This is a working paper for the purpose of evaluating alternative scenarios for 2050 and as such does not represent Government policy.

Energy Efficiency: DEFRA Paper on Low Carbon Options for the Domestic Sector

This paper is one of a series produced by DEFRA for the Interdepartmental Analyst's Group. It presents an update of previous work to develop scenarios of domestic energy demand to 2050. The main scenario assumptions on population, occupancy and household numbers are those agreed by the IAG. The paper has benefited greatly from discussions with the PIU and many of the more detailed assumptions (e.g. on the scope for improved energy efficiency) are consistent with those being used in the PIU's own analysis.

Projecting Domestic Energy Demand to 2050

Projections of domestic sector energy demand to 2050 have been made under 'Business-as-Usual' and four alternate scenarios, World Markets (WM), Provincial Enterprise (PE), Global Sustainability (GS) and Local Stewardship (LS), based on those developed by the Foresight Programme.

The interpretation of the scenarios in this paper has been that they lead to alternative 'reference' views of how UK domestic energy demand may develop under different social values and governance systems. Although the emphasis placed on environmental issues and values clearly varies between the scenarios, none of them is considered to explicitly address or answer the challenge posed by the RCEP of a 60 % reduction in CO_2 emissions by 2050. As such, under all the scenarios there is further (but differing) scope for reducing emissions, including the use of additional energy efficiency.

Methodology

The approach to projecting domestic energy demand has been to identify five principal end-uses and make forecasts for each under the different scenarios. These end-uses are:

- Space heating
- Water heating
- Space cooling
- Lights
- Appliances

For each end-use a number of common assumptions are relevant including population levels, the number of households and their occupancy. These assumptions are shown in tables 1 to 3.

Table 1 Population assumptions

	BaU	WM	PE	GS	LS
2000	59.72	59.72	59.72	59.72	59.72
2010	61.80	62.00	61.60	61.50	61.40
2020	63.50	63.80	63.20	62.90	62.40
2030	64.60	64.90	64.10	63.40	62.50
2040	65.00	65.70	64.20	63.30	62.30
2050	65.00	66.00	64.00	63.00	62.00

Table 2 Household assumptions

hh	BaU	WM	PE	GS	LS
2000	25.63	25.63	25.63	25.63	25.63
2010	27.47	28.31	26.67	27.21	26.47
2020	28.73	30.24	27.24	28.33	26.55
2030	29.50	31.66	27.39	28.82	25.83
2040	29.82	32.69	27.09	28.77	24.92
2050	29.95	33.00	26.67	28.64	23.85

Table 3 Occupancy assumptions

	BaU	WM	PE	GS	LS
2000	2.33	2.33	2.33	2.33	2.33
2010	2.25	2.19	2.31	2.26	2.32
2020	2.21	2.11	2.32	2.22	2.35
2030	2.19	2.05	2.34	2.20	2.42
2040	2.18	2.01	2.37	2.20	2.50
2050	2.17	2.00	2.40	2.20	2.60

Space Heating

Future energy demand for space heating (SH) is calculated using a simple spreadsheet model. This is calibrated using the historical relationship between the average energy demand for SH per household and the average internal temperature, average external temperature, average heat loss and the average space heating efficiency as reported in BRE's Domestic Energy Factfile. The model then projects future SH demand based on scenario assumptions about these same parameters. The model makes a further distinction between existing (pre 2001) houses and new (post 2001) houses. For existing houses there are scenario assumptions about the take-up of retrofit energy efficiency measures and for new houses different standards for new building regulations are assumed depending on the scenario. The major assumptions are shown in Table 4.

Table 4 Assumptions underlying the space heating demand projections in 2050

	BaU	WM	PE	GS	LS
Total number of households (M)	29.95	33.00	26.67	28.64	23.85
Internal temperature (º C)	21	22	20.5	21	20
Insulation level on existing buildings (% of cost effective level)	80 %	60 %	60 %	80 %	90 %
Efficiency of heating appliances (%)	90 %	90 %	90 %	95 %	95 %
Number of 'new' houses (m)	8.0	11.6	4.1	6.0	1.5
Improvement in new building standards (heat loss) relative to now	63 %	56 %	56 %	70 %	70 %

Water heating
Trend in energy use for water heating per household are determined by changes in the demand for hot water and the efficiency with which the hot water is provided. Following discussions with the PIU, the approach adopted to projecting the demand for hot water per household is based on an equation with the form:

$$\text{Demand for hot water (litres per day)} = A + B \times \text{Occupancy}$$

where A and B are constants representing 'household' hot water demand and 'personal' hot water demand respectively. The values for A and B for each scenario are shown in Table 5. For 2000 they are based on work undertaken by British Gas in 1980 and inflated to reflect current hot water usage. For 2050 estimate have been made for each scenario taking into account differing income levels and the consumption by water using appliances such as washing machines and dishwashers.

