DECADE

2MtC

Energy and Environment Programme
Environmental Change Unit
University of Oxford

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EXECUTIVE SUMMARY

This report concerns electricity consumption by UK domestic lights and appliances and represents the culmination of 18 months work by the DECADE team. The primary aim is to suggest how, through EU and UK policy actions, significant electricity and thus carbon dioxide savings can be made, without the consumer suffering any loss of service or incurring a financial penalty. Over 2 MtC (million tonnes of carbon) savings have been identified in Scenario 1. Identifying detailed policies to access savings is particularly important at present given the forthcoming Climate Change Convention negotiations at Kyoto in December, the UK Government's ambitious carbon saving targets (20% reduction in CO_2 from 1990 levels by 2010) and the UK presidency of the EU from January 1998. Other aims include: furthering the understanding of domestic electricity use; discussing the effectiveness of various policy instruments and combinations of policies in achieving efficiency improvements; looking at behaviour with regard to both electricity consumption and response to policies; and investigating other opportunities for carbon dioxide savings.

Essential numbers

The basis of much of DECADE's work is a detailed end-use model of domestic electricity use in lights and appliances. The model contains information on the ownership, sales, usage and electricity consumption of domestic lights and appliances in greater detail than previous studies. Results from the model show that electricity consumption in domestic lights and appliances has doubled between 1970 and 1995 and now represents 25% of UK electricity sales. Current projections are that with no additional policy measures, electricity consumption will rise by 6 TWh from current (1996) levels to 80 TWh in 2010. However, savings of 27 TWh (33%) in 2010 could be achieved by the widespread adoption of improved lights and appliances using known technologies, over 60% of which would be provided by efficiency improvements to cold appliances and lighting. The natural replacement cycle of lights and appliances (between 1 and 18 years depending on the equipment) provides frequent opportunity for purchase of more efficient appliances. What is required are policies to ensure efficient appliances are available and to access these potential savings.

Developing a strategy

The savings identified can be accessed by transforming the current market in favour of more efficient lights and appliances. The market transformation concept provides a useful policy framework, as it emphasises the importance of a strategic approach. Isolated policies have a limited impact, whereas, when planned together, they can create a powerful synergy. Successful strategies can only be assembled by taking into account the special circumstances of each appliance group. The appropriate package and sequence of policies is specific to each product sector and is determined both by the characteristics of the appliance group and by the major policy objectives.

Several clear policy insights emerge from this analysis, including the following:

- EU Energy Labels, based on harmonised test procedures, are prerequisites for effective policy in most, but not all, appliance groups;
- procurement helps manufacturers to bring forward improved products by constructing an initial market;
- financial incentives (rebates) can be used both to establish a market for new, efficient products and to ensure that low-income households have access to more efficient lights and appliances;
- a rolling programme of minimum standards and revisions to the EU Energy Label are the main drivers that will ensure the spread of the technology further into the market;
- both mandatory minimum standards and voluntary agreements can be based on efficiency levels that imply no net extra cost to the consumer.

Clearly a strategy for energy saving will also take into account other issues such as such as certainty of energy savings, cost (to government, consumers and manufacturers) and equity between income groups. These wider issues are discussed within the report.

Policy Scenarios

In order to progress from the theoretical framework to demonstrate how savings could be achieved in practice, three scenarios have been developed. For each scenario the effect of a combination of EU and UK policies has been modelled for each appliance group to give estimated electricity and carbon dioxide savings for the UK. The cost of the scenarios to government has also been estimated, as have the savings to the consumer (Table 1).

Scenario 1

This scenario assumes that there is strong political support for carbon dioxide reductions, both in Europe and the UK. The scenario envisages a systematic programme of European legislation, starting forthwith and including minimum standards of efficiency for a number of products. For such a programme to be realised would require the commitment of a majority of Member States, possibly in the form of a Framework Directive. This scenario provides savings of 2.7 MtC in 2010. Scenario 1 represents the fastest feasible introduction of the efficient technologies identified.

Scenario 2

If strong European support for carbon dioxide savings is not obtained, then it is assumed that voluntary agreements with manufacturers will be reached. These, along with a UK programme of procurement and rebates, form the basis of Scenario 2. This scenario provides savings of 1.4 MtC in 2010, half of those identified in Scenario 1.

Scenario 3

In Scenario 3 it is assumed that political support for efficiency improvements is weak in both the UK and in Europe, so there are no major investment programmes in the UK: policy and investment are at a similar rate as today. Voluntary agreements are entered into by the manufacturers, as in Scenario 2, resulting in savings of 0.4 MtC.

Table 1: Summary of savings and costs for Scenarios 1-3

		Scenario 1	Scenario 2	Scenario 3
UK Savings	Electricity in the year 2010 (TWh pa)	20.9	10.9	3
	UK CO_2 in the year 2010 (MtC pa)	2.7	1.4	0.4
	Money (£bn cumulative to 2010)	10.5	5.5	1.5
	Certainty for decision-making (see 3.6.1)	high	middle	low
Cost to UK	To manufacturers	minimum	minimum	higher
	To taxpayers (£bn cumulative to 2010)	2.7	2.7	0.125
Savings per household	Electricity in the year 2010 (kWh/yr)	785	407	113
	Money in the year 2010 (£/yr)	58.90	30.52	8.50
	Equity	good	good	poor

The costs of achieving savings in Scenario 1 are an order of magnitude cheaper than accessing these savings through other uses of energy in the domestic sector.

Changing behaviour

Scenarios 1-3 investigated potential savings from policies aiming to ensure purchase of more efficient lights and appliances. Savings can also be made by changing the usage of appliances with no loss of service and at no cost to the consumer. The potential exists for electricity savings of almost 12% from domestic lights and appliances by consumers making changes to their usage patterns. This represents a saving of around 8 TWh or 1 MtC in 2010. The end-uses with the highest potential for behavioural savings are: cooking appliances, wet appliances and lighting. As more efficient equipment permeates the stock, the savings from more careful use would be reduced, and these savings overlap to some extent with the savings identified in Scenarios 1-3.

The feasibility and cost of effecting the behavioural changes necessary in order to make these savings has not been quantified, and there are few indicators about the degree to which changes in usage would be permanent. A survey of previous behavioural policies indicates that, on a per household basis, targeted energy advice administered to self-selecting consumers is the most successful means of securing savings. Social characteristics and lifestyle segmentation analysis provide a basis for discerning the most suitable consumer segments for targeting by behavioural policy, in other words, which consumers are willing and able to change their behaviour.

Further carbon savings
In addition to improving the efficiency of new appliances and making zero-cost behavioural changes, there are still further means by which electricity or carbon dioxide savings may be achieved without affecting the level of service received by the consumer.

Individual carbon emissions factors were modelled for appliance groups in order to determine which are most polluting per kWh used. This is the first definition of emission profiles for domestic appliances. The work on appliance-specific carbon emission factors arrived at two clear conclusions:

- reducing energy consumption at times of peak demand will affect carbon emissions more than at off-peak times, therefore policy should be focused on cooking appliances and lighting in particular;
- time-shifting use of washing machines, tumble dryers and dishwashers to times of lower demand can achieve CO_2 savings without significantly affecting service to the consumer.

Options for fuel switching from electricity to gas for tumble dryers, ovens, hobs and kettles were identified and the CO_2 savings which would result were quantified. If all households which are currently connected to mains gas used gas rather than electricity in these appliances CO_2 savings of about 1 MtC in 2010 would result. Finally, electricity savings were identified from infrastructure and other changes, for example using a hot-fill washing machine. These changes could result in CO_2 savings of 0.2 MtC in 2010.

Final remarks
The approach throughout this report has been cautious. Savings from new technologies have only been assessed where the technologies are already well-developed and involve no additional life cycle cost to the consumer. Scenarios 1-3 have been developed around policies whose effect can be quantified by reference to previous experience and no attempt has been made to include potential savings from behavioural, infrastructure or fuel-switching changes. Nevertheless, the expected savings from Scenario 1 are in excess of 2 MtC.

Reducing consumption in domestic lights and appliances can be achieved more rapidly, more cheaply and with greater certainty than in most other areas of energy use. The UK could obtain an important 2 MtC saving from more efficient lights and appliances and provide a policy lead in Europe to assist with general European reductions in CO_2 emissions. However, the opportunity to achieve these savings depends upon extremely strong political commitment and support from manufacturers, and a willingness to act promptly and decisively based on the firm evidence presented in this report.

CHAPTER 1: CONTEXT

The context for this report is international concern about climate change and the specific contribution that could be made to reducing carbon dioxide emissions by efficient lights and appliances in the home. The forthcoming debate at the Climate Change Convention in Kyoto in December 1997 is a demonstrable expression of that concern, and of the need to succeed in lowering pollution levels rather than just planning to. The acceptance that there is a discernible human influence in the way in which the climate is changing reinforces the need for defined actions and for legally binding targets. This report is primarily concerned with furthering understanding of electricity use by domestic lights and appliances in the UK (that is, Great Britain and Northern Ireland) and using this knowledge to identify UK and European Union (EU) policy options which will secure reductions in energy use and therefore reductions in carbon dioxide emissions.

The Government has committed the UK to a 20% reduction in carbon dioxide emissions by 2010, in relation to the 1990 level. In practice, this means reducing the level of carbon dioxide emissions by 35 million tonnes of carbon (MtC) from the level it would otherwise have been in 2010 (Table 1.1). Domestic lights and appliances could contribute a potential 2 MtC to this goal. Current policy will only deliver a small proportion of the savings that could be achieved from lights and appliances, therefore saving 2 MtC depends on vigorous policies being adopted by the European Union. This report is largely focused on policies to achieve 2 MtC savings (Scenario 1), however, two less ambitious alternative scenarios are also described. All of these are backed up, in the rest of the report, by a detailed description of the UK situation and electricity consumption in lights and appliances. The objective is to provide sufficient detail that any reader, in any European country, can establish the way in which the debate has been crafted and, if desired, substitute alternative data.

The United Kingdom takes over the presidency of the Council of Ministers for the period January - June 1998, thus providing the UK with an important role in the necessary discussions on carbon dioxide targets. This report aims to inform the European debate about policies on more efficient domestic lights and appliances.

1.1 CLIMATE CHANGE AND CO_2 EMISSIONS REDUCTION TARGETS

Reduced carbon dioxide emissions are a key element of the global strategy to try and limit the extent of global warming. Carbon dioxide remains the most important contributor to anthropogenic forcing of climate change. Projections of future global mean temperature change and sea level rise confirm the potential for human activities to alter the Earth's climate to an extent unprecedented in human history.

The most widely accepted current prediction, based on a mid-range emissions scenario, is that the global mean surface air temperature will be 2°C higher in 2100 than it was in 1990 (IPCC, 1995). The predicted range of temperature change is 1 - 3.5°C, and even a 1°C increase would represent a rate of warming greater than any seen in the last 10,000 years. Warmer temperatures would also lead to more severe droughts and/or floods in some places. In addition, sea levels could rise by around 50 cm (prediction range 15 - 95 cm). Sustained rapid climate change could shift the competitive balance amongst species and also lead to forest die-back.

The global response to the threat of climate change has taken the form of the United Nations Framework Convention on Climate Change which was adopted at the 1992 Earth Summit in Rio de Janeiro. It entered into force on 21 March 1994 and has been ratified by 165 countries and the EU. Under the Convention, developed countries have agreed to take measures aimed at returning their greenhouse gas emissions to 1990 levels by the year 2000. According to the UK Government's forecast of CO_2 emissions (Table 1.1) this target will be met, although some doubts have been expressed about the basis on which these forecasts have been made (ENDS, 1995). By contrast, the EU as a whole is expected to overshoot the stabilisation target by 0 - 5% according to one estimate (CEC, 1996a). A more recent estimate suggests that EU emissions in 2000 will be even higher, over 8% greater than 1990 levels, and indeed CO_2 emissions across the EU-15 rose by 2.3% in 1996 over 1995 (WEC, 1997). The fact that UK CO_2 emissions (which had fallen between 1990 and 1995) rose by 2.9% from 1995 to 1996 raises further doubts as to whether the UK will meet its stabilisation target.

The accepted logic of the negotiations to reduce emissions of carbon dioxide is that the developed world has to make the greatest contribution, partly because historically these countries have contributed most to the growth in concentrations and because they already have a high standard of living. Within the developed world, the European Union, with approximately 150 million households, is one of the largest trading blocs. The EU agreed to adopt a negotiating position for Kyoto of a 15% reduction in 1990-level greenhouse gas (carbon dioxide plus methane plus nitrous oxide) emissions by 2010. The agreement included a system of burden-sharing across the EU, with Member States committed to individual targets. The UK target was agreed as a 10% cut under the previous Government, which is in contrast to the present Government's target of 20% or 35 MtC (the detailed plans for achieving these savings are to be published in a Government White Paper early in 1998). The aggregate of Member States' targets comes to only a 10% reduction: the remaining 5% was to be achieved through unspecified additional national and common and co-ordinated measures.

The final numbers for developed country targets and timetables for their achievement will be determined during the next negotiating round, known as the third conference of the parties, which is to take place in Kyoto, 1 - 10 December 1997. A new, and possibly legally binding, agreement under the Climate Change Convention is to be finalised by ministers when they meet in Kyoto. The opportunity exists for EU Member States to demonstrate how to achieve, with certainty, specified and legally binding targets.

Table 1. 1 Energy related carbon dioxide emissions, UK, 1990-2010

End Use Sector	Emissions in year (MtC)		
	1990	2000	2010
Domestic	41.7	36.6	36.5
Public and commercial	23.0	20.2	22.5
Industry	48.0	44.2	47.6
Road transport	33.2	37.8	43.5
Other	12.4	10.9	11.7
TOTAL	**158.3**	**149.7**	**161.8**
of which electricity	54.3	44.1	40.3

Source: EP65, CL scenario

1.2 DOMESTIC ELECTRICITY USE IN CONTEXT

The work of the DECADE team is focused wholly on domestic energy use, and within the domestic sector mainly on electricity use by lights and appliances (DECADE 1994, 1995 & 1997).

In the UK, electricity consumption across all sectors has risen since 1970. In the home, electricity is used for space and water heating and for lights and appliances. Of the rising national consumption of electricity, an increasing proportion is going into domestic lights and appliances (Table 1.2). In 1970 the proportion used by domestic lights and appliances was 20%, whereas by 1995 it had increased to 25%. Therefore, in the UK, the use of electricity in domestic appliances is a substantial and growing proportion of all electricity use and thus a major contributor to carbon dioxide emissions.

Although the majority of energy used in the home goes into space and water heating (about 75%, most of which is gas), reducing electricity use by lights and appliances is a useful focus for policy aiming to achieve the UK's carbon reduction targets. There are several reasons for this. First, as homes become better-insulated, the main opportunity for savings in households will come from the energy used by domestic appliances. Secondly, the turnover in the stock of appliances is relatively rapid as most equipment has an average lifetime of 10-15 years, so that improvements can spread naturally and more quickly than improvements to the Building Regulations. Thirdly, with the present generating mix, electricity is the most polluting fuel in terms of carbon dioxide emissions per unit of delivered energy. Therefore any strategy to curb carbon dioxide emissions should include the more efficient use of electricity in lights and appliances.

Table 1. 2 Electricity consumption, UK, 1970 and 1995 (TWh)

	1970	*1995*	*% growth 1970 to 1995*
All sectors	192.4	290.8	51
Domestic sector total	77.0	101.6	32
Domestic lights and appliances†	39.3	73.4	87
Domestic lights and appliances as a % of total electricity consumption	20	25	

† the list of products included in 'lights and appliances' is given in Appendix B.

Sources: DUKES 1978:29 and 1996:104 and DECADE

The Government has estimated that the reduction in VAT on domestic fuel to 5% will result in an annual increase in carbon dioxide emissions of about 0.24 MtC/annum by 2010 (about 0.15% of current carbon dioxide emissions). It has pledged to take account of this effect in developing the programme to meet their target to reduce carbon dioxide emissions by 20% by 2010 (The Green Alliance Parliamentary Newsletter, 1997). Due to the on-going liberalisation of UK energy markets, electricity price reductions are expected from April 1998 onwards. It is assumed that electricity price reductions are not likely to have much effect on energy consumption by lights and appliances, since usage patterns are generally constrained by factors other than perceived running costs (except perhaps in the case of tumble dryers, see Chapter 5, Section 5.5). However, these downward pressures in prices are likely to lead to some increases in consumption, eg for space heating, making effective energy efficiency policies even more important.

1.3 THE POLICY FRAMEWORK FOR ENERGY EFFICIENCY

Policy affecting domestic lights and appliances has been developed at both EU and UK level. Since lights and appliances are traded goods and therefore subject to harmonisation policy, anything that is a mandatory requirement (either in terms of affixing a label to an appliance or requiring a certain level of efficiency) has to be done at the level of the single market (see Chapter 3, Section 3.3.3). EU Directives need to pass the Commission, the Council, and the Parliament. A common form for European agreements is framework legislation and implementing legislation (similar to primary and secondary legislation). Energy Labels were introduced as primary legislation, which sets out the principle and creates a regulatory committee to oversee implementation. The detail for each appliance group is contained in an implementing directive. EU Directives need to be translated into UK national legislation through a statutory instrument, and do not normally require fresh Parliamentary scrutiny.

Advice and information that is additional to any legal requirement, or incentives, either technology procurement or rebates, can be introduced at local, regional or national level since they do not create a barrier to trade. Such measures are probably influenced by local factors. The ability to fund efficient light bulb subsidies under the Office of Electricity Regulation's (OFFER) Standards of Performance, for example, is clearly a legal framework specific to the UK.

1.3.1 EU Policy

The importance of energy efficiency in domestic lights and appliances in making contributions towards carbon dioxide reductions has been recognised at the European level. Energy Labels, Ecolabels and energy efficiency minimum standards are all EU initiatives to encourage the more efficient use of energy. In addition, the EU SAVE (Specific Actions for Vigorous Energy Efficiency) programme funds research into the more efficient use of energy. Nevertheless, progress has been slow: the EU first began discussing energy labelling in 1979 and the first labels only appeared on appliances in the UK at the beginning of 1995. The widespread introduction of Energy Labels has only been possible because of framework Directive 92/75/EEC.

A brief summary of action affecting lights and appliances at the EU level, including both legislation and voluntary initiatives, is given in Table 1.3 (voluntary initiatives are shown in italics).

Table 1. 3 EU policy on domestic appliances

Appliance	*Date*	*Details*
All	*1979*	*Directive (79/530/EEC) on voluntary energy labelling*
	1992	Mandatory energy labelling framework Directive (92/75/EEC)
Cold	1995	Energy labelling of refrigerators and freezers becomes effective 1/1/95
	1996	Directive on mandatory efficiency standards for cold appliances passed (96/57/EC)
	1999	Mandatory efficiency standard for cold appliances to be implemented September
Wet	1993	Ecolabel introduced for washing machines and dishwashers in November 1993
	1996	Energy labelling of washing machines and tumble dryers became effective on 1/9/96
	1998	Energy labelling of washer-dryers becomes effective 31/1/98
	1998	*Voluntary agreement on washing machines prohibits sales less efficient than D on the Energy Label scale from 31/12/97*
	1999	Energy labelling of dishwashers becomes effective 1/1/99
	2000	*Voluntary agreement on washing machines prohibits sales less efficient than C on the Energy Label scale from 31/12/99*
Lighting	*up to 2008*	*Voluntary agreement to phase out magnetic ballast CFLs by 2008*
Brown	*up to 2009*	*Voluntary agreement to reduce the average passive standby power demand of TVs and VCRs to 6W by the year 2000, then by a further 1W every subsequent 3 years.*

Further policies currently under discussion include redrawing the Energy Label categories for cold appliances in 2000 and applying the Energy Label to light bulbs. In addition, a preliminary study on cooking appliances is currently underway, which could lead to Energy Labels/minimum standards.

