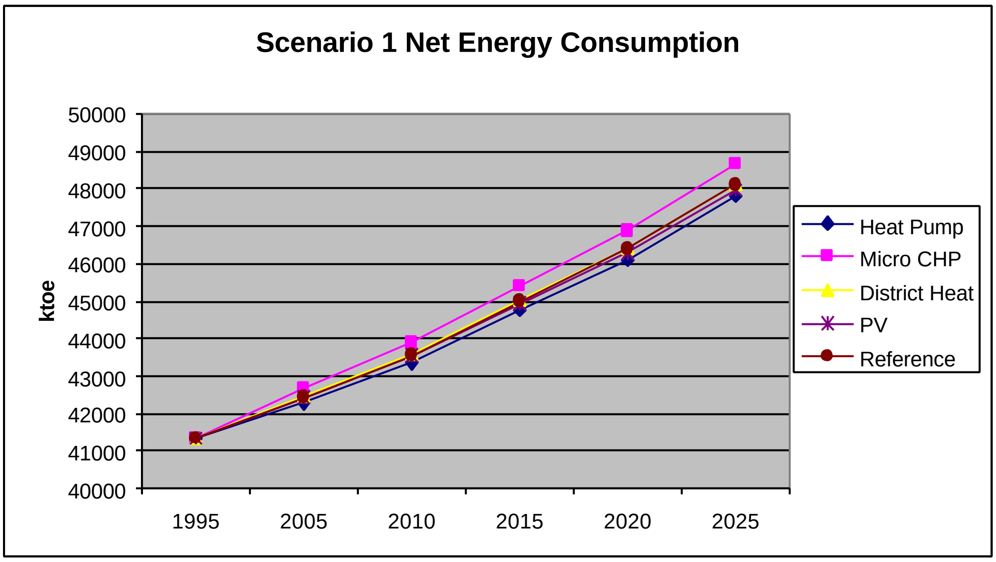
The results of the simulation sessions are given in the table below.

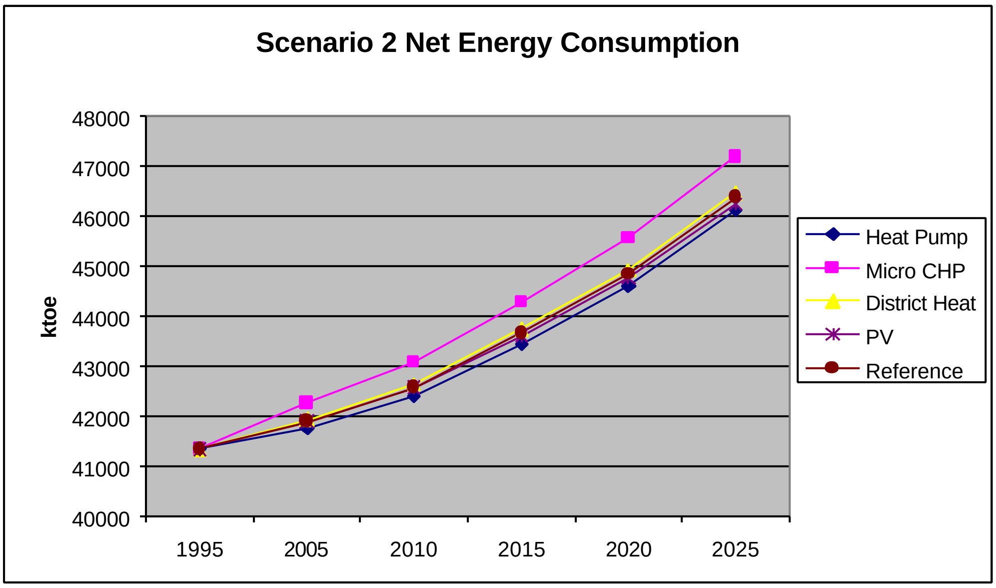
Table 7.1 Energy Savings of the New Technologies (ktoe)