Table 5 also shows the assumptions made about changes in the efficiency of providing hot water. These take account both of improving boiler efficiency and additional insulation of hot water tanks and piping.

Table 5 Assumptions underlying the water heating demand projections in 2050

	2000	BaU	WM	PE	GS	LS
Increase in household water demand relative to 2000		10 %	10 %	10 %	0 %	-10 %
Increase in personal hot water demand relative to 2000		20 %	30 %	20 %	20 %	5 %
Equation for hot water demand	40+30N	44+36N	44+39N	44+36N	40+36N	36+31.5N
Occupancy level	2.33	2.17	2.00	2.40	2.20	2.60
Hot water demand (l/d)	110	122	122	130	119	118
Improvement in efficiency with which hot water is provided		37 %	35 %	32 %	37 %	42 %

Space cooling
The demand for air conditioning under the BaU scenario is based on extrapolating industry forecasts of appliance penetration (these are available up to 2010) together with assumptions from BRE about the energy use per unit. For the other scenarios lower or higher penetration of air conditioning has been assumed as shown in Table 6. Improvements in the efficiency of air conditioning units have not been included in the current analysis.

Table 6 Number of air conditioning units in 2000 and 2050

	2000	BaU	WM	PE	GS	LS
No. of units ('000s)	112	10385	14982	4372	7041	1281

Lights and Appliances
For lights and appliances the approach is based on extrapolating the results from the DETR's Market Transformation Programme (www.mtprog.com) and making further scenario dependent assumptions about future ownership levels of different appliance groups and possible improvements to efficiency. In the case of lights, assumptions about the penetration of CFLs are explicitly included. Table 7 shows the major assumptions.

Table 7 Assumptions underlying the lights and appliances demand projections for 2050

	2000	BaU	WM	PE	GS	LS
No. of households	25.63	29.95	33.00	26.67	28.64	23.85
Stock per household of:						
Lightbulbs	21	32	34	28	30	26
Wet appliances	1.36	1.58	1.62	1.50	1.54	1.46
Cold appliance	1.50	1.55	1.63	1.54	1.55	1.50
Electronic appliances	8.21	16.1	17.7	13.0	14.6	11.2
Cooking appliances	6.21	6.05	6.03	6.10	6.08	6.13
% of CFLs		70 %	50 %	65 %	80 %	90 %
Improvement in average UEC from 2000:		21 %	10 %	10 %	31 %	31 %
Wet appliances		26 %	20 %	20 %	51 %	51 %
Cold appliance		-1 %	-12 %	-12 %	16 %	16 %
Electronic appliances		15 %	8 %	8 %	23 %	23 %
Cooking appliances						

Results of the Projections

For each end-use the analysis enables the contribution of three factors to changes in domestic energy demand over the period 2000 to 2050 to be explicitly identified: These factors are:

- Number of households (HH);
- Service intensity (SI) - level of demand for energy services per household;
- Energy intensity (EI) - energy demand per unit of service.

These three factors affect changes in the level of overall domestic energy demand (E) according to the relationship:

$$E = (EI) \times (SI) \times (HH)$$

where EI = energy intensity of service
SI = service intensity of households
HH = number of households

For small changes this leads to

$$\Delta E/E = \Delta EI/EI \times \Delta SI/SI \times \Delta HH/HH$$

A further factor denoting the level of carbon intensity (carbon emissions per unit of energy demand) can also be included, but this is largely as supply side issue and has not been included in the current analysis.

Tables 8 to 13 show the results, together with a brief explanation.

Table 8 Contribution of factors for space heating demand in 2050 (relative to 2000)

	D**EI**	D**SI**	D**HH**	D**E**
BaU	0.51	1.47	1.17	0.88
WM	0.53	1.66	1.29	1.14
PE	0.58	1.34	1.04	0.80
GS	0.46	1.51	1.12	0.78
LS	0.48	1.28	0.93	0.57

Service intensity increases under all scenarios as a result of rising internal temperatures. Compared to BaU, WM has a slightly higher internal temperature and PE and LS are slightly lower, reflecting differences in wealth.

Energy intensity falls in all scenarios affected by improved heating efficiency (more and more efficient central heating), the extent to which energy efficiency measures are retrofitted to existing houses and the proportion of post 2000 houses in the 2050 housing stock (built to higher energy efficiency standards). For instance LS assumes more extensive retrofitting of existing houses than WM. However, this effect is partially offset by the higher stock turnover of WM. By 2050 a greater proportion of the housing stock is 'new' under WM than under LS and these new houses are significantly more energy efficient than the existing stock (even when extensively retrofitted with energy efficiency measures).