1.3.2 UK Policy

In addition to implementing EU Directives, the UK is also taking independent action on energy efficiency. This is in the form of rebates and information campaigns rather than further legislation. Many of the current actions are funded through a £1 annual levy on each domestic consumer collected via the Public

Electricity Suppliers (PESs) which distribute electricity in Great Britain (see Appendix A). The PESs are required to spend £100m over the four years 1994-98 on domestic energy efficiency schemes under criteria laid down in the Standards of Performance (SoP) programme (OFFER, 1994), some of which is spent on national programmes organised by the Energy Saving Trust (EST). The PESs submit proposals to the EST, which assesses whether they meet the required energy and cost saving criteria. 25% of the total £100m was targeted to be spent on electrical appliances, but less has actually been spent on appliance schemes due to a shortfall of proposals. The Electricity Regulator, OFFER, has proposed that this SoP should be extended until March 2000 at a similar level, but the extension has not yet been confirmed.

An information/awareness campaign was launched at the beginning of 1997 by the EST. It aims to brand energy efficiency as 'It's clever stuff'. The EST plans to encourage the purchase of energy efficient appliances by displaying labels carrying their 'Energy Efficiency' logo on appliance packaging and in catalogues (see Chapter 5). The EST has also introduced subsidy schemes for light bulbs and cold appliances, which are described in more detail in Chapter 2.

The Government (through the EST) provides funding for Local Energy Advice Centres, which give free and impartial advice on energy saving measures to householders. The centres mainly concentrate on giving advice on saving energy used for heating and hot water, however they also give advice on appliances and lighting. The Government has also launched a general environmental initiative, 'Going for Green', which follows on from previous environmental initiatives such as 'Helping the Earth Begins at Home'.

1.4 RESULTS OF PREVIOUS DECADE WORK

Since its formation in 1994 the DECADE team has achieved significant progress in furthering the understanding of electricity use in domestic lights and appliances. This report, the culmination of three years' work, builds on previously published research (DECADE 1994, 1995, 1997). During this time research has been carried out into many aspects of domestic electricity consumption, including:

- modelling consumption based on ownership, usage and technology changes of domestic lights and appliances;
- investigating the link between environmental values, attitudes and actions;
- identifying the potential for energy savings; and
- understanding which policy instruments are likely to be most effective in achieving those savings.

In addition to policy analysis based on technical understanding, the DECADE team is working towards a better understanding of the social context of energy consumption. This understanding is crucial to designing policies that can achieve long-term, substantial energy savings.

Research carried out during the first year of the project was published in DECADE (1994), which provides a full background on the project's methodology and achievements over the first twelve months. The main findings were summarised in the first model of electricity consumption in lights and appliances, known as Run 1. This work formed the basis for the modelling carried out in DECADE's Second Year Report (DECADE, 1995) which identified the economic and technical potential for savings in electricity consumption of lights and appliances as 39% of the expected consumption by 2020. The suitability of different policy instruments for influencing the energy efficiency of each type of domestic appliance was also investigated, as was the interaction between policy instruments. One of the key conclusions was that if overall electricity use was to be stabilised or reduced, substantial improvements in energy efficiency would be required in order to offset the effect of additional households and higher appliance ownership levels.

More recently, DECADE has published two more specialist reports: *Transforming the UK Cold Market* (DECADE, 1997), focusing on cold appliances (i.e. refrigerators, freezers and fridge-freezers); and

Environmental Values and the EU Energy Label (Strang, 1996), which focused on the relationship between consumers' attitudes and appliance purchase.

Transforming the UK Cold Market reported in great detail on the policies that have been used to try and make the cold appliance market more energy efficient, and assessed their effectiveness to date. The report was based on in-depth quarterly analysis of cold appliance sales over two years and a detailed study of consumers' responses to the EU Energy Label. It also contains the results of work with retail staff and an investigation into faulty appliances in low-income households, and predictions of the likely effectiveness of the minimum energy efficiency standards to be introduced in 1999. The main conclusion was that the cold market had been partially transformed by policy actions to date, but that far more remained to be done in order to tap the potential cost-effective improvement in energy efficiency that is known to be available.

Environmental Values and the EU Energy Label provides support for the idea that there is a critical threshold in people's awareness and concern about environmental and energy issues at which they will act. A combination of policy instruments may therefore be much more effective than individual initiatives. The report also concluded that since people have different motivations for conserving energy which may be influenced by a wide range of factors, the targeting of policy instruments may need to be commensurably sophisticated.

1.5 STRUCTURE OF THIS REPORT

Before any discussion can take place on the policy options to reduce carbon dioxide emissions, it is important to clarify the baseline assumptions. These are provided in Chapter 2, historically for the period 1970-96 and with two projections to 2020. These are for the Reference Case - what would happen with existing trends and declared policies (known as the Business As Usual scenario in previous reports) - and the Economic and Technical Potential (ETP) for reduced consumption. The most sensitive assumptions are also identified, so that other researchers can establish their confidence in these projections.

To intervene and 'transform the market' in favour of energy efficient appliances requires a suite of policies designed, from the beginning, as a coherent strategy. The scope for individual policies, the constraints provided by the separate appliance groups and the objectives to be fulfilled in developing a strategy are all covered in Chapter 3. This provides the theory behind the selection of initiatives that would constitute a scenario.

Three possible scenarios are described in Chapter 4. The main scenario, known as Scenario 1, is designed to deliver a 2 MtC reduction in carbon dioxide emissions by the UK in 2010. In order to achieve this, there have to be strong policies enacted both in the UK and in the European Union. Scenario 1 is, therefore, a strong-strong combination and is the only basis for a UK saving of 2 MtC. However, such a political combination cannot be guaranteed, particularly when it involves 14 other national governments. Scenario 2 depicts the likely savings from a strong UK, in the context of a weak Europe (strong-weak) and Scenario 3 examines the savings from a weak (particularly financially constrained) UK together with a weak European approach - the weak-weak combination.

Chapters 3 and 4 are therefore concerned with the influence of policy on the new appliances purchased. Additional or alternative savings can however be obtained from the way in which people use their equipment, without requiring any capital expenditure by the consumer. This behavioural potential is examined in Chapter 5, together with some of the important social characteristics (eg family size, income) of appliance owners that could help to identify policy targets. The savings from advice and exhortation are difficult to guarantee and of uncertain duration, which is why they have been excluded from the scenarios, where certainty was an important policy selection factor. However, the behavioural potential, or at least a proportion of it, could be achieved given the right social attitudes and government policy.

Another debate concerns the inter-relationship between the demand for electricity in domestic lights and appliances, the requirements of other sectors and the future of the electricity supply industry. This vast subject is briefly introduced in Chapter 6, which examines some of the ways in which the carbon dioxide emissions per unit of electricity might vary. The average emission factor amalgamates the effect of usage patterns that vary by time of day, day of the week and season of the year. Thus, each appliance group has its own individual emission profile and expected emissions factor. Emissions from different appliance groups vary by 10% and can be up to 22% greater than off-peak emissions, providing an additional way of targeting policy to obtain higher carbon savings.

The last area of policy, also covered in Chapter 6, is the savings that could come from other infrastructure changes - specifically those relating to fuel switching. This is another major area that is poorly researched - the DECADE team will be working with the Universities of Coimbra in Portugal and of Utrecht in the Netherlands to examine the opportunities for switching between gas and electricity. Among appliances, cooking provides the largest opportunities for fuel switching, but gas-fired tumble dryers could become increasingly important. Households can also make savings by making longer-term decisions, for example improving the positioning of cold appliances during a redesign of the kitchen, or changing the plumbing to take hot-fill appliances.

The discussion of all these issues in Chapter 7 considers the savings, in electricity and carbon dioxide, that could accrue from the purchase and wiser use of more efficient appliances.

CHAPTER 2: ESSENTIAL NUMBERS

In order to develop policies which will result in reductions in electricity use and carbon dioxide emissions due to domestic lights and appliances it is first necessary to have a good understanding of current and expected future electricity use in this sector. The detailed modelling presented in this chapter forms the basis for policy discussions and scenario development in Chapter 4 and provides the underlying numbers from which the effects of behavioural change (Chapter 5) and other options such as fuel-switching (Chapter 6) can be explored.

1.6 THE DECADE MODEL

The basis of much of DECADE's work is a detailed end-use (or bottom-up) model of domestic electricity use in lights and appliances. The model contains information on the ownership, sales, usage and electricity consumption of domestic lights and appliances in greater detail than previous studies. Linked to this is information about household numbers in the UK, reported in DECADE (1995). The data which inform the model are being constantly revised as new and improved information is acquired, and the outcome of a new run of the model is reported in this chapter. In addition, statistical confidence limits of this run (using the Monte Carlo method) are presented. An important part of the work is investigation, in considerable detail, of the potential effects of policies designed to access energy savings. The model facilitates recommendations regarding which policies can be used to save energy for each appliance group, based on a thorough understanding of the stock of UK appliances, the number of purchases each year, the usage patterns of the appliances and the underlying rate of technical change, with projections of these factors into the future.

The previous run of the model (referred to as Run 2) was completed in 1995 and included measured and survey data up to 1994 (DECADE, 1995). This, the third iteration of the model, known as Run 3, includes measured data to 1996 and projections to 2020. Numerous sources have been used to update and check information in the model including the results of various SAVE studies, sales data, market research reports and monitored household consumption. All the historical data and assumptions in the model have also been re-checked in the light of any further information which has been acquired in the past two years. Run 3 also includes estimates of confidence limits on consumption estimates. For further details on modelling methodology see DECADE (1995).

This chapter will outline changes in the historical data up to 1996 and two projections, both outputs of the DECADE model. The two projections to be described are both over the period 1970 to 2020, and they are the Reference Case and the Economic and Technical Potential 2002 (ETP2002). These are identical from 1970 to 1996 and provide a diverging envelope from 1997 to 2020, representing different assumptions about the efficiency of new appliances purchased. There is no difference in the levels of ownership or usage between the two projections. Although the model provides results up to 2020, electricity consumption and CO_2 emissions in 2010 are the major focus of this report as future UK and EU carbon reduction targets to be negotiated at Kyoto will be based around 2010.

The **Reference Case** (RC), known as 'Business As Usual' in previous reports, describes electricity consumption between 1970 and 1996 and is projected forward to 2020. This projection incorporates the likely effects of policies that have already been defined with a known implementation date, such as Energy Labels for dishwashers and washer-dryers and minimum energy efficiency standards for cold appliances.

For the **ETP2002** projection, technical improvements to new appliances are phased in from 1997 to 2002, so that by 2002 all new appliances on the market are assumed to meet the Economic and Technical

Potential (ETP) energy efficiency level. The ETP is the maximum level of energy efficiency which is economically justified to the consumer over the life time of an appliance, that is, any additional purchase cost is paid back through energy savings. The ETP level is based on proven technology, average usage patterns, current EU electricity, water and equipment prices, with average market mark-ups and an 8% discount rate. This therefore does not represent the theoretical limit on energy efficiency which is somewhat higher. Neither does it include any reduction in consumption from additional changes in behaviour (eg reduced wash temperatures).

A five year period was chosen because it should be technically feasible to achieve ETP energy consumption levels within this time scale. However, it is important to note that ETP2002 is not a policy scenario, it is a theoretical construct. It has not proven possible to design a policy strategy to achieve ETP by 2002 (see Chapter 4 for discussion of this point). The ETP2002 projection provides a lower boundary for the energy consumption which may be achieved by improvements in appliance efficiency.

1.7 OVERVIEW OF DOMESTIC LIGHTS AND APPLIANCES ELECTRICITY CONSUMPTION AND SCOPE FOR INTERVENTION

The product sectors included within ‘lights and appliances’ are cold, wet, cooking, lighting, brown and miscellaneous (for details of the products included in each of these sectors see Appendix B). The output from the DECADE model for all UK domestic lights and appliances is shown in Figure 2.1. Electricity consumption has been rising since 1970 and is expected to continue to rise under RC, largely as a result of increasing household numbers and increasing levels of appliance ownership. However, ETP2002 shows energy consumption falling, despite these factors exerting an upward pressure, due to large technical improvements in lights and appliance energy efficiency. Appendix C contains graphs showing RC and ETP2002 for each appliance group.

95% confidence limits are shown for the Reference Case scenario in Figure 2.1 as ‘RC upper’ and ‘RC lower’ (see Section 2.9.2 for full explanation). When 80.4 TWh is quoted for total UK domestic lights and appliance consumption in 2010, this is the expected figure and there is only a 5% chance it lies outside the range 69 - 92 TWh. Similarly, in 1996 the range is 67 - 81 TWh, or 74.1 TWh ± 9%.

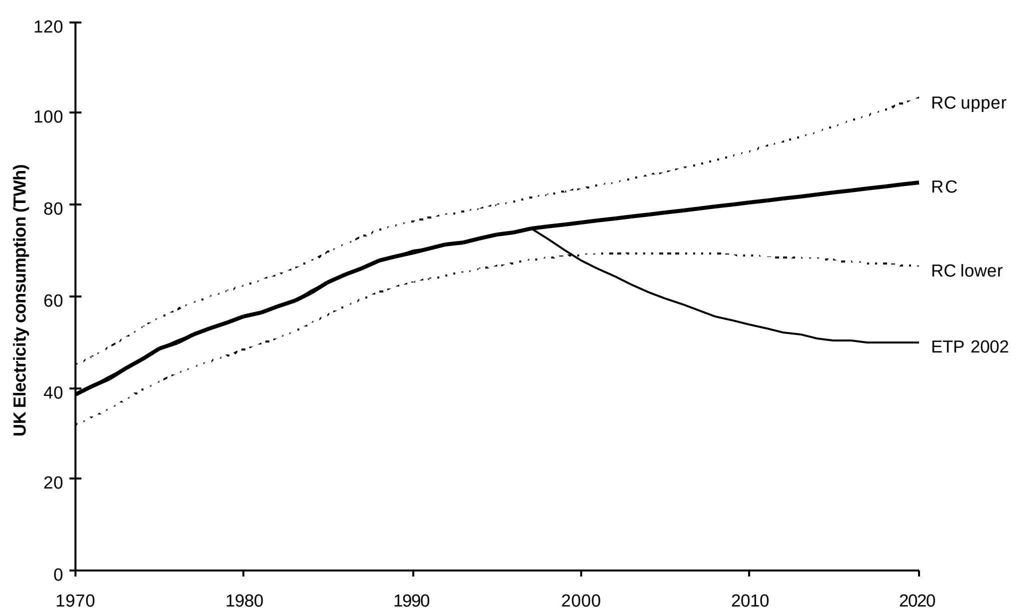

Figure 2. 1 Domestic lights and appliances electricity consumption, UK, 1970-2020

The cold appliance and lighting sectors use the highest proportions of electricity and are also the sectors where the greatest savings (both in percentage and absolute terms) are expected (Table 2.1). Together cold appliances and lighting account for over 60% of identified savings in 2010.

Table 2.1 Domestic lights and appliances electricity consumption, UK, 1996 and 2010

	1996		*2010*			
Appliance Group	*Electricity (TWh)*	*(%)*	*Electricity RC(TWh)*	*Electricity ETP2002 (TWh)*	*RC-ETP2002 Electricity savings (TWh)*	*RC-ETP2002 CO_2 savings (MtC)*
Cold	17.5	*(24%)*	16.1	8.7	7.4	0.9
Wet	12.0	*(16%)*	12.4	10.4	2.0	0.3
Cooking	12.8	*(17%)*	14.3	10.5	3.8	0.5
Lighting	17.2	*(23%)*	20.2	10.7	9.5	1.2
Brown	8.4	*(11%)*	9.5	5.5	4.0	0.5
Misc	6.1	*(8%)*	7.8	7.8	0	0
TOTAL	**74.1**	***(100%)***	**80.4**	**53.6**	**26.8**	**3.4**

Note: the kg CO_2/kWh conversion factors used are based on EP65

The potential savings (RC - ETP2002) are considerable. In 2010, 26.8 TWh per annum could be saved, which represents 33% of RC electricity consumption. This translates to carbon dioxide savings of around 3.4 MtC.

Total carbon emissions from electricity use in domestic lights and appliances are expected to decrease until 2000 and then start rising (Figure 2.2). The decrease, despite rising electricity consumption in RC, is due to the predicted changing fuel mix used for electricity generation (EP65, CL scenario), with lower carbon emitting generation taking an increasing share of the market.

Figure 2. 2 Carbon dioxide emissions from lights and appliances under the RC and ETP2002 scenarios, UK, 1970-2020

The following sections (2.3 through to 2.8) will provide a brief overview of each appliance group in terms of the factors influencing electricity consumption. In addition, current UK and EU policy for each appliance group will be described. Particular technological improvements are identified for appliances, however, efficiency improvements could clearly be made by other changes to technology.

1.8 COLD

Refrigerators, fridge-freezers and freezers are collectively known as the cold appliances, and together they represent 24% of electricity consumption by domestic lights and appliances in 1996.

The basic ownership and energy consumption information used in the DECADE model is shown in Table 2.2 below. The kWh/year figures are based on test consumption figures. The average new appliance uses less energy than the average appliance in the stock because cold appliances have become more efficient over time.

Table 2.2 Cold appliance data from the DECADE model, UK, 1996 and 2010

Appliance	*1996*			*2010*		
	own (%)	*new (kWh/yr)*	*stock (kWh/yr)*	*own (%)*	*RC new (kWh/yr)*	*ETP new (kWh/yr)*
Refrigerator	43	270	320	43	210	40
Fridge-freezer	60	590	640	65	460	120
Upright freezer	24	420	500	30	340	90
Chest freezer	18	420	510	16	350	90

1.8.1 Reference case for cold appliances

The cold appliances are the only appliance group where electricity consumption has not risen significantly since the late 1980s and is expected to fall under the RC scenario despite increases in household numbers and levels of ownership (Appendix C, Figure C.1). This decline is due to the significant improvements in energy efficiency (Table 2.2) which have occurred historically and which are expected to continue, particularly in response to policy, as outlined below. The improvement in energy efficiency which has occurred is impressive, especially given that CFCs were also being phased out from 1993 onwards, a change which necessitated re-design of appliances.

One important finding in DECADE (1997) was that changing sales patterns towards larger and frost-free appliances are counter-acting some of the drop in energy consumption due to technical change and consumer choice of more efficient appliances. Frost-free appliances use about 45% more energy than conventional appliances. Sales of fridge-freezers are increasing, particularly at the expense of standard refrigerators. If the trend towards buying frost-free and larger appliances were to become stronger than at present total electricity consumption for the cold appliances would rise, perhaps strongly enough to reverse the current downward trend.

<u>Current policy on cold appliances</u>
RC includes the likely continued effects of the EU Energy Label introduced in January 1995 and the expected effects of the minimum energy efficiency standards to be introduced in September 1999. Minimum standards will prohibit the sale of cold appliances less efficient than Energy Label category C, except for chest freezers where only Fs and Gs will be banned. The effects of minimum standards were modelled by developing both a 'best case' and 'worst case' estimate, based on possible manufacturer response to the standards. By 2010 minimum standards could be responsible for 4 - 14% energy savings compared with expected energy consumption without standards. An average of the best and worst case

projections has been used in RC. *Transforming the UK cold market* (DECADE, 1997) examined the cold market and the effects of policy on energy consumption in considerable detail.

The EST have recently launched a subsidised refrigerator replacement programme. Low-income householders who own a working but faulty standard refrigerator can trade it in for a new refrigerator at a cost of only £25. At a maximum, 50,000 households will receive this rebate by 1998, but this level of intervention is not sufficient to affect the RC. For comparison, almost 400,000 new refrigerators were sold in 1994 (MINTEL, 1995).