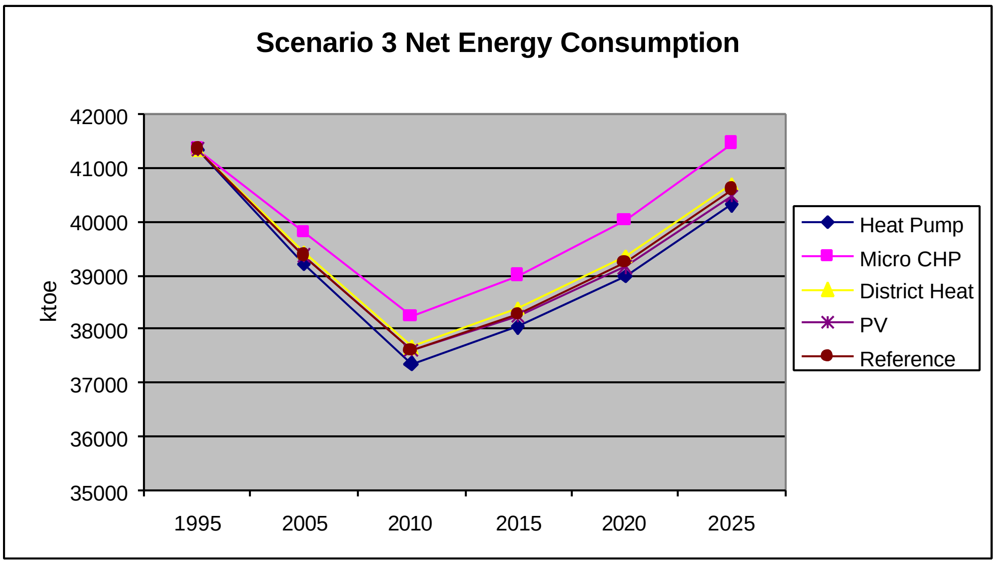
Gas Heat Pump	2005	2010	2015	2020	2025
Scenario 1	153	202	242	275	304
Scenario 2	137	181	217	247	273
Scenario 3	158	232	251	270	288
Micro CHP					
Scenario 1	-244	-332	-408	-477	-543
Scenario 2	-376	-507	-617	-714	-805
Scenario 3	-433	-643	-709	-776	-848
District Heat					
Scenario 1	-18	-24	-29	-33	-36
Scenario 2	-48	-64	-77	-88	-97
Scenario 3	-56	-83	-90	-96	-103
PV					
Scenario 1,2,3	0	0	45	92	141

It is noticeable that, in energy terms, the installation of micro CHP and district heating result in lower savings than the replacement of boilers to a higher efficiency. However, these technologies achieve higher savings in terms of primary energy (compared to standard electricity generation at 33% efficiency) and in carbon dioxide emissions.

The graphs below show the net impact on the 3 scenarios of these energy supply technologies. Other than micro CHP (which was applied at a much higher penetration rate than the others) the general impact is minimal. The greatest difference is between the scenarios rather than between the new technologies.


Scenario 1 Net Energy Consumption
ktoe
50000
49000
48000
47000
46000
45000
44000
43000
42000
41000
40000
1995
2005
2010
2015
2020
2025
Heat Pump
Micro CHP
District Heat
PV
Reference


Scenario 2 Net Energy Consumption
ktoe
48000
47000
46000
45000
44000
43000
42000
41000
40000
1995
2005
2010
2015
2020
2025
Heat Pump
Micro CHP
District Heat
PV
Reference


Scenario 3 Net Energy Consumption
ktoe
42000
41000
40000
39000
38000
37000
36000
35000
1995
2005
2010
2015
2020
2025
Heat Pump
Micro CHP
District Heat
PV
Reference

8 SUMMARY

The MURE database has been used to demonstrate the potential impact of a number of energy efficient technologies on the energy consumption of the UK's domestic sector.

This has shown that compared to a baseline in which unitary energy consumption remains constant (comparable with the trend over the last 25 years) the following savings are possible through the installation of energy saving technologies.

	% energy savings over baseline	
	2010	2025
Scenario 1 – Business as Usual	8%	11%
Scenario 2 –Policy Implementation	10%	14%
Scenario 3 – Best Available Technologies	21%	25%

Overall, the installation of higher efficiency gas and oil boilers will have the most significant impact on domestic energy consumption. This measure is also the one most likely to succeed as it could be implemented via the manufacturers, requiring no structural or behavioural changes at the level of the household.

Improved insulation, notably increased depth of loft insulation, cavity wall insulation and double glazing, can have a significant impact on overall energy consumption. However, retro-fitting of existing buildings is rarely cost-effective in energy saving terms except as part of a normal replacement/maintenance activity.

The technical potential from higher efficiency electric appliances is very high and requires little or no change in habits or comfort level on the part of the users. In this area in particular the market is trans-national and requires a concerted programme across, for example, the EU.

In addition, some further savings in primary energy can be achieved through the promotion of energy supply technologies. In the UK the alternative supply technologies most likely to produce savings are CHP-based district heating, micro-CHP and gas heat pumps, with some contribution from photovoltaics possible further into the future.

Appendix A

References

Domestic Energy Fact File 1998; *BRECSU, LD Shorrock and G A Walters*

EP 65 Energy Projection for the UK 1995-2020; *Department of Trade & Industry*

WP 99 Draft Energy Projections to 2020; *Department of Trade & Industry*

Decade (Domestic Equipment and Carbon Dioxide Emissions) 2MtC; *Brenda Boardman et al, Environmental Change Unit, University of Oxford*

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EP 66 Energy Consumption in the UK, Dec 1997; *Department of Trade & Industry*

Building Regulations Part L Conservation of Heat and Power; *Department of Environment, Transport and the Regions*

UK Climate Change Programme, Consultation Paper and Draft Report Feb 2000; *Department of Environment, Transport and the Regions*