Table 9 Contribution of factors for hot water demand in 2050 (relative to 2000)

	D**EI**	D**SI**	D**HH**	D**E**
BaU	0.63	1.11	1.17	0.82
WM	0.65	1.11	1.29	0.93
PE	0.68	1.19	1.04	0.84
GS	0.63	1.08	1.12	0.76
LS	0.58	1.07	0.93	0.58

Service intensity increases under all scenarios reflecting greater use of hot water. At one extreme, under WM it is assumed that a combination of high living standards and a lack of environmental awareness mean that households are more extravagant with their use of hot water (more, longer showers etc). In contrast, under LS hot water use is constrained both by lower incomes and by a concern not to waste both energy and water. These effects are somewhat offset by trends in household size, with occupancy significantly lower under WM than LS.

Energy intensity is larger affected by the use of more efficient boilers. Under all scenarios it is assumed that gas condensing boilers are the norm. Variations between scenarios largely reflect differences in the level of insulation fitted to the hot water system.

Table 10 Contribution of factors for space cooling in 2050 (relative to 2000)

	D**EI**	D**SI**	D**HH**	D**E**
BaU	1.00	92	1.17	108
WM	1.00	133	1.29	172
PE	1.00	39	1.04	40
GS	1.00	63	1.12	70
LS	1.00	17	0.93	16

There is a significant increase in the service intensity of space cooling, which increases by over 100-fold under WM. In contrast the increase under LS is only 17-fold. However, under all scenarios energy use for space cooling remains a small fraction of total domestic energy use.

Table 12 Contribution of factors for lighting demand in 2050 (relative to 2000)

	D**EI**	D**SI**	D**HH**	D**E**
BaU	0.52	1.52	1.17	0.92
WM	0.68	1.62	1.29	1.42
PE	0.56	1.33	1.04	0.77
GS	0.44	1.43	1.12	0.69
LS	0.35	1.24	0.93	0.41

For lighting service intensity is affected by the number of lightbulbs and their hours of use. Under all scenarios there is a continued increase in the number of bulbs per household, and this increase is greater for WM than for BaU and less than BaU for LS. This reflects in part different levels of external (e.g. security) lighting.

The energy intensity is affected by the penetration of CFLs. Under all scenarios the proportion of CFLs increases reflecting their cost-effectiveness and improved acceptability (improvements in design). However, the payback period required is assumed to be shorter under WM than for LS and thus the proportion of fittings in which the bulbs are deemed cost effective (affected by use of the bulb) is less for WM than for LS.

Table 13 Contribution of factors for appliance demand in 2050 (relative to 2000)

	D**EI**	D**SI**	D**HH**	D**E**
BaU	0.83	1.19	1.17	1.16
WM	0.91	1.24	1.29	1.47
PE	0.91	1.12	1.04	1.07
GS	0.69	1.16	1.12	0.89
LS	0.69	1.07	0.93	0.68

Service intensity for appliances increases under all scenarios, reflecting a greater number of new appliances in the home. For some of the traditional white goods (e.g. washing machines, freezers) saturation levels are reached by 2050, although at different levels of ownership depending on scenario. One of the biggest differences between scenarios is in the increase of electronic goods, with the growth under WM significantly higher than under LS.

Energy intensity is affected by the efficiency improvements to appliances and the proportion of the most efficient appliances in the stock. Both of these factors are higher under GS and LS than under WM and PE. For WM and PE the average efficiency of electronic goods declines reflecting a greater use of motors in the home (can openers, tooth brushes, electric curtains etc).

Table 14 Contribution of factors for total domestic energy demand in 2050 (relative to 2000)

	DEI	DSI	DHH	DE
BaU	0.58	1.37	1.17	0.93
WM	0.61	1.50	1.29	1.18
PE	0.64	1.28	1.04	0.85
GS	0.52	1.38	1.12	0.80
LS	0.52	1.21	0.93	0.59

Using the results of Table 14 and the breakdown of domestic sector energy use in 2000, Table 15 shows the domestic energy demand in 2050 under each scenario and Table 16 shows the split between fossil fuel and electricity. This last table reveals that fossil fuel demand falls under all scenarios with the exception of WM, whereas electricity demand rises under BaU, WM and PE, but falls under GS and LS.

Table 15 Domestic energy demand in 2000 and 2050 (Mtoe)

	2000	**2050**				
		BaU	**WM**	**PE**	**GS**	**LS**
Space heating	27.4	24.2	31.1	22.0	21.4	15.7
Water heating	10.6	8.7	9.8	8.9	8.1	6.1
Space cooling	0.0	1.0	1.6	0.4	0.7	0.2
Lights	1.5	1.4	2.1	1.2	1.0	0.6
Appliances	6.3	7.3	9.2	6.7	5.6	4.3
Total	**45.8**	**42.6**	**53.9**	**39.1**	**36.8**	**26.9**

Table 16 Domestic energy demand split by fossil fuel and electricity (Mtoe)

	2000	**2050**				
		BaU	**WM**	**PE**	**GS**	**LS**
Fossil	36.8	31.5	39.7	29.5	28.1	20.4
Electricity	9.0	11.1	14.3	9.7	8.6	6.5
Total	**45.8**	**42.6**	**53.9**	**39.1**	**36.8**	**26.9**