1.8.2 Economic and technical potential for cold appliances

Dramatic savings in energy have been identified for the cold appliances, as shown in Table 2.2. The technical potential for improvement for cold appliances is based on a combination of the improvements identified by GEA (1993) and the introduction of vacuum insulation panels (VIPs), which were not included in GEA's analysis because costs of VIPs were not well known in 1992. Subsequently Waide and Herring (1993) have reported on VIP technologies. Vacuum panel insulation is now on the market in freezers made by AEG and Norfrost. Given that the technology is on the market, or in prototypes, these high levels of savings (using 80% less energy than an average appliance in 1992) are justified within the ETP definition used. However, it should be noted that there is a larger gap between the current best on the market and the ETP energy consumption for cold appliances than for any other appliance group.

1.9 WET

The wet appliances consist of four types: automatic washing machines, washer-dryers, tumble dryers and dishwashers. Washer-dryers have been modelled by including them within the washing machines and tumble dryer projections, as if they were two separate appliances. Non-automatic washing machines and spin dryers, which make up a very small section of the market, are not included in the DECADE model.

The basic ownership and energy consumption information used in the model is shown in Table 2.3 below. Note that the ownership levels of washing machines and tumble dryers include washer-dryer ownership. No growth in ownership of tumble dryers is projected; this is more conservative than some industry projections. If ownership levels increased beyond this level then the RC projection for wet appliances would clearly be an underestimate.

Table 2.3 Wet appliance data from the DECADE model, UK, 1996 and 2010

Appliance	*1996*				*2010*		
	own (%)	*uses/yr*	*new (kWh/cycle)*	*stock (kWh/yr)*	*own (%)*	*RC new (kWh/cycle)*	*ETP new (kWh/cycle)*
Washing machine	91	270	1.24	225	94	1.12	0.90
Dishwasher	20	250	1.47	415	29	1.34	1.10
Tumble dryer	51	150	3.52	380	51	3.28	2.60

All kWh/cycle values are test values for a particular cycle and so a new kWh/yr figure cannot be calculated by simply multiplying the number of uses per year by the kWh/cycle figure. Instead the model uses information about the number of cycles at different temperatures and the relationship between the test energy consumption and that of different temperature cycles (see section 2.4.1). The stock kWh/yr energy consumption refers to the average appliance in the stock, not the average new appliance. Note that the washing machine annual consumption figure is for a hot-fill machine, whereas the dishwasher figure is not.

1.9.1 Reference case for wet appliances

The increases in washing machine, dishwasher and tumble dryer consumption (Appendix C, Figure C.2) are based on the expected slight increases in ownership of these appliances in combination with increasing household numbers. Usage is either projected as unchanging or declining and the energy consumption of the appliances is expected to fall due to a combination of technical trends and policy initiatives.

The technical information about the average energy consumption of new appliances is believed to be reliable for recent years, the information is less certain prior to 1990. The data used in Run 3 have been greatly enhanced by GfK sales information, which at the time of carrying out the Reference Case calculations covered over 70% of branded sales.

The data which are most unreliable for the wet appliances are the usage figures. The energy consumption of wet appliances is strongly dependent on the way in which consumers use them as well as how often they are used. For example, washing clothes at 40°C uses only 70% of the energy needed to wash them at 60°C. From 1996, following historical trends, the proportion of 40°C washes is expected to increase into the future. As a consequence of the rising spin speed of the average washing machine and washer-dryer, the average programme time of tumble dryers is expected to decrease (clothes have more water extracted before leaving the washing machine and thus require a shorter time in the tumble dryer). An interesting finding from Lothian and Edinburgh Environmental Partnership data (LEEP, 1996) was that up to a third of households owning a tumble dryer did not to use it at all, presumably for reasons of economy. This has been taken into account in modelling tumble dryer usage. Dishwashers are also expected to be used increasingly on lower temperature programmes in future. These usage trends could be affected by many factors including improvements in detergents, changes in fabrics, changes in cooking and eating habits and changing perceptions of cleanliness.

Current policy on wet appliances

The EU Energy Label for washing machines and tumble dryers became effective in the UK on 1st October 1996. The vast majority of washing machines on the UK market are Bs, Cs and Ds, whereas most tumble dryers are either Ds or Gs. The washing machine Energy Label also includes information on wash performance. However, as good wash performance and energy efficiency tend to be associated with each other, this is not expected to detract from the effectiveness of the label. EU Energy Labels for washer-dryers will be in place by 31 January 1998 and labels for dishwashers are to be introduced on 1 January 1999. The expected effects of the EU Energy Label for all wet appliances have been included in RC.

A voluntary agreement to reduce the energy consumption of washing machines is currently being finalised between CECED (the European appliance manufacturers' association) and the EU. Under the voluntary agreement, participants will no longer produce or import E, F and G washing machines after 31 December 1997. Washing machines in class D will be no longer be produced or imported after 31 December 1999. The only exceptions to the agreement are machines with load capacity equal or smaller than 3 kg or with a spin speed lower than 600 rpm. CECED also propose to educate consumers on how to save energy when using their washing machines (CECED, 1997). Although the voluntary agreement will have some effect, as Ds at present make up only 10% of UK sales, a proportion which is falling, it is barely noticeable. This has been modelled and included in RC.

The International Energy Agency launched a competition at the end of 1996 to help introduce a super-efficient tumble dryer onto the market. The aim was to encourage development and procurement of a dryer with a class A Energy Label. However, as yet no competition winner has been announced and no attempt has been made to include effects of this initiative in RC.

1.9.2 Economic and technical potential for wet appliances

The potential for savings from technical changes for the wet appliances is less dramatic than for cold appliances. The technical improvements which make up the ETP level are largely based on the work of GEA (1995) for which the Environmental Change Unit (ECU) carried out the modelling of policy options. However, washer-dryers and tumble dryers have been examined in more detail. The energy consumption figure for washing machines proposed in ETP has already been met by more than one washing machine currently on the European market (CECED, pers comm).

COOKING

The four major types of cooking appliance are ovens, hobs (both of which may be free-standing units or built-in components of a cooker), microwaves and kettles. Minor cooking appliances include toasters, deep-fat fryers and food processors (see Appendix B). The minor cooking appliances account for only 6% of total cooking energy consumption. They are included in the model but will not be reported on in detail here; the data remain largely unchanged since Run 2 and no ETP level has been defined for these minor appliances.

The RC and ETP2002 projections for the major cooking appliances have been revised on the basis of recently-acquired LEEP and EA measured electricity consumption data on ovens, hobs and kettles. The basic ownership and energy consumption information used in the model are shown in Table 2.4 below.

Table 2.4 Cooking appliance data from the DECADE model, UK, 1996 and 2010

Appliance	*1996*		*2010*				
	own (%)	*stock (kWh/year)*	*own (%)*	*RC stock (kWh/year)*	*RC technical improvement since 1996 (%)*	*ETP stock (kWh/year)*	*ETP technical improvement since 1996 (%)*
Oven	56	277	63	237	0	158	52
Hob	46	270	45	264	0	160	64
Microwave	72	84	80	90	0	69	see text
Kettle	95	170	96	170	0	142	20

1.9.3 Reference case for cooking appliances

The modelling of cooking electricity consumption was enhanced by use of new data and insights from analysis of LEEP monitoring data for higher income households in Edinburgh, a project known as Billsavers2 (LEEP 1996a & b). Interesting new data included the following:

- annual consumption for cooking has declined from 630 kWh in 1992 (DECADE, 1995) to 530 kWh in 1996 per household per year. The decline in oven and hob usage can be explained both by declining household size and increasing ownership of microwaves;
- an improved understanding of the effect of household size on cooker electricity consumption (see Figure 2.3);
- further estimates of the split between ovens and hobs in cooker consumption: Billsavers2 data show that free-standing ovens use 60% of the electricity consumed by cookers (consisting of electric oven, hob and grill), and from this a 60%:40% split of oven:hob consumption was derived. An alternative estimate (based on measured consumption data from free-standing ovens and hobs) from Billsavers1 (LEEP monitoring of low-income households) provided a split of 52% ovens to 48% hobs. Both are based on relatively small samples;
- Billsavers2 provided sufficient data to examine the effect of microwave ownership on cooker consumption. Consumption appears to be higher when a microwave is present, but this is deceptive

since larger households are more likely to own microwaves. If household size is accounted for, a microwave displaced some 150-200 kWh pa of cooker consumption in the sample (Figure 2.3). This supports a previous Electricity Association finding to the effect that microwave ownership reduced consumption in free-standing electric cookers.

No further technical improvements in any of the cooking appliances have been included in RC, as there is no reason to believe improvements are likely to occur in the absence of policy action. Indeed no historical evidence has been found to show any improvements in hob or kettle efficiency.

<u>Current policy on cooking appliances</u>
There is no current policy at either EU or UK level which is aimed at improving the energy efficiency of new cooking appliances, and hence none has been included in RC.

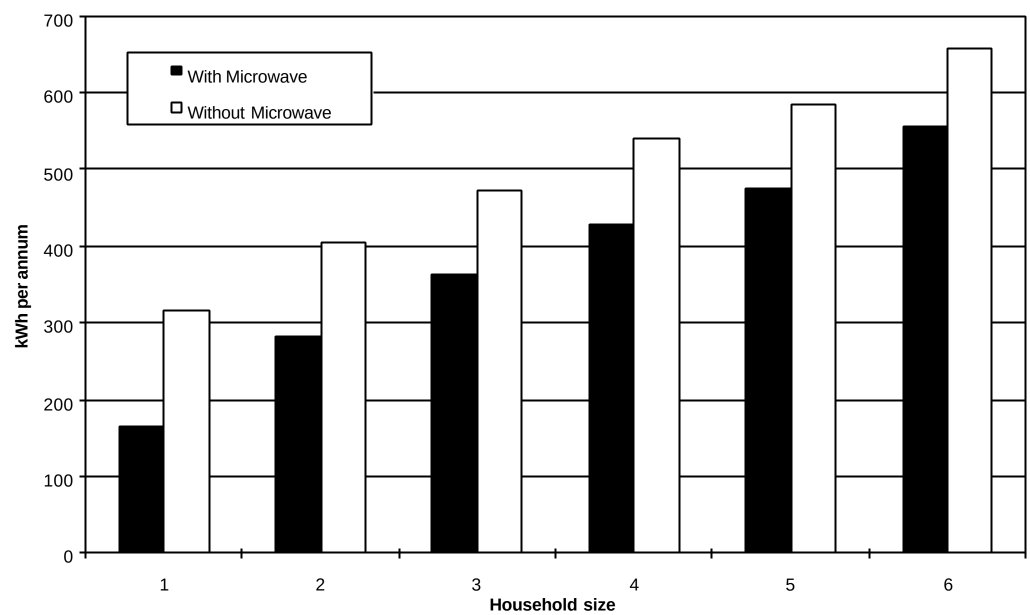

Figure 2. 3 Electricity consumption by cookers in households with and without microwaves

Source: LEEP (1996a)

1.9.4 Economic and technical potential for cooking appliances

It is estimated that a combination of low emissivity surfaces, improved controls and insulation and an unglazed door could save up to 52% of oven electricity consumption (Hinnells *et al*, unpublished). These options are likely to lead to an increased cost of around 20% because of the use of high temperature alloys and some additional expenditure on electronic controls. However, this additional cost would be economic to the consumer and hence a 52% reduction in energy consumption is the ETP level.

The ETP consumption level for hobs is achieved by the introduction of induction hobs, which are more efficient than other forms of electric hob, but at present cost considerably more.

For kettles the ETP consumption levels is based on insulated kettles which could save energy by reducing the need to re-boil the water once boiled.

ETP microwave consumption is based on a reduction of standby consumption in new microwaves from 4W to 1W. No reduction in the energy used in the on-mode is assumed.

1.10 LIGHTING

Lighting is the second highest consuming sector, representing around 23% of all electricity consumed by domestic lights and appliances. It is also the most poorly understood area with the fewest data. However, this situation is gradually improving as lighting attracts increasing interest as an area which offers potentially large and rapid savings.

1.10.1 Reference case for lighting

Domestic lighting electricity consumption has been revised to 17.2 TWh in 1996, rising to 20.2 TWh by 2010. A major revision of the lighting model has been made possible by using the results of the EU SAVE funded Electricity Association (EA) domestic light monitoring project.

The EA project monitored the lighting consumption of all fixed and the majority of portable fittings in one hundred households throughout Britain and collected information on the number and type of light bulbs in these homes. Participants also completed a detailed questionnaire examining their attitudes to lighting in general. A key piece of information derived from the EA project is the split in consumption between fixed and portable fittings. In the past, monitoring studies have often ignored the portable fittings and so the importance of these fittings in determining overall lighting consumption was not known. A previous study estimated a ratio of consumption of fixed fittings to portable fittings of 63:37 (DECADE 1995), based on peoples' estimates of usage rather than actual measurements. The EA figures give a much lower ratio of 82:18. This split is not required as an input to the model, but is helpful when considering how to access potential savings.

Market research has shown that 23% of households in 1997 have at least one compact fluorescent light bulb (CFL) (GfK, pers comm). Another important finding in the EA project is that the households that owned a CFL had an average of three. This figure is confirmed by data from the Billsavers project. Hence, it appears that once a household has purchased a CFL they are more likely to buy more. It is possible that each household has, on average, three fittings which are suitable for CFLs in terms of usage, appearance and technology. In order to be able to install more CFLs, the fittings may need to be altered. This could be as simple as changing the shade or may require the purchase of new fitting, or, in extreme cases, rewiring of the fitting. Such alterations mean additional cost to the householder. Since cost is already seen as a barrier to people purchasing CFLs, the extra cost of adapting the fitting is likely to be a significant problem. Through the SAVE funded DELight (Domestic Efficient Lighting) project the ECU is currently tackling the issue of the role of the fittings in determining the realistic level of savings possible. In terms of the DECADE model the projected sales of CFLs have been revised downwards in order to make allowance for the fact that the fittings within the home will limit the growth of CFL ownership, without further investment by the householder. Apart from such considerations, fittings are not included in the model explicitly, mainly due, again, to the lack of data. However the rate of fitting replacement is thought to be fast enough to replace the whole stock by 2020.

Historically, the rise in lighting consumption has been driven partly by the rising number of households and partly by the increasing number of light fittings (and therefore light bulbs) in the home. This is expected to continue into the future, the increase being mainly in portable fittings due to the growing interest in creating atmosphere through lighting, which requires more than just a central ceiling fitting. It has also been assumed that CFL ownership will increase as the technology continues to improve towards smaller bulbs giving similar light to incandescent bulbs. However, gains in efficiency will be partially offset by the overall increase in bulb ownership.

Although improvements have been made in the lighting model, there is still a need for more data, particularly usage data. While monitored data are useful in confirming that lighting consumption is higher than previously thought, details on hours of use are also needed. Peoples' estimates of usage have been found to be unreliable; actual measurements of the number of hours for which lights are on are required.

The RC projection incorporates the assumption that CFL ownership will continue to rise into the future from an average of 0.6 per household in 1996 to 1.9 in 2010.

<u>Current policy on lighting</u>

The Energy Saving Trust (EST) has two national schemes which aim to increase the purchase and use of CFLs. Since 1993, a CFL subsidy scheme lowering the sale price of the bulbs has been in operation. The subsidy is direct to manufacturers at a rate of £1 per bulb. By the time this reaches the consumer the price of the bulb is reduced by around £5. In 1994, this resulted in an additional 950,000 bulb sales in three months. The effects of these subsidy campaigns are reflected in the model through the sales and ownership data. Free CFLs, given away as part of the Home Energy Efficiency Scheme to households in receipt of means-tested benefits, are reflected in ownership data only. These two EST programmes will be continued into the future along with a new scheme in autumn 1997 introducing a national subsidy on CFL dedicated fittings.

The expected effects of proposals for extending Energy Labels to light bulbs have not been included.

1.10.2 Economic and technical potential for lighting

The ETP takes into account both the role of the fittings and technological improvements. Considering current bulb technology, there are CFLs on the market that are practically the same size as ordinary incandescent bulbs and so, technically, could replace incandescent bulbs in *all* fittings. It is not economically or technically feasible for CFLs to replace fluorescent strips or halogens. Therefore, the ETP calculation is based on replacing all incandescent bulbs used over a certain number of hours a year with CFLs (Table 2.5). To determine the replacement threshold, a 12 year pay back period for CFLs was assumed to be reasonable as this is the average time a CFL would last in the home if the ETP were achieved. A different threshold for replacement was calculated for 40W, 60W and 100W bulbs since the economics change at each wattage.

Table 2. 5 Lighting ETP: criteria for replacement of incandescent bulbs with CFLs

Incandescent	*Replaced by CFL*	*Pay back period (years)*	*Minimum usage per year for replacement (hours)*	*replaced (%)*
40 W	10 W	12	150	80
60 W	14 W	12	100	85
100 W	25 W	12	75	85

Source: DECADE based on EA data

The result is that ETP is estimated to be equal to a projection of between 17.6 and 22 bulbs to be installed in the average household in 2010.

To access the ETP by 2002 would require a huge increase in sales of CFLs: from 2% of light bulb sales in 1997 to over 85% in 2002. Obviously, this is not feasible from the point of view of production in the short term and in the longer term bulb sales would drastically decrease due to the longer life of CFLs. In reality, ETP levels of CFL ownership would have to be introduced over a longer time scale, with mechanisms in place to provide security for the manufacturers (Chapter 4).

1.11 BROWN

The brown goods include televisions (TVs), video-cassette recorders (VCRs), satellite TV decoders, cable TV decoders, hi-fi stereos, cassette players and clock radios: the ‘brown’ refers to the original wooden casings of these appliances. Until recently there were very few studies on the UK or EU domestic brown goods sector. However, this was partially remedied by an EU study (Huenges Wajer, 1995, 1996) which examined energy consumption by the major brown goods.

Although the model uses ownership and consumption information for all of the brown goods (Appendix B), only data for TVs and VCRs are presented in Table 2.6 (below), since these two appliances accounted for 84% of brown goods' electricity consumption in 1996.

Table 2. 6 TV and VCR data from the DECADE model, UK, 1996 and 2010

Appliance		*1996* own (%)	*1996* new (W)	*1996* stock (kWh/yr)	*2010* own (%)	*2010* new RC (W)	*2010* new ETP (W)
TV	on mode	}179	69	}118	}186	80	56
	standby		7			3.0	0.5
Video	on mode	}89	25	}104	}110	20	13
	standby		9			3.8	1.0

Ownership levels of greater than 100% for TVs and VCRs (by 2010) are due to the fact that many households own more than one of these appliances.

1.11.1 Reference case for brown goods

The brown goods in total consume around one eighth of the electricity used in UK domestic lights and appliances. TVs in their on-mode consume the most energy in this group, mainly due to their high ownership levels and increasing hours of usage. The power demand has been falling, but is expected to increase slowly as additional features (eg surround sound and larger screen) become more common.

Projecting energy consumption by the brown goods is difficult since the market for consumer electronic goods is dynamic. The technology changes fairly rapidly in comparison to other domestic appliances. One common feature in consumer electronic goods is the increasing use of standby features, which consume energy whilst not performing the primary function of the appliance. Standby consumption is significant in satellite and cable decoders: here, no major reduction in power demand has been assumed in the Reference Case. Presently the household ownership of satellite decoders (16%) is larger than cable decoders (8%) and both are rising rapidly. The number of cable decoders is expected to increase as the number of homes which have access to cable is now at 40%.

Current policy on brown goods

Part B of the 'Standby study' (Huenges Wajer, 1996) examined various policy options for reducing standby consumption. Subsequent to the study, the European Association for Consumer Electronics Manufacturing (EACEM) proposed a scheme to reduce the energy consumption of TVs and VCRs in their standby mode. The voluntary agreement will reduce the average passive standby power demand of these appliances from 7.5W (TVs) and 9.5W (VCRs) in 1995 to 6W by the year 2000, then by a further 1W every subsequent 3 years. Each company would agree to have a fleet average. The estimated effects of this agreement are included in RC.

As yet there are no other policies in place to increase the efficiency of UK consumer electronics. However, 6 countries within the EU have a memorandum of understanding to increase the efficiency of TVs and VCRs in the standby mode. Target values and a labelling scheme are based on a Swiss scheme - E2000 (Schmit, 1996). A further discussion of possible policies is given in Lane and Huenges Wajer (1997).

1.11.2 Economic and technical potential for brown goods

The product life time of brown goods is much shorter than the cold, wet and cooking appliances. This, coupled with rapid redevelopment of these goods, means that efficient brown goods may be in the home relatively quickly. The largest savings are to be made from the on-mode of TVs. At present, the ETP level is defined as using 30% less energy than RC technology. It does not, however, include experimental technologies such as liquid crystal displays.

As discussed in the previous section, many of the brown goods have a significant standby power demand. For TVs and VCRs power demand levels of 0.1W have already been developed and put onto the market. It is certainly cost effective to reach 0.5W for TVs and 1W for VCRs over the life time of the appliance, and this is the level taken as the ETP (Table 2.6).

Many brown goods have standby losses associated with the transformer. An EU study on miscellaneous standby appliances (Molinder, 1997) showed that very efficient cost-effective (over an appliance's life time) transformers are already available. They cost ECU 4-10 more than a conventional one, but use a fraction of the energy. These have been included for some standby appliances to calculate ETP.

1.12 MISCELLANEOUS

The DECADE model identifies 15 categories of electrical equipment that make up the 'miscellaneous' appliance group (Appendix B). Energy consumption for miscellaneous appliances is modelled in a simpler way than for the other appliance groups. Due to the diversity of products and a lack of information, an ETP consumption level has not been calculated for most of the appliances.

1.12.1 Reference Case

The miscellaneous appliances include home office equipment, defined as PCs, printers, answerphones and fax machines. Detailed figures for energy consumption for home office equipment which were not available at the time of Run 2 have been combined with ownership and usage information to give energy consumption figures and projections into the future. It is assumed that the energy consumption of this equipment will fall with advances in technology, but that rising levels of ownership will ensure that the total energy consumption of this sector continues to grow.

The other major energy consuming miscellaneous appliances are electric showers and central heating pumps. The energy consumption of both these appliance types is expected to rise in the future due to increased levels of ownership and rising household numbers. Ownership of electric showers is growing independently of central heating and gas water heating and this trend is expected to continue. Rising levels of gas central heating and hot water systems have increased electricity use in the pumps required to circulate the hot water.

1.13 CONFIDENCE IN MODEL OUTPUT

Considerable effort has been put into increasing confidence in the DECADE model output, so that it provides a solid basis for policy decisions. Improvements to input data have been described throughout Sections 2.3 - 2.8. This and other methods of increasing confidence are discussed in Section 2.9.1. In addition, the statistical confidence limits on the RC scenario have been calculated, as shown in Figure 2.1, and the methodology is outlined in Section 2.9.2.

1.13.1 Improving confidence

In order to increase confidence in the output of the DECADE model and to validate the results the following have been undertaken:

- input data have been improved;
- model output has been validated with monitored electricity consumption data wherever possible; and
- DECADE results compared with those of other models.

Run 3 has been enhanced by the use of quarterly sales data on the wet and cold appliances, supplied by GfK for 1995 and 1996. These data have been used to calculate sales-weighted average energy consumption figures of new appliances, in addition to allowing in-depth analysis of many factors. All the historical data and assumptions in the model have also been re-checked in the light of any further information which has been acquired in the past two years. The appliance-specific electricity consumption data supplied by LEEP and the Electricity Association has allowed validation of model outputs.

As DECADE is the only detailed model available of UK domestic lighting and appliance electricity consumption, no direct comparisons with the output of other models can be made. However, the Building Research Establishment (BRE) carry out detailed modelling for UK household energy use by heating and hot water (BREHOMES). BRE add the output of their model to that from DECADE and check that the resultant average electricity use per household matches the known data for past years. In their forthcoming update to the Domestic Energy Fact File BRE will use DECADE's figures for lights and appliances usage (BRE, pers comm), confirming that these two models together give an accurate picture of average UK household electricity use.

ETP2002

The data used to inform ETP2002 are identical to those for RC except for the technical improvements to appliances expected to occur between 1997 and 2020. The additional uncertainty attached to ETP2002 is due to the difficulty of deciding what the ETP level of electricity consumption will be. It is recognised that the ETP level is not exact, not least because additional technical improvements are costed from an engineering analysis which is thought to over-estimate the cost of additional efficiency. For further discussion on this point see Chapter 3.

In addition, the economic basis for ETP is that of no additional cost to the consumer. For purposes of policy analysis, it is best to base economic assessments on the societal perspective, which would tend to give a lower discount rate of 2-3% (Krause *et al*, 1995). By choosing the consumer perspective, DECADE has used a much higher discount rate of 8%. The cost of saved energy is strongly dependent on the discount rate chosen. Therefore, because of the discount rate chosen, the ETP consumption level is likely to be higher than the socially optimum level of energy consumption and thus potential savings, at no additional cost to society, are underestimated.

Despite the limitations identified above which introduce additional uncertainty into any scenarios based on ETP, it remains a useful concept in terms of identifying achievable targets for efficiency improvements, the rate of accessing improvements, and prioritising appliance groups. As the ETP is an energy efficiency level per appliance most of the debate in the policy scenarios (Chapter 4) is about the speed with which it is achieved.

1.13.2 Estimating confidence

Electricity consumption by domestic lights and appliances has been estimated through time using a stock model (described in DECADE, 1995). These estimates, known as point estimates, are not exact and are subject to the error of the input data (ie ownership, specific energy consumption, life span and usage of appliances). And, of course, these inputs also become less certain (ie have a larger margin of error) when they are projected into the future.

The confidence limits on the estimated consumption have been calculated by employing a Monte Carlo method. This technique is computationally intensive but allows confidence limits to be estimated where the certainty of input variables are known. This method will state the level of confidence in the estimates of the Reference Case, given current underlying trends.

Knowing the source of the input data it is possible to provide a statement of confidence in the input variables. Error ranges (or more correctly, probability density functions - distributions of the likelihood of the variables' true values) are specified for the average new consumption of a machine sold (Tech) through time, the ownership (Own) through time and the average life span (Lifespan) of each appliance. Using a random number generator all the input variables are chosen (from the probability density function) and the consumption estimated using the stock model. This process is repeated many times (greater than 1000) and the results are used to describe a (probability likelihood) distribution of the estimated consumption, the mean of which is the point estimate. The standard deviation of this distribution is used to determine the confidence level.

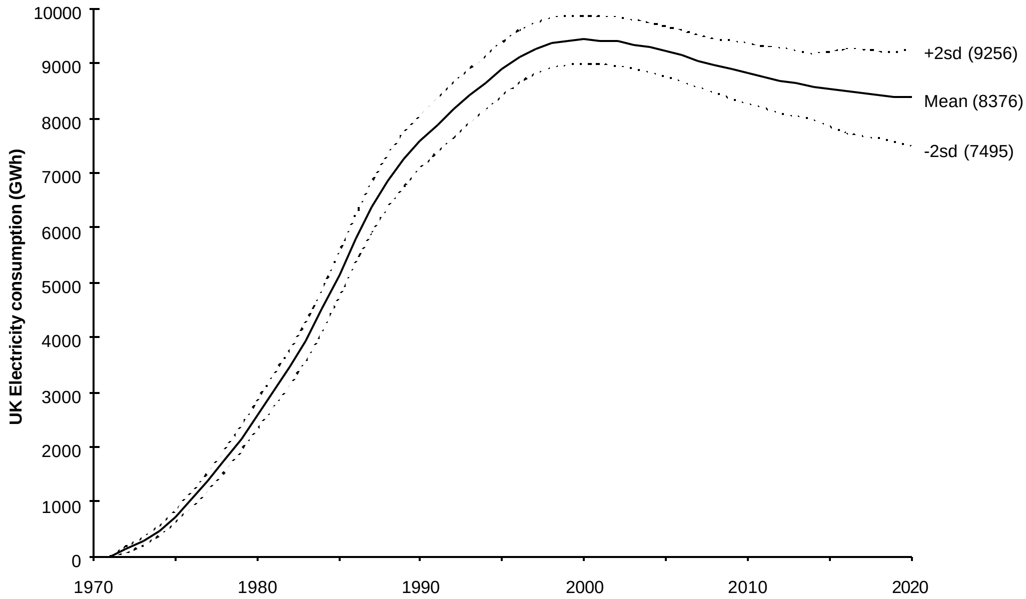

Figure 2.4 Monte Carlo estimation of UK fridge-freezer electricity consumption (with 95% confidence limits, ± 2 standard deviations)

A probability distribution for fridge-freezer consumption has been calculated by sampling the estimated probability density functions of the input variables, estimating the consumption and repeating the process many times. Plotted in Figure 2.4 are the mean of the estimated consumption distribution and confidence intervals two standard deviations either side. Two standard deviations roughly correspond to 95% confidence limits, which means that in the year 2020 there is a 1 in 20 chance that the electricity consumption in UK fridge-freezers actually lies outside the range 7495 - 9256 GWh, given the current underlying trends.

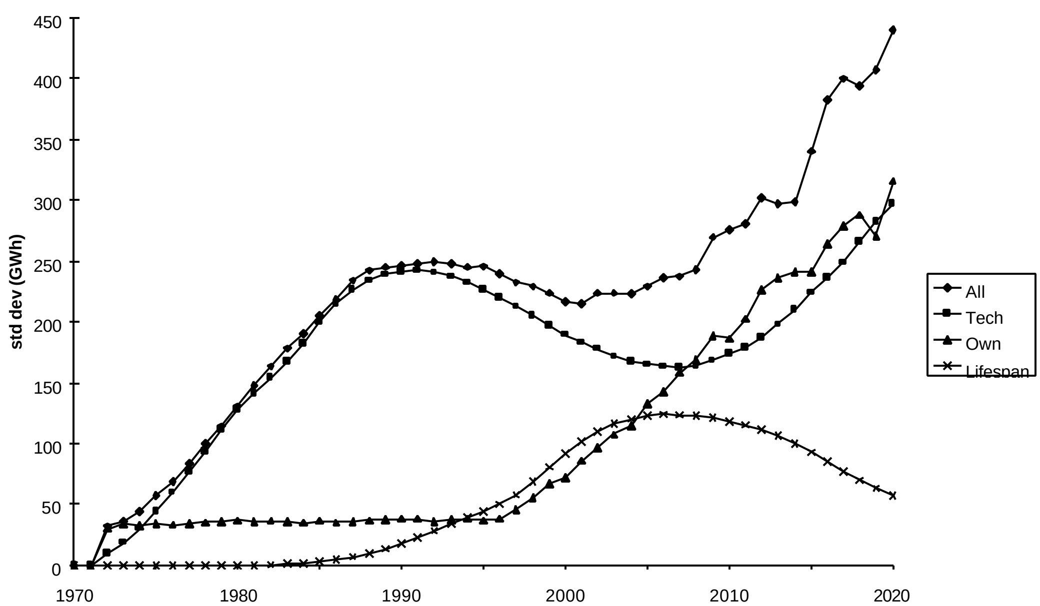

Figure 2.5 Standard deviation of UK fridge-freezer electricity consumption as a result of changing inputs

The Monte Carlo method can also be used to describe how individual input variables affect the estimate of consumption. Figure 2.5 shows that the uncertainty on the electricity consumption estimate as a result of ownership (Own) prior to 1996 is small. This is because the estimates of ownership are based on very large surveys, and are well known historically. However, as the ownership is projected into the future, it becomes less certain, so that estimated consumption is also less certain. The energy consumption of new fridge-freezers sold (Tech) is best known in 1995-96, where GfK sales data have been used. Historical data and projections are less certain. Since there is a time delay (life span of 18 years) the most certainty about the consumption of new appliances (Tech in Figure 2.5) is in around 10 years time. The 'All' line in Figure 2.5 (created by combining Tech, Own and Lifespan) is the one used to provide confidence limits for the estimate of consumption by fridge-freezers (Figure 2.4).

This method then reveals which are the most important variables needed for estimating consumption, and may in turn be used for examining these variables further. Also if this statistical confidence limits were estimated for the various policy scenarios then probabilities of certainty could be attached to the potential energy savings.

The Monte Carlo method described above is repeated for all the other appliances to reveal the confidence in total estimated electricity consumption, already given in Figure 2.1. The 'RC upper' and 'RC lower' confidence limits are the 95% levels.

1.14 SUMMARY OF MAJOR DEVELOPMENTS SINCE 1995 (RUN 2)

Total UK domestic lights and appliances electricity consumption for RC Run 3 is not significantly different from the Run 2 RC (BAU) scenario. Considering the number of changes that have been made to the model and the considerably improved data it is perhaps surprising that Run 3 is not more different from Run 2.

The potential savings (RC - ETP2002) are slightly larger than for Run 2 due to revisions made.

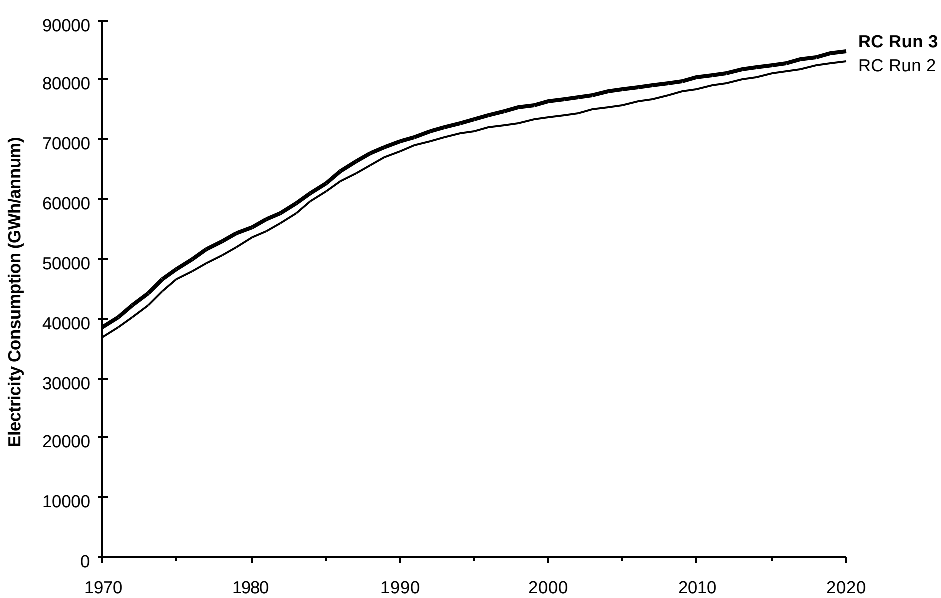

Figure 2. 6 Comparison of Run 3 RC and Run 2 RC (BAU) of the DECADE model

Changes between Runs 2 and 3 are described briefly for each appliance group.

Cold

There have been a number of changes to RC since Run 2, the most significant of which are:

- upright and chest freezer electricity consumption has been revised downwards from 1970 - 2000;
- fridge-freezer electricity consumption has been revised upwards from 1995 onwards, due to the influence of frost-free sales on the electricity consumption of an average appliance.

Wet

There have been a number of changes to RC since Run 2, the net effect of which has been to estimate a higher total consumption for the wet appliances than for Run 2 of the DECADE model by 2020. The most significant changes are:

- washing machine, tumble dryer and dishwasher efficiency improvements are projected to be greater than in Run 2 due to the expected influence of the EU Energy Label, more comprehensive GfK sales data, and (for washing machines) the effect of the CECED voluntary agreement;
- the proportion of lower temperature programmes for washing machines and dishwashers has been increased, based on new LEEP data;
- average annual tumble dryer energy consumption has been revised upwards, based on GfK sales data, and monitored data from LEEP;
- washer dryers have been explicitly included in the tumble dryer ownership figures. This, together with the increased annual consumption figures, has led to considerably increased UK tumble dryer consumption, eg 1996 consumption rose from 2.55 TWh in Run 2 to 4.61 TWh in Run 3.

Cooking

In Run 2 a technical potential (TP) rather than ETP was used for cooking appliances. The TP had no costs attached to the chosen technology, however, it has since been possible to identify the costs associated with technical improvements and thus ETP has been identified. In addition, stock models for microwaves and for kettles have now been incorporated into the DECADE model. New microwave ownership data from GfK suggest that the saturation level for ownership will be higher and will be reached sooner than was projected in Run 2. Data on minor cooking appliances have not changed significantly from Run 2.

Lighting

Run 2 was based on sales figures historically, with projections based on estimated ownership. This differed from the modelling of the other appliance groups, which was based primarily on ownership data, because such data were unavailable for lighting. Light bulb sales figures are problematic because of the uncertainty of the split between the domestic and commercial sectors. Figures quoted for domestic sales vary by up to 30% and hence imply a wide margin of error for validating the model. The revision to the lighting model has been to base it on bulb ownership data collected by the EA and GfK, thus giving greater confidence to the figures as well as making the lighting model consistent with the rest of the DECADE model. Sales figures still form an integral part of the model, since there are few other data available, and these have been linked with ownership levels to determine how long bulbs last on average in the household.

In Run 2, the lighting ETP was based solely on economic criteria, with pay back periods for CFLs calculated at various levels of usage. There was no consideration of the role of the fittings or technological improvements in these calculations. The ETP has now been revised, taking these two factors into account, as explained in section 2.6.2. The savings from lighting are slightly lower than in Run 2 due to improvements in the way ETP has been calculated.

Brown

In Run 2 a TP rather than ETP was used for brown goods. It has since been possible to identify the costs associated with technical improvements and thus ETP has been identified in Run 3.

Miscellaneous

The modelling of miscellaneous appliances has changed little from Run 2 with the exception of home office equipment, where more information has become available.

1.15 CONCLUSIONS

After examining the total consumption in the RC and ETP2002 scenarios, the main findings may be summarised as follows:

- appliance consumption has almost doubled over the last 25 years;
- consumption is projected to increase by another 6TWh from 1996 to 2010;
- exploitation of the full ETP could reduce consumption by 33% from the level projected in 2010;
- CO_2 savings are dominated in early years by changes in the electricity supply industry;
- the quickest savings are to be gained through improvements in lighting efficiency;
- the largest efficiency gains are in cold appliances and lighting.

To achieve the ETP levels of efficiency a variety of policies will have to be introduced. The general theoretical framework for transforming the market towards efficiency is described in Chapter 3. Chapter 4 discusses policies to access ETP in more detail.

CHAPTER 3: DEVELOPING A STRATEGY

1.16 INTRODUCTION

Chapter 2 outlined the Reference Case and the Economic and Technical Potential, and policy actions which have been used in individual cases to date. This chapter examines how a more complete strategy[1] might be evolved to access a much greater proportion of the potential savings. It describes:

- what is meant by market transformation strategy, in particular that it is an integrated process (section 3.2);
- the policy instruments which are the tactical components of a strategy (section 3.3);
- the tactics that might be adopted for each end use (eg lighting) given the different circumstances and main technologies of each (eg incandescent, halogen or compact fluorescent bulbs) (Section 3.4);
- optimising a strategy, in particular the crucial links between instruments (section 3.5); and
- the wider context of market transformation, including issues such as certainty of energy savings, cost (especially cost to whom) and equity between income groups (section 3.6).

These elements form the decision-making framework for the scenarios developed in Chapter 4, and provide a more generalised framework for decisions by Government facing a different set of circumstances than those outlined in our scenarios.

There are additional savings to be achieved through changes in usage, but it is by no means certain how easy it is to change behaviour, how much it costs or how permanent is the change. Behavioural change is not included in ETP, nor in this analysis of market transformation nor the scenarios in Chapter 4, but is the subject of Chapter 5.

1.17 THE THEORETICAL BASIS FOR MARKET TRANSFORMATION

The aim of market transformation is to produce significant and lasting change in the efficiency of appliances sold. The most important dimensions, for this study, are:

- in free market situations, products naturally evolve. Societal influences can direct or focus evolution towards societal goals, such as reduced greenhouse gas emissions;
- a range of policies are available, and different policies will be appropriate at different stages of this evolution. Most policies will have a function during the lifetime of most products;
- the policies are interactive and should be seen as a complete and long term strategy. Therefore the timing of an intervention is important. In this way the maximum benefits will be achieved through a synergetic effect; these benefits are considerably greater than the sum of the individual policies.

The first requirement is a reproducible measure of consumption and efficiency. Once efficiency can be measured, it can be influenced. Figure 3.1 shows a distribution of efficiency on the current market in the UK and how parts of that distribution may be affected in the future. The three curves show:

- before intervention: the baseline is the distribution of efficiency for all cold appliances offered by Scottish Hydro Electric prior to the introduction of labelling, when the average model was an F;

[1] In this sense, strategy is used to mean the plan of campaign (ie for market transformation), and tactics, being short term means towards a larger end (ie particular policy instruments or particular appliance groups), and therefore a subset of strategy.

- after labelling: the distribution of efficiency of models offered by Scottish Hydro after the introduction of labelling. The average model offered moved up to a D, with a overall improvement of 19% in a single year;
- market transformation: a theoretical distribution is illustrated, combining a 15% efficiency standard plus rebates or tax differentials, to increase sales of more efficient products, and a procurement programme. The average appliance might become a B on the label, equal to a 40% improvement on the EU average in 1992 (GEA, 1993).

This process is continuous until technical limits have been reached.

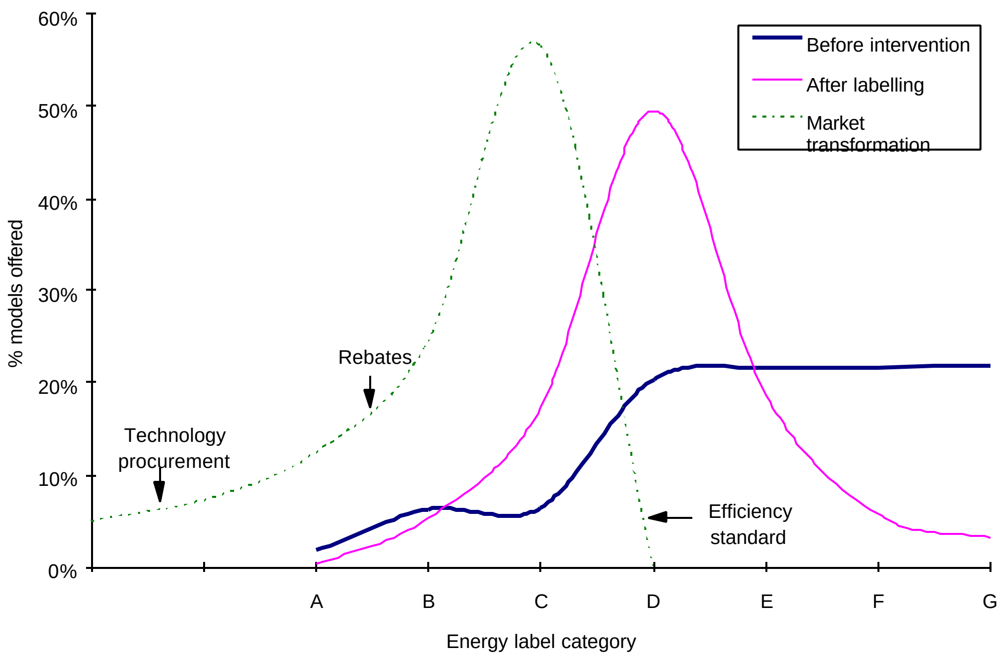

Figure 3. 1 Three stages in market transformation

Source: DECADE (1995)

The theory behind market transformation has been explained and developed in earlier publications by the DECADE team (DECADE, 1995, 1996 & 1997) with an analysis of the costs and benefits (Hinnells and McMahon, 1997), much of which is based on innovation theory. Within a specific service or end-use, there are several stages to the evolution of a technology or product (Roy, 1994):

1. the exploration stage, in which inventions and experimental designs are conceived and developed,
2. consolidation, when a limited range of dominant designs is established,
3. maturity, in which a range of standardised products is produced efficiently and diffused widely into society, the emphasis shifting from product to process innovation,
4. minor innovation and development of product families to capture new markets,
5. decline and replacement by products based on a new concept or technology, thus beginning the evolutionary process once again.

For the purposes of this discussion it is assumed that innovations or technologies or products may change (eg foam insulation), but the service, or end-use (eg of refrigeration) remains the same, with no diminution (and sometimes an increase) in the level of service. Policy can encourage the transition from one phase of development to another. Table 3.1 shows the relationship between stages of innovation and market transformation initiatives. The direct effects of technology procurement could be to increase market penetration of a new technology to 2% while the indirect effect may be much greater. As rival manufacturers introduce similar products to market in order to compete, the technology may increase to, say, 10% penetration. Rebates or tax differentials could increase penetration up to around 20%. Minimum standards underpin the transformation and increase penetration of an efficient technology to 100% (Geller and Nadel, 1994). In this chapter, the tactical components (policy options and appliance groups) are first reviewed, then reassembled and discussed in the context of optimising strategies.

Table 3. 1 Innovation theory and market transformation

Stages of innovation	Policy objective	Appropriate policy instruments	Market share of 'efficient' products
exploration (new technologies)	encourage innovation	R&D, procurement	0-2% market share for new technology
consolidation	give the more efficient products an advantage	labels and advice, tax differentials or rebates	2-20% market share for new technology
maturity	overcome structural barriers to new technologies		20%+ market share for new technology
minor innovation (optimise existing technology)	discriminate between products on the market	labels, first round standards	100% market share for optimised existing technology
replacing old and inefficient technologies	threaten the survival of the worst products	second round standards	100% market share for new technology

Source: Hinnells and McMahon (1997)

1.18 TACTICAL POLICY COMPONENTS

Having outlined how different instruments interact as part of a market transformation process, the individual options are now discussed in more detail. Since basic information by appliance group is described in Chapter 2, this discussion focuses particularly on where existing options could be improved or extended. Each one alone may bring about transformation of a segment of the market.

1.18.1 Test protocols

The ability to measure efficiency is crucial, common to all policy and depends upon international agreement on a test procedure. From a strategic perspective, the process by which test protocols are developed is less than optimal. At present in the EU, manufacturers are almost solely responsible for test protocols. A process of defining test procedures is needed that is faster, and includes the concerns of more stakeholders, for instance, consumer organisations and energy agencies. Test procedures for all appliance groups need updating to be more in line with actual consumer behaviour. In addition, the tolerances of the test procedures need to be reduced in order to make the tests more reproducible and less open to challenge or interpretation.

1.18.2 Energy Labels

Energy Labels can serve several purposes. They can act as a source of information for the consumer, providing a means of comparing appliances on the basis of energy consumption. Labels also provide a means of giving a long-term signal to the manufacturers of the direction in which the market needs to go. They can act as a market pull towards the most efficient technologies.

There is already an EU Framework Directive on mandatory appliance labelling and this has resulted in labels for a number of appliance groups (see Chapter 2). There are two crucial elements:

- the Commission's ability to give CEN and CENELEC a mandate to draw up a test procedure and to allocate Commission funds for the purpose;
- the regulatory committee which is empowered to make decisions without reference back to another authority such as the Council of Ministers.

The labelling procedures for those appliances where agreement is relatively easy will be completed by around the turn of the century. Labelling of other appliances is more complex and will depend on the extent to which the difficult issues in test protocols are tackled effectively.

1.18.3 Using the EU Energy Label for information and advice

As noted in DECADE (1995), there is a big difference between information and advice. Information is generalised, whereas advice is personal, targeted and relevant, making it more likely that the consumer will respond. Energy Labels provide information about the energy consumption of appliances, a necessary although not a sufficient part of getting the consumer to act on that information. Advice is clearly best given by trained retail staff, but training is lacking in the UK.

Article 7 of the Framework Directive on labels requires that "Member States shall take all necessary measures to ensure that....the introduction of the system of labels and fiches concerning energy consumption is accompanied by educational and promotional information campaigns aimed at encouraging more responsible use of energy by private consumers" (OJ No L 279, 13.10.92). The type and extent of support are not explicit. International comparison of these information campaigns is sparse, however DECADE is currently looking at the provision during the first three years of the Energy Label on cold appliances throughout the EU. There is clear opportunity here for further work, including: Best Practice programmes on use of the Energy Label; more explicit Guidance Notes; and even further Directives on how the label should be supported, including a requirement for retailers to explain the information. This would be entirely within the spirit of the original Directive; that consumers should have equal access to information on running cost as they have to information on price. One system that provides this information quickly and graphically is the ELDA database (see Appendix A) which could be made available to consumers either at the point of sale through retail outlets, or through advice centres like the Local Energy Advice Centres (LEACs).

1.18.4 Technology procurement

The aim of procurement is to advance a specific technology, or to optimise existing technologies to achieve a specified level of energy consumption. In several appliance groups, early procurement is crucial to the later introduction of minimum standards. A separate report by DECADE to the Department of the Environment, Transport and the Regions (DETR) examined the particular role and areas of interest for procurement in the UK (Hinnells *et al*, unpublished).

The responsibility for investing in procurement programmes depends on the stage of the technology. A brand new technology that is not yet on any market, may be best addressed by a co-ordinated EU-wide programme. Technology that has been developed and marketed successfully in one country, but is not present in another is best developed by a national programme. At present, no-one has ownership of, or the resources for, such a brief in the UK, nor at EU level. Whilst there is work at the IEA level, programmes are largely national programmes serving national interests, with little focus on common strategic needs.

The cost of such programmes is difficult to assess. While the initial cost can appear large, the economics are more favourable if the indirect and 'ripple' effects are taken into account. While other policies such as standards and labels appear to be far cheaper, these depend critically on procurement programmes if market transformation is to be achieved. Hence, an element of the procurement costs could be assigned to these dependent policies.

1.18.5 Rebates and financial incentives

The role of rebates is to encourage sales of the most efficient appliances: to provide a positive 'pull' effect to offset the 'push' from minimum standards.

A rebate overcomes any potential price differential between efficient and inefficient equipment, and the relationship between price and efficiency is crucial to whether rebates are appropriate to a particular end-use. For cold appliances, there is little relationship between price and efficiency. Additional price for an 'A' was often coincident with, and explained by, high value brand name, large size, and alternative refrigerant system (DECADE, 1997). For wet appliances, there is a strong relationship between brand and price, and between spin speed and price, and a weak relationship between efficiency and price. Rebates on more efficient appliances may therefore be subsidising other aspects of the appliance rather than efficiency and therefore effectively wasted in terms of encouraging efficiency. However, for lighting, the most efficient equipment (CFLs) is clearly more expensive, and a rebate is an appropriate instrument. Rebates are most likely to be taken up by better-off households who can afford the residual extra price.

An alternative approach is to target particular groups, for example where reducing poverty and reducing environmental impact are coincident, or where water savings and energy savings are coincident. In both of these examples there are dual benefits. With low-income households, the rebate may have to be given through replacing equipment still in the home, as many low-income families would normally purchase second-hand, not new, equipment. A key example of targeting rebates to reduce poverty is in cold appliances. One quarter of all annual cold appliance purchases are second-hand, and are older and less well maintained, representing a low capital-cost, high running-cost purchase for poorer households. There are as many as 6 million old and poorly maintained cold appliances in 8 million low-income households (DECADE, 1997). If these appliances were replaced with best new equipment, rather than inefficient second-hand machines, substantial benefits would accrue to the household, and to manufacturers who would increase sales to include groups who would not normally buy a new appliance. However, while middle income households need only a marginal incentive to switch from new average to new best models, low-income households may only be able to switch from second-hand to best new technology if the whole of the price difference is provided for them.

The cost effectiveness of rebates is difficult to assess relative to other policies. Every £25 spent on a rebate can only influence one purchase, whereas £25 spent on retailer training and point-of sale systems such as ELDA could influence many purchases. The problem is that from an accounting perspective it is harder to measure the effect of good retailer advice, whereas for every rebate given, a certain number of kWh is normally assumed to have been saved. In addition, it would be appropriate to count some of the cost of rebates as the cost of policies for which they pave the way (eg efficiency standards).

1.18.6 Differential levels of Value Added Tax

Varying the rate of VAT on purchase price is an alternative to a rebate programme for diffusing innovation.

- it is not geographically or temporally as limited as a one-off rebate programme. While the effect of a rebate programme may be limited to increasing sales of efficient models which are already available rather than encouraging the design of new models, the effect of a change in VAT is more likely to encourage redesign;
- VAT may have lower programme costs since it is already collected by shops through computerised tills. Changing systems will incur some cost, but this will be substantially lower than the cost of administratively intensive rebate programmes where programme costs add around 30% to the direct costs of the rebate (EST, 1995).

However, a rebate programme has the advantage that it can be socially targeted whereas a VAT reduction cannot. Indeed, reduced VAT would only benefit those who buy new appliances, and this would tend to exclude lower-income households.

Variable rates of tax based on efficiency may be timely. The Royal Commission on Environmental Pollution, in its 18th report, recommended graduated Vehicle Excise Duty for motor vehicles (RCEP, 1994 paragraph 8.49) and there are strong hints that the concept of varying tax based on car efficiency is under consideration by the Treasury. In addition, a Private Members' Bill has proposed reduced VAT for energy-saving materials. In this context, the opportunity exists to vary VAT for efficient appliances. However, there may be political obstacles to this proposal. Rates of VAT are set within a legal framework agreed between the Member States of the European Union. Reduced rates of VAT are allowed only for goods and services listed in Annex H of the Sixth VAT Directive (EEC 77/388). However, the list of goods and services eligible for a reduced rate of VAT is expected to be reviewed as part of the programme for a common VAT system for the EU. There remains the potential to discuss variable rates of VAT, across the EU, based on an EU label and therefore more easily defined in legal terms within revisions to the directive. Variable VAT could be implemented in two main ways, either:

- allowing only a small percentage of products (eg A labelled appliances) to qualify for the minimum level of 5%; or
- graduating VAT with efficiency category, perhaps so that the net effect of the changes was revenue neutral.

1.18.7 Creative financing schemes

At the present time in the UK it is not possible to buy equipment and pay for it through the electricity bill (the system was outlawed because consumers were being disconnected from supply for not paying for equipment, though it does happen elsewhere). These schemes have greatest applicability to lighting. CFLs are relatively low cost (compared to refrigerators), with big enough savings to actually see the payback on the electricity bill. There are several ways of operating such a scheme: one way would be to deal directly with a single manufacturer. The resulting economies of scale mean a good price could be negotiated which could then be passed onto the consumer purchasing bulbs by mail order through the utility. Alternatively, a voucher, redeemable in certain stores, could be included with the bill. Consumers would then be able to look at bulbs before they buy them, the voucher being paid off through the electricity bill. These methods appear to encourage people to buy more CFLs than they would otherwise buy if paying directly (Brond, 1991; Willerstrom, 1995).

1.18.8 Voluntary agreements

The European Commission has defined the following criteria for accepting a voluntary approach over a mandatory approach (laid down, for example, in early drafts of the Directive on mandatory standards for cold appliances).

- manufacturers taking part should represent 80-90% of the market, partly to avoid the problem that some manufacturers could avoid the cost of compliance and thus potentially gain a price advantage, and partly to ensure that agreed savings are in fact achieved;
- agreements should include quantified efficiency improvements within a specified timetable, phased to allow checking of results at intermediate steps;
- there must be an efficient and independent monitoring mechanism;
- there must be significant energy savings beyond 'business as usual'.

There are several barriers to improved efficiency: knowledge, institutional, economic and technical. In the industrial sector in the Netherlands, voluntary agreements with manufacturers and commerce have successfully overcome knowledge and institutional barriers, but are not able to address either economic or technical barriers (Korevaar *et al*, 1997).

The following concerns have been expressed about voluntary agreements for goods sold to the domestic sector:

- improvements in efficiency which can be obtained at zero cost will be accessed, but industry is unlikely to agree with efficiency improvements which entail increased purchase without a clear legal obligation to do so, as it may put companies which comply at a price disadvantage compared to non-complying companies;
- voluntary agreements concentrate on what is achievable in the short term and thus put off discussion of what might be the long-term target (eg reaching the least life cycle cost). This increases the uncertainty of improvements over the longer term.

This is more than mere semantics about whether a series of small short-term agreements adds up to the same savings as a large, long-term target. Appliance manufacturers find it easier initially to accept the shorter term smaller target, but may put off strategic decisions about changes in tooling and technology that might take 5 years to bear fruit. In addition, there must always be doubt about whether a new agreement will be reached: the German 1980 voluntary agreement for fridges, freezers, washing machines, dishwashers and ovens was not renewed in 1988 because manufacturers were concerned that further improvements would imply an increase in purchase cost, putting manufacturers who complied at a disadvantage in the market (Hass, 1992).

1.18.9 Mandatory energy efficiency standards

Standards could be based on a variety of factors, or set at a variety of levels:

- statistical, to make the current average on the market a minimum (this would encourage optimisation of existing technologies and is easy, proven, and could be costed);
- technical, to make the best on the current market a minimum (which is at least technically feasible, but which has unknown cost implications);
- cost effective, aiming at minimum life cycle cost (purchase cost plus running costs over the life of the appliance are minimised); and
- cost effective, aiming at no overall increase in life cycle cost (so that so that any increase in first cost is paid back from energy savings within the lifetime of the appliance).

The first two levels above may be seen as short term standards, whereas the latter two levels will need procurement and rebate programmes to develop markets for new technologies. Long-term objectives, such as enshrining minimum life cycle costs in legislation, are crucial to reducing uncertainty for manufacturers, and minimum life cycle cost standards have been assumed to be the long-term target in Scenario 1 (see Chapter 4). Cost effective options must be kept under review, and as new technology becomes more established, the range of options considered to be cost effective is likely to increase.

In terms of legislation, standards are best introduced at the level of the single market. Attempts at implementing standards at the national level have, to date, been seen as a barrier to trade in Europe.

At present, standards have to pass through the Council, Commission, and Parliament on a case by case basis. The only standard that has been agreed is on the cold appliances, and this is weak compared to original proposals. Apart from a statement from the last, outgoing, Commission that they would prefer to see voluntary rather than mandatory arrangements, there is no clear decision-making framework within which to judge proposals. This situation is not likely to lead to the savings that would be necessary to reach the proposed target of 15% reduction in CO_2 by 2010.

One possible approach is a Framework Directive. This is enabling legislation and would demonstrate political agreement on the principles within which additional regulation may proceed on a technical and economic basis, without the need to refer back to the Council of Energy Ministers or the Commission, thus avoiding further political debate and delay. The precedent comes from the current EC Framework

Directive on energy labelling (extending the power of the regulatory committee to mandatory efficiency standards, as well as Energy Labels). An earlier precedent is the USA National Appliance Energy Conservation Act (NAECA, 1989). The minimum time needed to get a directive through the Council, Commission and Parliament is 18 months, and the earliest date for tabling a draft directive would be the beginning of the British Presidency in January 1998. Like its precedents, a draft directive could:

- outline an overall target for appliance standards based on an objective such as minimum life cycle cost;
- include a timetable for particular appliances up to 2007;
- delegate power to agree levels and timetables to a regulatory committee.

Such legislation is assumed to be the basis of Scenario 1 in Chapter 4. Clearly, if individual product directives continued to be dealt with on a case-by-case basis, or if levels were less stringent or took longer to introduce (eg if revisions to test procedures could not be speeded up substantially), the timetable would slip and savings would be lower.

TACTICS FOR APPLIANCE GROUPS

Having discussed the variety of instruments available, and how, in the future, these instruments might be developed under a market transformation strategy, this chapter will now explore how these policy options can be used in combination for particular appliance groups. The two most important appliance groups are cold and lighting since they form 60% of the ETP.

1.18.10 Cold appliances

In terms of technical development for the cold appliances, market transformation might aim to promote:

- sales of the most efficient products through labels and retailer education;
- minor innovation, such as more efficient frost-free, better door seals, thicker insulation and better compressor sizing, through a first round of efficiency standards;
- new innovation such as vacuum panels or gas panels through procurement;
- once established, increased penetration of vacuum panels through rebates; and
- finally, full market penetration of vacuum panels through efficiency standards.

Energy Labels exist and minimum standards will come into effect in September 1999, as included in the Reference Case (Chapter 2). *Transforming the UK Cold Market* (DECADE, 1997) demonstrated that, even under Best Case conditions, minimum standards, effective as they are at lowering energy consumption, will only access 23% of the total savings that could be achieved by 2020 under ETP (Chapter 2).

- Education, both of retail staff and consumers, would complement labelling. There has been limited promotion of the EU Energy Label during the first two years and no national programme to alert retailers to the importance of energy efficiency for their customers. DECADE (1997) demonstrated that two consumer groups (profiled as ‘Young Aspirants’ and ‘Strugglers’) did not see, understand or use the label and less than a third of these groups bought an efficient machine. These groups could be the target of future campaigns and policies.

Introducing vacuum panels to market is crucial to accessing ETP (Chapter 2). A key conclusion of DECADE’s study of vacuum panel technology and the role of procurement (Hinnells *et al*, unpublished) is that it is necessary to develop the innovation in two phases. At present, insulation blowing agents and assembly methods are common elements across all products. Initially, vacuum panels can be incorporated into the existing foamed cabinet which remains the major structural component (a ‘drop-in’ innovation). As the cost of panels becomes both clearer and lower, a single integrated panel shell can be developed during a second round of innovation.

An existing EST rebate scheme for low-income households provides a new refrigerator to those households in receipt of a means-tested benefit if they have an old appliance that is defective but still working. The cost to the household is £25 and enables them to reduce their annual electricity costs by about £30. A substantial expansion of this scheme could get the new technology of vacuum panels into 8 million low-income households with benefits in terms of reduced fuel poverty, improved electrical safety, better food storage, reduced emissions and an increased market for manufacturers. However, it is clear from this scheme and past evidence from HEES, that low-income households have to receive these benefits at nil cost, if the scheme is to include the poorest households.

Once these technologies have been widely demonstrated, they can be the subject of successive rounds of mandatory efficiency standards.

1.18.11 Wet appliances

The various wet appliances are functionally similar and are treated as a single appliance group. However, the range of technologies of each are at different stages of evolution, therefore each end-use requires a separate policy approach.

Washing machines - the EU Energy Label and a voluntary agreement thus far agreed will result in little more than removal of a few inefficient designs. The best technologies will still not be widespread. The ETP level described in Chapter 2 is 0.17 kWh/kg of load in a 5 kg machine, on a 60°C wash. This level has been reached by machines already on the market, but for the whole market to reach this level a further round of minimum efficiency standards may be necessary. Relatively new technologies such as tubless drums, ultrasound and bubblewash appear to make little additional savings at high extra cost. There is little to be gained through public support for them, although this may need reviewing in around 5 years.

Tumble dryers - the EU Energy Label is not supported by any voluntary or mandatory agreement. At the end of 1996, the IEA initiated a programme to introduce a super-efficient dryer - most likely to be achieved with the aid of a heat pump. Although not a typical procurement activity (since there is not a single buyer or group of buyers) it should promote international industry participation on a scale that would be difficult to achieve on the national level. The winner of the competition would be the first electrical dryer in the EU Energy Label class A on the market. Such a machine may provide the technical basis for long-term efficiency standards. An alternative way (and according to analysis by ECU and ETSU for EST, a more effective way) of reducing running costs and CO_2 emissions is through gas fired tumble dryers, described in Chapter 6.

Dishwashers - the EU Energy Label for dishwashers is to be introduced on 1st January 1999. The dishwasher market is relatively active in terms of improvement, even before any policy intervention, but such improvements are based on optimising existing technologies rather than developing new technologies. Efficiency standards will be needed to reach the ETP level. There may be technologies, such as ultrasound, which are not included in the current evaluation of ETP since they are not yet cost effective, that could be stimulated as longer term projects.

1.18.12 Cooking appliances

There are no existing policies to encourage improvements in efficiency. The European Commission has announced a study of gas and electric ovens for the whole of the EU, to start early in 1998.

Electric ovens -

- procurement could facilitate the entry of new designs (50% more efficient than the current average) onto the market;

- labels covering the entire range of efficiency, coupled with short-term standards to eliminate inefficient models, could improve efficiency by 10%-15%, based on fan assisted ovens and better thermal design with fewer heat bridges; and,
- long term standards based on procurement could achieve reductions of 50%.

Hobs - there are two key issues: first, the lack of reproducible and agreed test procedures on hobs is a major obstacle. Secondly, manufacturers and marketers of hobs may not have the electronics design and manufacturing skills necessary to produce induction hobs. Bringing the traditional manufacturer and the new technology together is not a standard R&D or procurement activity, though there may be a significant group of buyers who could be brought together to lever a significant market share for a procurement project. Following on from this and assuming a test procedure, an Energy Label could be developed and then used as the basis for rebates to increase market penetration.

Minor cooking appliances - heat loss from a number of small appliances where temperatures are very high or are maintained over a long period (eg kettles, coffee makers, deep fat fryers and slow cookers) could be reduced from improved insulation. Procurement of better-insulated designs is a priority. Given the small amount of energy they account for individually, labelling is unlikely to be very effective. In the longer term, the procurement programmes could be used as the threshold for mandatory standards, with a maximum allowable heat loss during a typical duty cycle. While heat loss from kettles could be reduced through improving insulation, the best option is fuel switching, ie using a kettle on a gas hob. This could reduce emissions from 120 to 14 kg CO_2 per year, with cost reductions in a similar ratio. In microwaves, standby consumption could be reduced from 4 W to 1 W, achieved through voluntary agreements similar to those implemented for home entertainment equipment.

1.18.13 Lighting

Lighting, as stated in Chapter 2, contributes 40% of the potential savings (the difference between RC and ETP) making this sector the most important component of the scenarios. With incandescent bulbs, there are several purchases each year, making the potential effects of intervention rapid.

Rebates are an appropriate means to encourage consolidation of a new technology, and have already been used in EST programmes for bulbs. A new scheme in autumn 1997 will introduce rebates on dedicated fittings. In addition, the International Energy Agency (IEA) is running a procurement programme, which will be implemented in the UK, for a bulb of intermediate efficacy between conventional incandescent bulbs and CFLs. These programmes are not expected significantly to enhance the efficiency of the lighting market, merely to provide a useful nudge. Transformation of the lighting market will require substantial new programmes.

Market transformation for lighting essentially means replacing the dominant technology (incandescent bulbs) with CFLs with a ballast unit integral to the bulb in the short term, followed, in the longer term, by dedicated CFL fittings with an integral ballast. Fittings dedicated to CFLs can ensure:

- optimal light distribution and performance from the bulbs, producing a better quality of light;
- that the consumer will not revert back to incandescent bulbs when the CFL needs replacing; and,
- that replacement bulbs are cheaper than CFLs with ballasts and therefore more cost effective.

As a consequence of this scale of change, lighting is the hardest of all appliance groups in terms of describing and accessing the ETP. There are several difficult issues to resolve:

- the price of CFLs has already fallen over the past few years and is likely to fall further in the future;

- cost effectiveness is dependent on usage: the percentage reduction in Watts by a CFL will be the same wherever the bulb is put, but savings will accrue over very different time periods. A CFL in one of the four main fittings will last about four years, whereas one used infrequently (say, the spare room) could last 30 years or more.

There are additional structural factors in the lighting industry:

- achieving the ETP level would require a massive increase in CFL sales over a very short space of time, with a corresponding decline in future sales (but not revenue) due to the longer life of CFLs. Therefore, an important dimension in the debate on policy is what is perceived as an acceptable profile for the turnover and profit of the manufacturers;
- the light bulb market is dominated by five major manufacturers in Europe, whereas light fittings are made by a myriad of manufacturers. Working with light bulb manufacturers would be relatively easy, but working with the fitting manufacturers as a totality represents an impossible task. Historically, there is no evidence of co-operation between these two industries.

Thus, there is a sequence of technologies to work through the market if the maximum savings are to be achieved. Effectively, two or three markets are being transformed in parallel. Stages in transformation include:

- incandescent bulb sales decline while other, fairly efficient bulbs, such as fluorescent tubes and halogens, remain a small portion of the market for the foreseeable future;
- CFLs with magnetic ballasts are gradually phased out;
- electronic CFLs become the standard technology, increasing market share first through rebates and later through agreements with manufacturers;
- CFLs with electronic ballasts are gradually phased out, removing all integral ballast CFLs from the market, leaving only those bulbs suitable for dedicated fittings;
- the proportion of dedicated fittings increases, first through rebates, and later through changes to building regulations;

Eventually the dominant form of lighting is a CFL in a dedicated fitting. The costs of this are substantial when it is recognised that there are about 13 fittings and 17 bulbs in each household, amounting to over 300 million light fittings.

1.18.14 TVs, VCRs and other brown goods

Brown goods are fundamentally different from white goods. They are electronic rather than electro-mechanical and have much faster turnover of both products and technologies. There is probably as great a potential from encouraging innovation in the right direction (low energy screens) as there is from discouraging development of technologies in the wrong direction (regulation of standby losses). There are three main areas for possible policy focus:

- standby in TVs and videos;
- on-mode in TVs (90% of consumption in televisions); and
- standby consumption, or more properly standing transformer loss, in many small appliances such as answering machines and audio equipment (DECADE, 1995).

Standby consumption in the passive mode in TVs and videos has already been addressed by the voluntary agreement (Chapter 2). No further policy is deemed necessary, beyond consumer education (Chapter 5).

There is some limited potential to optimise existing screen technologies through efficiency standards. A more important issue is the development of future screen technologies, concerning which current understanding is poor. There are problems with defining service: consumption is proportional to screen size, sound level and quality. Surround sound is now an important market issue. There are also problems in estimating the potential for and cost of reductions in screen power consumption. These factors, along with rapidly changing technology in this appliance, mean that manufacturers need to be involved (Lane and Huenges Wajer, 1997). A test procedure and label based on typical operating cycles (including on- and standby modes in proportion) needs to be developed. Procurement could be useful to stimulate LCD low energy screens or flat screens. In the long term, once a new more efficient technology becomes established, voluntary agreements or standards are an option to make their use widespread.

Goods such as power tools and telephones that have been essentially electro-mechanical up to now, are becoming electronic in nature as power management, storage and recharging, or information storage and retrieval become key value-enhancing features. The need to supply small amounts of power continuously has created an explosion in inefficient power transformers. Some regulatory framework, indication of best design practice or procurement of efficient power management systems could play an important role in preventing future growth in standby consumption.

1.19 OPTIMISING A STRATEGY

The above sections have defined some of the tactical policy options (eg procurement and standards), and how these might be applied in combination to appliance groups as part of a strategy (eg lighting). A number of points can be drawn out of the specific illustrations above to develop a set of general 'decision-rules' for drawing up a strategy in any given set of circumstances.

Assembling these tactical components into an overall market transformation strategy requires recognition of several important principles. Most notably, policy initiatives should be designed to be complementary, should be in stages to make a progressive and logical transition, and should avoid conflicting policy signals and disruptive changes.

1.19.1 Developing the links

Incentive and regulatory programmes are not alternatives, although they have often been presented as such in the past. Instead they should be seen as having a complementary effect:

- labels (or at least some 'line in the sand' about what is efficient and what is not) are a necessary base for several policies including rebates and consumer advice;
- the impact of labels is strongly influenced by the knowledge of the retail staff. Consumers are influenced by sales assistants, particularly with infrequent purchases, such as white goods that are often bought in 'distress' because the old appliance has failed. If the retail chain has not trained their staff and discussed the importance of energy efficiency with them, the impact of the label will be much reduced;
- the effect of a one-off minimum efficiency standard could be limited if manufacturers do not have a continuing incentive to improve their products as a result of, for instance, revisions to the labels (introducing a new level for A rating) and the expectation of further targets for efficiency standards. With cold appliances (DECADE, 1997), these continuing incentives were what differentiated the 'Best Case' from the 'Worst Case'.

In terms of policy design, there are further interconnections between the different actions. For example:

- technology procurement programmes could be used in the short term to define the upper boundary of label categories, so that only products from or equal to the procurement exercise achieve an A rating;
- label categories could be used to set clear definitions of mandatory efficiency standards (eg ABC survive);

- in the longer term, procurement programmes set the target for efficiency standards. The USA 'golden carrot' refrigerator programme provided a useful basis for discussion about what was technically and economically feasible;
- ideally, implementation of standards should be carried out in conjunction with revisions to the Energy Label since these two policies are heavily interlinked.

In addition to having differing roles, policy instruments can be shaped at various political levels, including Member State or EU level or through the IEA. For example:

- the extent of financial support (eg through rebates or through advertising and information) are national political decisions. Changes to the level of VAT on appliances, within certain limits, are properly introduced by primary legislation in each country;
- EU labels and minimum standards require the support of Member States, as well as separate implementing legislation in Member States (on issues such as responsibility for verification, enforcement procedure and penalties for non-compliance);
- the IEA is devising a series of initiatives on technology procurement. Member countries inside and outside the EU can opt into these programmes.

It is important for optimising cost effectiveness that these options are developed and assessed together. A lack of co-ordination between policy-makers working on apparently separate elements of market transformation could lead to, say, rebates and efficiency standards trying to make the same saving twice. It is clearly important to spend public money in the most cost effective way, and integrate these policies. The most appropriate combination of policies will achieve a synergetic effect and produce greater savings at lower costs than the sum of the individual initiatives. A particular example of this is the balance between market building and market consolidation.

1.19.2 The balance between exploration, consolidation and maturity

Exploration, consolidation and maturity are three stages in the development of an innovation, taken from innovation theory (as discussed at the beginning of this chapter). It was argued that these stages link to procurement, rebates and standards. What size should each programme be in terms of time and money, and in terms of gaining market share? How can programmes be designed to fit together? These are important questions, the answers to which are still unknown.

Exploration is the process of developing markets where none exist, where there are technical or economic barriers, or a high level of risk for one manufacturer, or where there is no clear market for a new product. Procurement is designed to address some of these issues. A successful programme may result in a market share of around 1-2%, but the size of the programme will vary from one product area to another, and may need to be larger if:

- the risk associated with a new product is higher: for example, because it is not clear that the new product will continue to have a market after the procurement programme has finished;
- the levels of uncertainty and risk are higher because the product is so new;
- the market is less well adapted to innovation and change, and does not have the product development capability (eg some manufacturers have an innovation-led culture, and others are still metal box manufacturers); or
- the capital costs are higher (eg the capital investment in changing metal forming tools is higher than changing plastic moulding tools, or changing bought-in components).

The security of the market may depend, for example, on the procurement programme being seen not as a one-off initiative but as part of a process (eg the technology will be the only level that would qualify for an 'A' on the Energy Label), or on a clear perception that the procurement will influence long term efficiency standards, and preferably on a combination of these things.

Government support for research and development or for technology procurement is relatively inexpensive for the taxpayer, but results in few direct savings. It is in consolidating and maturing markets that greatest savings are made through replication, but rebates are clearly much more expensive than programmes such as standards. So what is the appropriate balance between the two mechanisms? This report has assumed that rebates are needed to get a new product up to 20% market share, and that beyond this point standards can assure take-up of innovative technologies. Again, this area of policy is not a certain science and the development of the market will need to be studied to assess whether 20% is indeed the appropriate level to aim for. For example, if equity is an important consideration, rebates may be needed to increase market share beyond this point, given that one-third of all households are on some form of means-tested benefit. Clearly this balance will affect the real cost of accessing efficiency improvements. Many of the barriers to the increased take-up of innovative technologies are structural barriers and start up costs such as:

- **A change in the nature of a business:** Several transformations will require building of new partnerships between firms, especially suppliers: between manufacturers of light bulbs and fittings (so that fitting manufacturers gear up for CFL dedicated fittings); between the chemical giants who produce insulation materials (such as ICI, DuPont, Bayer) and refrigeration manufacturers; between washing machine manufacturers and detergent manufacturers (for low temperature detergents), and between cooker manufacturers and electronics manufacturers in order to design and build induction hobs. There are many second level barriers to this: a need to share risk across an industry sector rather than by an individual manufacturer, which conflicts with a resistance to sharing sensitive market information; a need to understand an unfamiliar business (eg adapting an understanding of fast moving consumer goods to an understanding of consumer durables); and a perception that such activity is peripheral and not 'core business'.
- **High product development, marketing and tooling costs:** new products are inevitably more expensive to produce since there will be fixed costs associated with 'newness' that need to be amortised, including product development, marketing and tooling costs.
- **Lack of economies of scale**: new products are made in lower volumes, and may be made using batch production rather than full mass production methods. A differential in price, and therefore penetration, may be due to manufacturing differences and not to a true difference in the cost of an efficient versus an inefficient product. The solution is not only to ensure that there are a number of manufacturers, but also that those manufacturers are able to make economies of scale in production.
- **Greater risk from larger innovations:** if an existing production facility can be 'tweaked' to produce more efficient products through minor innovation (eg thicker insulation), there is little interruption to production, and a relatively low level of commercial risk (both from production changes and potential product failures). If, through major innovation (eg vacuum panels), production and assembly methods need to change, then existing production facilities would need either to be interrupted, or discontinued and replaced, which inevitably imposes a large one-off cost of change.
- **Lack of competition**: energy efficient products or technologies may be protected by patent, or may be proprietary (a particular company having a monopoly) or one company may have a dominant position in terms of market share. Whilst a procurement programme may demonstrate a market for a new technology or product, it will do little to create competition.
- **Low volume implies high margin:** this is in many ways a consequence of the above factors. Low cost, high production volume items are likely to be sold with a low profit margin (around a factor of 2-3), whilst products seen as high value, high efficiency, low production volume items are likely to carry a high manufacturer and retailer mark-up (around a factor of 4-5). Thus cost and profits on different products are structured differently.

In terms of addressing these issues, encouragement, discussion, hand-holding, and (if necessary) financial support may be the best approach. Regulation cannot encourage firms into a closer partnership. The balance between approaches will therefore be different for each appliance group given the nature of competition and the nature of change in each market.

Cost is an issue common to all markets and one of overriding interest in terms of the balance between approaches. From a theoretical perspective, the future price to consumers of additional efficiency is very difficult to estimate. The traditional approach has been an engineering analysis to identify the increase in purchase price associated with improvements in efficiency. To date, technical analyses of costs and benefits undertaken as part of the SAVE programme (by GEA of cold and wet appliances; by NOVEM of TVs and VCRs; and by EVA of water heaters) have not taken into account the fact that many of the additional costs identified are associated with either structural barriers or start-up costs, and are not typical of mature markets. Short-term costs, identified by GEA, tend therefore substantially to over-estimate the long-term future cost of additional efficiency (Hinnells and McMahon, 1997; Krause *et al*, 1995). Once such barriers have been overcome, the future cost of efficiency may be close to zero. In the USA, Greening (1996) analysed two rounds of refrigerator standards using a dataset from retailers representing 2-3% of refrigerator sales and actual prices paid before and after standards. The 1989 standards required a 10% improvement, and 1993 required a 30% improvement. Once increases in size are accounted for, the average annual price increase was 1.25%. These results are consistent with a previously observed annual increase in current refrigerator prices of 1.1% between 1948 and 1983. In general, the units meeting the 1990 standard levels had either a similar level or an improved level of features, as manufacturers took the opportunity of redesign to update their product range.

This is an important conclusion, since analysis prior to standards (US DoE, 1989) had predicted that there *was* likely to be a cost penalty for improved efficiency. Similar evidence in Europe is not yet available, since the first set of standards will not be implemented until 1999. However, price can be monitored through the GfK dataset collected by ECU. First evidence suggests that there is little link between price and efficiency, therefore increasing efficiency will not increase price as assumed by GEA (DECADE 1997). Put simply, for the example of a fridge-freezer, there is considerable certainty about the 300 kWh that can be saved, because it can be measured under test conditions, and there is therefore considerable certainty about the £270 that can be saved over the life cycle. However, there is uncertainty about the £140 that it might cost to access that improvement in efficiency, and the actual cost in future may be closer to zero. These issues are discussed in more detail in a separate ECU paper (Hinnells and McMahon, 1997).

However, importantly for this discussion, Greening also found a doubling of capital investment over the period. In other words, manufacturers may have found efficiency improvements in production while improving energy efficiency in products. This period of change indicates the need to support manufacturers in terms of procurement and rebates to cover start-up costs, in order to take advantage through efficiency standards later. In practice, rebates may have to continue for the period for which industry traditionally amortises its product start-up costs, typically 3-4 years.

At the end of a period of support through rebates, it is reasonable to assume that many of the structural barriers above will have been addressed to a greater or lesser extent. Analysis at that point could confirm the level of efficiency at which, from a societal perspective, a technology or product has the optimum net cost-benefits. Defining that threshold both in terms of efficiency level and timing is difficult, and will vary for different product groups.

The period allowed between agreement on standards and the implementation of standards should not be faster than normal rates of product redesign, in order to avoid additional costs for manufacturers. For cold appliances, DECADE (1997) found that 50% of products are replaced in two years, and 75% in three years. Four years is thus a reasonable period of notification. At an optimum level (in terms of accessing the greatest savings, in the shortest possible time, at the least cost to stakeholders) it may therefore take 7-8 years to proceed from completing a procurement programme through rebate schemes to implementing standards.

Having discussed how individual tactical elements can be combined in a strategy, and how that strategy can be optimised in terms of the balance between costs and timescales of individual programmes, it must be recognised that market transformation takes place in the context of much wider issues, and these are now discussed.

1.20 WIDER ISSUES

There are a number of different and competing selection criteria for deciding policy approach. The major issues include:

- certainty of energy and carbon dioxide savings;
- cost to various stakeholders;
- equity;
- political acceptability.

1.20.1 Certainty

In this context, certainty is used to mean clear parameters for decision-making for both Government and manufacturers (not numerical certainty in terms of modelling, which is dealt with in Chapter 2).

Given the forthcoming Climate Change negotiations in Kyoto, and the potential for agreements on targets which may be legally binding for the first time, certainty of CO_2 savings may become increasingly important. Clearly there are a number of important factors affecting energy consumption that are outside the control of policy, such as levels of ownership and usage and the level of service required or demanded by the consumer. This makes it impossible to truly ‘guarantee’ savings: the best that can be done is to devise policy combinations which increase the likelihood of making predicted savings.

Manufacturers, too, are increasingly placing a high priority on certainty in their decision-making framework. With regard to cold appliances, Owens Corning and ICI identify regulatory pressures as crucial in the mass production of Vacuum Insulated Panels (VIPs). Widespread adoption of the technology is unlikely without additional incentives, which could take the form of procurement, extension of the labelling categories or clear long-term signals regarding mandatory efficiency standards (Hinnells *et al*, unpublished). In this context, it is discouraging that cold appliances can qualify for the ‘A’ category on the Energy Label without needing to use VIPs. The USA refrigerator efficiency standards programme was frozen between 1995 and 1997 (but is now back on track), the EU standards were revised down from the targets defined by GEA, and long-term EU efficiency standards may well be voluntary. In this climate of uncertainty, investment in VIP production is not a good economic prospect, and manufacturers are tempted to rethink their strategy.

Another indication that manufacturers are placing a high priority on certainty comes from a recent SAVE study of electric water heaters. Responses by manufacturers to questionnaires indicated that they were concerned at the price advantage gained by non-compliant imports under voluntary rather than mandatory arrangements. Some manufacturers are increasingly seeing a level playing field and reduced uncertainty as lower cost alternatives.

What programmes are likely to improve certainty? Savings from even very exact regulatory policies, such as minimum standards, are still uncertain. For example, the likely effects of the minimum standards legislation for cold appliances on energy saving by 2020 in the UK were estimated at 18% under ‘Best Case’ conditions and as low as 2% under ‘Worst Case’ conditions (DECADE, 1997). Additional pressure to improve efficiency, such as revisions to the Energy Label in 2000, and discussions on a further round of efficiency standards under Article 8 of Directive 96/57/EC (CEC 1996b), were identified as being essential to promote Best rather than Worst Case conditions. Compared to mandatory standards, instruments which are based on voluntary action (whether this be voluntary agreements, rebates or labels) are even less certain. As was noted in Section 3.3.8, voluntary agreements tend to focus attention on what is achievable in the short term at little or no cost, at the expense of discussions about what is an appropriate long-term target. They tend to increase uncertainty in decision-making both for Government (since it is not clear whether targets will be met, nor which additional policies may be needed in each sector) and for manufacturers (since it is not clear whether a particular technology will have a market). Factors that increase certainty, both for government (over savings), and for manufacturers (over policy) include:

- policies introduced by regulation;
- integrated market transformation strategy - combination of policies; and
- a firm timetable for introduction of future policies - framework legislation.

1.20.2 Cost to stakeholders

Policies to introduce energy efficiency measures can be assessed in terms of the cost to manufacturers, the cost to the consumer, the cost to government, or the net cost to society. Concerns over the cost implications for manufacturers have previously been seen as overriding, whereas arguments over least life cycle cost to consumers had few advocates. It is becoming increasingly recognised that savings should accrue at the least net cost to all stakeholders, including consumers and governments, and not just manufacturers.

The net cost and benefits of improving energy efficiency depend on the mix of policy and this should be explicit in any market transformation strategy. Two of the major determinants are the speed with which technical change is required and the range of policy options available. Section 3.5.2 above discussed structural barriers and noted that innovative products carry higher development, tooling and marketing costs. On the other hand, economies of scale from increased production volume would reduce the cost of efficiency improvements. It follows that the actual cost of future efficiency improvements is not fixed. Previous attempts to identify cost curves for a particular end use have been rather inadequate, since they have failed to identify the policy measure that brings about such a saving (Hinnells & McMahon, 1997).

The cost of a unit of conserved energy will be higher to the taxpayer and consumer if there is no economy of scale in efficiency improvements, ie when efficiency standards are not implemented and programmes are limited to information, labelling programmes and voluntary agreements (Krause *et al* 1995).

1.20.3 Equity

There are several definitions of equity. One is that the same amount of money is spent on all households. Another is that savings are made from all households equally. Labels and standards benefit only those who currently buy new equipment, and not those purchasers who buy second-hand equipment, who are most likely to be low-income households. On their own, therefore, labels and standards benefit higher-income households more than they benefit low-income households. In the case of refrigeration appliances, some 25% of all sales are second-hand, and second-hand equipment is more likely to be old, inefficient or faulty. Indeed, there is a greater potential for saving in these households than in the average household.

There is a clear opportunity to target programmes encouraging the development of new technologies at low-income households. At the same time this would improve equity, make greater than average savings and increase the market for appliances to include low-income households, a sector which manufacturers have not yet been able to access. However, as was noted in Section 3.3.5, this will increase the cost of programmes. This is mainly because while middle-income households may need only a marginal incentive to switch from new average to new best models, low-income households may only be able to switch from second-hand to best new technology if the whole of the price difference is provided for them.

The EST cold appliance scheme and the HEES scheme for CFLs provide clear precedents for the direct replacement of old equipment in the homes of families on a means-tested benefit. However, the programmes discussed here for cold appliances and lighting retrofits are some two orders of magnitude larger. Other programmes could be similarly targeted. A clear market transformation strategy could therefore have equity as an explicit objective, and at the same time provide higher savings as well as benefits to manufacturers.

1.20.4 Political acceptability

To date there has been a preference for voluntary agreements rather than mandatory standards in Europe. This has been based on manufacturers' resistance to perceived increase in first cost. However, manufacturers are not unanimous at any one moment, and their position has evolved with time. Many now see as advantageous the reduced certainty and level playing field that regulation would bring. In addition, the potential cost savings for the consumer have been under-represented in discussions over standards. But perhaps most importantly, there has previously been little need for Europe-wide targets for efficiency. After Kyoto, if legally binding targets for CO_2 reduction are agreed, certainty of savings is likely to have considerable political importance.

In order to reach ETP levels at the least cost, framework legislation on efficiency standards is necessary. There is a need to set out a timetable with goals (eg least life cycle cost or minimum levels of emissions with no increase in life cycle costs over current levels) for individual appliances. Without such framework agreements, programmes are likely to be sub-optimal, with the risk that savings are made at a greater cost than necessary, or a lower level of savings obtained, or obtained more slowly.

1.21 CONCLUSIONS

This chapter has considered the many elements of market transformation, individually, and in combination, and in a wider context. In particular it has discussed,

- what is meant by market transformation, in particular that it is an integrated process (section 3.2);
- the policy instruments which are the components of a strategy (section 3.3);
- assembling a strategy given the special circumstances of each end use (eg lighting) and the main technologies within each end use (eg incandescent, halogen or compact fluorescent bulbs) (Section 3.4);
- optimising a strategy, in particular the crucial links between instruments, and the differing requirements of market consolidation and market maturity (section 3.5); and
- the wider context of market transformation, including issues such as certainty of energy savings, cost (especially cost to whom) and equity between income groups (section 3.6).

The key points in terms of programme design that need to be emphasised are:

1. Innovation, consolidation and maturity are very different stages in the development of a technology and need to be dealt with in different ways by policy. Innovation can be promoted by incentives or procurement. Market consolidation involves overcoming many sub-barriers and requires substantial financial support over 3-4 years. Market maturity can be encouraged through minimum standards.
2. The long term costs of mature markets have been overestimated because analysis has ignored the fact that the current additional price of efficiency (if any) may be due to existing structural barriers. If these are removed, the cost of efficiency may be close to zero.
3. The real costs of programmes are policy dependent. Much of the additional cost involves start-up costs which can be supported through procurement and rebates, while minimum efficiency standards access economies of scale, and may approach zero cost to consumers.

The key points in terms of wider issues that need to be emphasised are:

1. Certainty - important to government (in CO_2 terms), consumers (in cost terms) and manufacturers (in planning their business) - is increased by regulation, clear timescales, and policies used in combination.
2. Equity is not improved by standards and labels, and needs clearly targeted rebate programmes. Equipment may need to be provided at no cost to the householder.

3. Since manufacturers' perceptions have changed, CO_2 savings are more important than previously, and with full representation of consumers' interests, there may be a consensus for change where none has been acknowledged previously.

The tools and methods developed in this chapter provided the basis for constructing three illustrative scenarios involving different combinations of policies (Chapter 4). This chapter also provides a coherent framework for decision-making under other circumstances not envisaged here. It is, for example, just as applicable to motor vehicles and houses, or to industrial and commercial equipment, or to different economic and political circumstances.

CHAPTER 4: POLICY SCENARIOS

1.22 INTRODUCTION

This chapter brings together the preceding discussions of the Reference Case and Economic and Technical Potential (Chapter 2), the policy instruments for market transformation and the constraints and opportunities for each appliance group (Chapter 3). Three scenarios are described in detail to illustrate how different policies may be combined and how the general decision rules outlined in the last chapter can be implemented. If circumstances change, or if the policy emphasis is different, the tools presented in the previous chapter can be used to define alternative scenarios.

There are many ways of building scenarios (eg a target-based approach, aiming for 10, 20 or 30% carbon reductions). A common approach in scenario analysis is to examine policy criteria, and look at alternative combinations of high or low importance attached to each criterion. In Chapter 3, the main criteria were certainty of savings, cost to different stakeholders, equity, and political acceptability: one approach would be to look at different combinations of these. However, the most crucial criterion for assembling a strategy is the political support given to energy efficiency at the EU and UK levels. The effect of strong and weak actions at these levels have therefore been taken as the variations between scenarios (Figure 4.1), with the effect on secondary criteria (certainty, cost, equity) analysed for each scenario.

	EU	UK	
Scenario 1	strong	strong	**Strong political support for reducing carbon dioxide emissions** - procurement and rebate programmes at the national level requiring substantial capital and which are cost effective at the societal level, underpinned by EU-wide efficiency standards
Scenario 2	weak	strong	**A regulation-constrained Europe** - procurement and rebate programmes at the national level requiring substantial capital and which are cost effective at the societal level, and extension of EU voluntary agreements
Scenario 3	weak	weak	**The UK following a constrained Europe** - no additional national investment, extension of voluntary agreements restricted by lack of new technologies

Figure 1.22 EU and UK policy commitment in the 3 scenarios

The combination of a strong Europe and a weak UK has not been examined for three reasons: firstly, it is thought to be an unlikely scenario whilst a UK Government has a more demanding target for CO_2 reductions than the EU as a whole (20% rather than 15%); secondly, a strong EU programme is unlikely without strong leadership from some national governments; and thirdly, strong regulatory programmes depend on supportive measures to expand market share for more efficient technologies in the early years.

Most discussion is of Scenario 1 which makes the largest savings and requires the most detailed strategy.

1.23 SCENARIO 1 - AN EMPHASIS ON CARBON DIOXIDE SAVINGS

Given the Labour Government's manifesto commitment to reduce CO_2 by 20% by 2010, and assuming the EU agrees to a legally binding target of a 15% reduction in CO_2 at Kyoto in December 1997, there will be much interest in how these targets will be met. Of particular importance are common and co-ordinated policies, because many actions cannot be taken unilaterally.

Scenario 1 aims to access the ETP efficiency levels as quickly as is feasible (see Chapter 2 for a discussion of ETP). It provides the quickest and largest electricity, cost and CO_2 savings that could be made by domestic lights and appliances during the period up to 2010 without loss of service to the consumer. The complete package of measures across all appliance groups for this scenario is given in Tables 4.1a (for cold and wet appliances and lighting) & 4.1b (for ovens, hobs, brown goods, generic standby and generic heat loss). If all policies and programmes were implemented across all appliance groups without delay, 2.7 MtC could be saved at a cost of around £2.7 bn, but with a saving over the period of £10.4 bn, and a cost to benefit ratio of 1:3.9. These savings would be compromised if the programmes were weaker or introduced more slowly than outlined in Tables 4.1a & b.

The key elements of the strategy are:

- new technologies are introduced speedily to market through procurement, in order to provide the basis for longer-term standards;
- the market share of new technologies is expanded to at least 20% through rebates. The rebates in this scenario are assumed to be socially targeted, since equity is seen to be an issue of concern to the Government;
- at the same time, the first round of standards optimises existing technologies, within three years of agreements; and
- the second (and, in the case of refrigeration, third) round of standards aims to make widespread the new technology with a suitable interval for retooling (three to four years after agreement).

For this scenario to succeed with this timetable, action must be swift and co-ordinated. The required action, which might be initiated under the British Presidency of the European Council of Ministers from January 1998, comprises:

- a strategy defined and resources and responsibility allocated for procurement programmes in EU and UK;
- a strategy defined and resources and responsibility allocated for national programmes for investment in rebate or appliance replacement schemes; and
- framework legislation agreed at EU level, giving power to the regulatory committee to require changes to test procedures and to implement mandatory standards at regular intervals, following consultation with industry.

Under this scenario, with a framework directive on efficiency standards aimed at least life cycle cost, some 70-80% of the savings could be attributed directly or indirectly to standards. Other programmes would be crucial, however, in preparing the market for standards by introducing (or expanding the market share of) technologies which would then become embodied in a second or third round of standards. The elements of this scenario are now outlined in more detail, and serve as a guide to how the various policies fit together.

1.23.1 UK Programmes

Procurement

Procurement is a key area and has been analysed in more detail elsewhere (Hinnells *et al*, unpublished). As outlined in Chapter 3, procurement could be undertaken at the UK level, and could be co-ordinated with similar programmes elsewhere in Europe for best effect. Timescales for the various stages of procurement programmes and increasing market penetration have been assumed as follows.

- Year 1: building of a suitable buyer group, and product specification.
- Year 2: competition announced with minimum specification for tender bids from manufacturers, and an outline of the market and money on offer.
- Year 3: winner announced and product launched onto the market.

In addition to existing IEA programmes for infra-red light bulbs and gas tumble dryers, the following are key areas:

- two stage procurement for vacuum insulated panels (VIP) technology for cold appliances (single panels inserted initially and later integrated panels);
- ovens;
- induction hobs;
- light fittings with integral ballasts;
- low-consumption TVs screens.

In the longer term, other programmes such as innovative washing machines may prove viable options for procurement.

Investment

Investment is required to ensure that new technologies (typically from procurement programmes) achieve at least a 20% market share, and can then be used as the basis for the development of efficiency standards (for this reason, they should ideally to be the subject of parallel investment programmes elsewhere in the EU). Investment could be made either through:

- targeted programmes through a body such as the Energy Saving Trust (EST), or
- by lowering VAT on the more efficient appliances where a label exists, either at the UK level or across the EU.

There are important differences between rebates and variable VAT (Chapter 3).

- The advantages of VAT are: first, that if it were implemented at the EU level, the effects for manufacturers would be clear, and it would increase the likelihood of a change in the products offered across Europe, rather than merely a change in UK sales alone. Secondly, programme costs are likely to be substantially lower, in the longer term, than an administratively intensive rebate scheme.
- The advantages of rebates are firstly that they can be socially targeted (assuming that equity is important), and secondly that they can be implemented without reference to EU partners: varying the rate of VAT may conflict with EU attempts to harmonise indirect taxes.

For these reasons, rebates are assumed to be the basis of this scenario, but variable VAT remains an option. The UK costs are likely to be up to £2.7 billion over the years to 2010 (Section 4.7). All of the investment is cost effective at the societal level, as it has an economic payback within the life of the installed equipment, along with concomitant environmental benefits.

The EST, or another UK agency, will have responsibility for delivering the programmes. It is important that this experience is shared in Europe, to influence thinking on efficiency standards. Analysis, strategy, efficiency levels and timing for a single appliance group should be common to all sources of funding, otherwise the net result will be sub-optimal. Different countries may have different objectives, for example regarding equity.

1.23.2 EU actions: legislation on efficiency standards

This scenario assumes that a new EU Framework Directive on efficiency standards is agreed as soon as possible, that the first round of standards is based on a statistical analysis, and that subsequent standards aim at minimum life cycle cost. This would not guarantee the largest possible savings, but represents the optimum coincidence between economic and environmental objectives. The time scale is assumed to be as follows:

- Year 1: agreement between manufacturers and government as to the level of standards.
- Year 4: implementation of standards, with agreement on the second round of standards.
- Year 7: implementation of the second round of standards based on new technology.

Clearly, if individual product directives had to be dealt with on a case by case basis, or if the standards were less stringent or took longer to introduce (eg if revisions to test procedures could not be speeded up substantially), the timetable would slip and savings would be lower.

Table 4.1a Policy timetable for Scenario 1 (cold, wet and lighting appliances)

	Cold	**Wet**	**Lighting**
Current Status	• Labels implemented 1.1.95 • Standards agreed in 1996 (96/57/EC)	• Labels implemented for washing machines and dryers • IEA heat pump tumble dryer programme under discussion	• CFLs 2% of bulb sales, this is growing at 10% pa • Voluntary agreement (VA) to phase out magnetic ballasts under negotiation • Procurement programme on new bulb technology
1998	**Following Kyoto,** • Framework legislation agreed at EU level, giving power to regulatory committee to require changes to test procedures, and implement mandatory standards at 4 year intervals, following consultation with industry • Strategy defined, and resources and responsibility allocated for procurement programmes in UK • Strategy defined, and resources and responsibility allocated at local level, with some national co-ordinating role for socially targeted appliance replacement programmes		
1998	• Launch 1st procurement programme for vacuum panels (VIPs) (with foam support), winner in 2000	• Labels agreed for dishwashers and washer dryers • Voluntary agreement (VA) removing all E, F and G-rated washing machines • Procurement for heat pump and gas tumble dryers launched	• 5 year programme begins to install 2 bulbs in every household • DELight reports • Mandatory 10 year targets for corporate average bulb efficiency (CABE), including agreements on luminaires with integral ballasts • R&D support on new control technologies
1999	• 1st round of standards implemented. 1st revision of label introduced • Agree 2nd round of standards requiring 40% improvement from 1992		• 5 year programme begins to install 2 dedicated CFL fittings in every household
2000	• VIP procurement winner launched • Begin 2nd stage (integrated panel) procurement	• Mandatory standard to remove all D-rated washing machines • Introduce revised Energy Label for washing machines	• Energy Label becomes mandatory for bulbs • Begin 15 year programme to retrofit 8 million targeted households
2001	• Programmes for VIPs to increase penetration to 5% new sales • Launch 2nd procurement programme for VIP (without foam), winner 2003	• Mandatory standards remove all dryers and dishwashers rated D or below, • Introduce revised Energy Label • Tactical policy programmes for heat pump tumble dryers to increase penetration to 5% new sales	
2002	• Programmes for VIPs to increase penetration to 10% of new sales • Integrated panel procurement launched	• Programmes for heat pump tumble dryers to increase penetration to 10% of new sales	
2003	• Programmes for VIPs to increase penetration to 20% of new sales • VIP 2nd procurement winner launched	• Programmes for heat pump tumble dryers to increase penetration to 20% of new sales	• 2 bulbs in every household achieved as a direct result of EST Actions (not including indirect benefits) • Target total market for CFLs of 24.5 million bulbs pa, to be maintained by Corporate Average Bulb Efficiency agreements
2004	• Programmes to increase penetration of new VIPs • 2nd round of standards becomes mandatory • 2nd revision to label • Set 3rd round of standards based on VIPs	• 2nd round of standards implemented requiring ETP, for washing machines and dishwashers, and 2nd revision to label	• 2 dedicated fittings in every household achieved as a direct result of EST Actions (not including indirect benefits)
2005	• Programmes to increase penetration of new VIPs		• Integral ballast luminaires included as part of building standards
2006	• Programmes to increase penetration of new VIPs		
2007			
2008	• 3rd round of standards implemented, new VIPs 100% market penetration • 3rd revision to label	• 2nd round of standards requiring ETP, for tumble dryers, based on heat pump procurement technology, and 2nd revision to label	• All magnetic ballast CFLs phased out by this date
2009			

Table 4.1b Policy timetable for Scenario 1 (ovens, hobs, brown, generic standby and heat losses)

	Ovens and hobs	TV and video	Brown goods and generic standby	Generic heat loss in small appliances
Current Status	• Test procedure for electric ovens agreed, gas ovens almost ready • Assume hobs lag ovens by 2 years	• Voluntary agreement (VA) to reduce TV and video standby to 6W by 2000, then by 1W every 3 years	• SAVE study reports 1997	
1998	• **Following Kyoto:** see Table 4.1a			
1998	• SAVE study interim report on ovens published	• Study reports on On-mode for TV, video, satellite and cable • EU award label on standby		
1999	• SAVE study reports • Technology procurement on ovens for launch in 2000	• VA reached on On-mode, pending test procedure • Standby mode agreement active	• Voluntary agreement (VA) reached with transformer manufacturers	
2000	• Standards (20% improvement) labels agreed simultaneously • Only products remaining on market eligible for label. • 'A' category of label defined by procurement programme • Ovens procurement winner launched (52% improvement in efficiency based on known technology) • SAVE study on hobs published	• IEC test procedure on On-mode and standby mode • Procurement on low energy screens • VA active on On-mode • Develop an Energy Label for TVs and videos on whole duty cycle		• SAVE study reports, including definition of test protocols for kettles, coffee pots, slow cookers, chip pans etc.
2001	• Technology procurement on hobs announced, to get induction hobs to market at reasonable cost	• Procurement results announced		
2002	• 1st round of standards for ovens implemented and labels introduced simultaneously • Programme to increase market penetration of A-rated ovens to 5% new sales • Winner of hobs technology procurement announced • Agreements on hob label	• Energy Label on duty cycle implemented	• 1st round of standards requiring 50% improvement in standby loss	• 1st round of standards requiring 20% improvement in heat loss
2003	• Programme to increase market penetration of A-rated ovens to 10% new sales			
2004	• Programme to increase market penetration of A-rated ovens to 20% new sales • Energy Labels for hobs introduced			
2005	• 2nd round of standards agreed based on technology procurement winner • Programme to take A-rated hobs to 5% market penetration	• Mandatory minimum standards to improve On-mode of TVs • Standards also include satellite, cable and VCRs		
2006	• Programme to take A-rated hobs to 10% market penetration		• 2nd round of standards (90% improvement in standby loss for clock radios, microwaves, etc).	• 2nd round of standards requiring near 40% improvement in heat loss
2007	• Programme to take A-rated hobs to 20% market penetration			
2008				
2009	• 2nd round of standards on ovens implemented and 2nd revision to label			
2010				

1.23.3 Illustrative programmes

In order to give some idea of the extent of transformation necessary, the ETP efficiency levels in Chapter 2, the decision-rules of Chapter 3, and the specific assumptions in Scenario 1 are now brought together and discussed in more detail. This is done for the two examples of cold appliances and lighting (summarised in Table 4.1a), which together represent two-thirds of the potential savings. The strategy for other appliances is similar to that for cold, except that where the ETP level is not as ambitious as for the cold appliances, fewer rounds of procurement and efficiency standards are required.

Cold appliances

Market transformation for the cold appliances under this scenario is aimed at full market penetration of integrated vacuum panels, by a target date of 2008. To get there involves many steps, outlined in Table 4.1a, including:

- optimising existing technology;
- new innovation through procurement;
- diffusion of innovation through rebates; and
- full market penetration of new technology through efficiency standards.

These themes must be developed in parallel. Retailer education programmes based on the Energy Label can focus consumers' attention on efficiency at the point of sale. Short-term efficiency standards (based on a statistical analysis of the current market) can be introduced over the next few years, and optimise existing technology, for example improved door seals, compressor sizing, insulation and more efficient frost-free appliances.

However, for a mandatory standard to require integrated vacuum panels in 2008, there must be significant prior market penetration of this technology. Thus, given the period of notice that standards normally require, integrated vacuum panels must be at around 20% market penetration by 2004. Achieving this target may require up to three years of support through rebates, in this case targeted at low-income households. A scheme aiming to replace 6 million cold appliances could effectively wipe out the second-hand market for cold appliances and increase the market for manufacturers. Such a scheme would have the added benefits of reduced running costs, improved food hygiene and better electrical safety standards for low-income households. In estimating programme costs below (Table 4.2) it is assumed that vacuum panels carry a nominal additional premium of £50, and that since low-income households cannot afford to pay any of the purchase cost, the appliance is bought through a financing scheme at preferential interest rates, and the purchase price is paid back over time from the energy savings. As outlined in Chapter 3, vacuum panels are an innovation that needs introduction probably in two stages, first as a drop-in innovation, retaining foam as the major structural component, and later as a single, integrated panel. To get the technology to the level where manufacturers are able to manage a large scale rebate programme in 2001 means (given design and tooling lead times) beginning with the first of two procurement programmes immediately. In this scenario, around 20% of the savings come from investment, and around 80% from regulation.

Lighting

Of all appliance groups, accessing the ETP levels of CFL ownership for lighting described in Chapter 2 requires the greatest changes. It involves a series of changing technologies: incandescent bulbs being replaced with magnetic and then electronic CFLs with the ballast as an integral part of the bulb, followed by CFLs with dedicated fittings incorporating the ballast (see Table 4.1a). Research carried out in 1997 as part of the SAVE funded DELight (Domestic Efficient Lighting) project showed that 43% of fittings can take CFLs. Accessing the ETP will therefore mean substantial adjustments in the lighting industry, including:

- an overall reduction in bulb sales, but not reduced turnover;
- much increased collaboration between bulb and fitting manufacturers; and
- substantial retrofit of existing dwellings with new fittings.

For these reasons, the ETP for lighting is realistically only accessible by 2020.

Even this target date means one new CFL must be installed per household per annum from 2001 to 2020, in addition to any existing CFLs. Figure 4.2 shows how the total new CFL installations come about. By 2020, CFL sales will account for half of all bulb sales and around 80% of burning hours in the average household. In order to achieve ETP by 2020, a combination of investment and regulation is necessary. In this scenario:

- 35% of the savings are from investment, either through the EST, retrofit programmes by local authorities (under the Home Energy Conservation Act), utility investment or some other route. The cost of these would be an estimated £2.1 billion at current prices, but spread over 15 years;
- 65% of the savings come from regulation, at little cost to government, through including dedicated fittings in building standards and corporate average efficiency standards for bulb sales.

The investment is concentrated in the early years to prepare the market, while regulation in the later years serves to underpin the market.

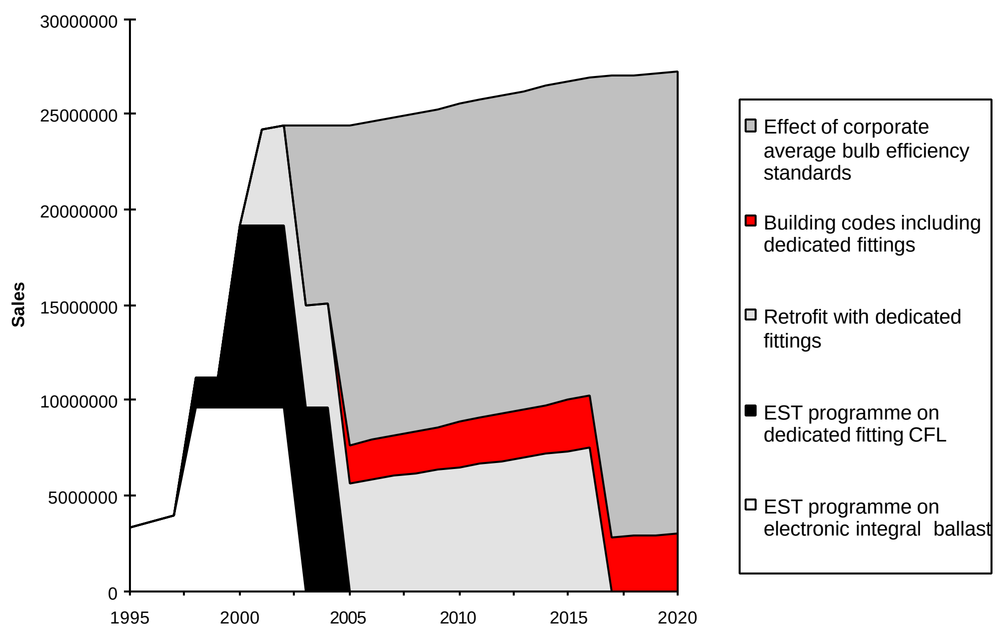

Figure 1.23 Building a market for CFLs: effects of programmes to 2020

An EU Energy Label for domestic light bulbs will be introduced in the year 2000 and is expected to provide an affirmation of reliability: the label has to state the expected life span and light output of the bulb. Combined with retailer education programmes, this should provide consumers with greater confidence in the benefits of CFLs. The public are known to have misconceptions about CFLs: 'early adopters' who experienced a number of disadvantages from the heavy, magnetic CFLs may not be aware of improvements in technology such as reduced flicker, reduced warm-up time and reduced size and weight.

Following the introduction of labels, the first phase is an EST rebate programme to install two electronic CFLs in every household over 5 years (1998-2003). Initially the focus would be on integral ballast CFLs. This phase would account for 9% of total lighting electricity savings.

The second phase is another EST programme of similar magnitude to get two dedicated CFL fittings into every household by 2004. This is in addition to the existing EST scheme to sell 3.2 million fittings by 2000. The development of a range of dedicated fittings is an important issue and will require co-ordination between the manufacturers of bulbs and fittings. This would account for a further 9% of total electricity savings.

The third phase is an investment programme to install dedicated fittings in around 8 million households over 15 years. This could be targeted at low-income households, because low-income households are unlikely to be able to afford to buy CFLs, and because they may suffer from under-illumination in order to keep electricity bills low. EST estimate that about 10% of improvements in efficiency may be taken as increased light (EST, 1995). This phase is assumed to cost £200 per household, giving a total cost of £1.6 billion over 15 years, accounting for 18% of lighting energy savings.

Once a sufficient market for dedicated fittings has been developed, the UK Building Regulations can underpin this transformation and play a role in guaranteeing future markets by requiring fixed fittings in new buildings to be dedicated fittings. Following the conclusion of the EST fittings programme in 2005, this policy would affect 100,000 new homes per annum and deliver 7% of total electricity savings by 2020 at no significant cost to government.

The above actions should generate a market of 24.5 million CFLs per annum by 2003, that is around 1 new bulb per household per year (not including replacement bulbs where older bulbs have expired). In order to maintain the market at this level, a mandatory corporate average efficiency of bulbs sold is crucial.

A Corporate Average Bulb Efficiency (CABE) standard provides some flexibility in shifting from a majority of incandescent bulb sales to a majority of energy efficient sales (similar to the Corporate Average Fuel Economy or CAFE standards for motor vehicles). It allows for the introduction of any intermediary bulbs onto the market, such as the bulb to be developed as part of the IEA procurement programme. It recognises that there will be sales of fluorescent and halogen bulbs, given the current fittings installed in people's homes. CABE standards would cover all sales, including both the commercial and the domestic markets, since it is difficult to attribute sales to the different sectors. There will therefore be the additional benefits of CO_2 reductions in the commercial sector, not included in any of these calculations.

To bring about the shift to CFLs for dedicated fittings, there is a requirement to phase out all ballasted CFLs by the year 2020. This follows on from the existing voluntary agreement to phase out all CFLs with magnetic ballasts by 2008.

Given the expectation that bulb sales will decline in the long term, it is important to help manufacturers manage the transition to new market conditions. Once electronics are in light bulbs and fittings, it is a small step to introduce better control systems. These may bring about additional energy savings not accounted for here (eg through the use of occupancy sensors). Such a transition may need cross-industry support for research into lighting control systems.

1.23.4 Estimated costs and benefits of Scenario 1

A best estimate of the costs of this scenario to the UK taxpayer over 15 years is given in Table 4.2. Some costs of procurement could be shared with EU countries, however cost savings would be minor: the important effect would be to multiply the size of the programme. The key variable in cost is whether reaching 20% market share is necessary before fixing mandatory standards, or if equity is an important issue, whether rebates may need to provide up to 33% of savings, and how these figures vary between appliance groups. Costs may be lower if similar programmes exist in other EU countries: if new technologies are widespread it becomes easier to incorporate them into efficiency standards. Costs could also be reduced by allowing more time before fixing standards, however, this scenario is based on ETP at the fastest possible rate.

Table 4. 2 Cost of Scenario 1

Item	***Number (million)***	***Comment***	***Cost (£m)***
Procurement		Including incentives and underwriting costs	15
Cold appliances	6.0	£50 for VIPs and £30 for finance	480
CFL subsidy	48.0	£5 per bulb with bulk purchase from manufacturers	240
CFL dedicated fittings	48.0	£6 for bulb and a ballast	288
CFL dedicated fittings retrofit	8.0	£200 per home	1600
Ovens	0.7	£50 premium for new technology	35
Induction hobs	0.5	nominal £100 for induction hobs	50
Tumble dryers	0.5	£30 per unit	15
Programme costs		Programme design and evaluation, including standards, 60 people for 10 years	18
TOTAL COST (£ million)			2741

1.24 SCENARIO 2 - THE UK ACTING IN A REGULATION-CONSTRAINED EUROPE

This scenario is based on a combination of a strong UK and weak Europe.

1.24.1 UK investment programmes

If it proves difficult to introduce mandatory standards directives at the EU level, the UK Government would have to resort to national programmes to make a 20% improvement in lights and appliances as part of a programme to fulfil its manifesto commitment. Incentives would be the principal option, possibly including both VAT and rebates. On the grounds of equity, rebates targeted at low-income households are the preferred solution, however variable VAT remains an important option. The resources and responsibility for rebate and procurement programme design need to be allocated.

It is assumed that for all appliances after the end of the rebate programme, market penetration of the new technology remains at 20% indefinitely.

1.24.2 EU actions

Unlike Scenario 1 minimum standards do not underpin the savings, but voluntary agreements may be forthcoming. In estimating the likely effect of voluntary agreements it has not been possible to apply a standard increase to the underlying rate of change of technology, or a standard energy saving percentage across all appliance groups. This is due to the large differences in current autonomous rates of improvement and the potential for efficiency improvements by the different appliances. In order to quantify the scenario, certain decision rules were used, based either on the German precedent for a range of cold, wet and cooking appliances (Simons, 1992; Hass, 1992) or on the CECED proposals for washing machines (CECED, 1997):

- for those appliance groups with no current Energy Label, a voluntary agreement is assumed to begin 1 year after the introduction of the Energy Label;
- as in Germany, voluntary agreements are for a standard period of five years (except for standby where a 12 year rolling programme has already been proposed);
- as for the CECED washing machine agreement, voluntary agreements are unlikely to achieve more than 15% energy savings for the average model over 5 years. Based on the German example, they are unlikely to much more than double the underlying rate of change for a short period;

- voluntary agreements will not encourage or demand the introduction of new technology or of a known technology which is significantly more expensive and which would imply an increase in purchase costs (eg induction hobs). This implies that a voluntary agreement can only access minor improvements to existing technologies, and a large part of the potential savings will not be accessed;

Table 1.24.a Policy timetable for Scenario 2 (cold, wet and lighting appliances)

	Cold	Wet	Lighting
1998	**Following Kyoto, and in the absence of framework legislation on efficiency standards,** • Resources and responsibility for procurement programmes are allocated to EST or ETSU • Resources and responsibility for socially targeted replacement programmes given to EST/Local Authorities • OR, lower rates of VAT on energy efficient goods are introduced		
1998	• Launch 1st procurement programme for vacuum panels (VIPs) (with foam support), winner in 2000	• Labels agreed for dishwashers and washer dryers • Voluntary agreement (VA) removing all E, F and G-rated washing machines • Procurement for heat pump and gas tumble dryers launched	• 5 year programme begins to install 2 bulbs in every household • DELight reports • R&D support on new control technologies
1999	• 1st round of standards implemented. 1st revision of label introduced. • Agree 2nd round of standards requiring 40% improvement from 1992	• VA for dishwashers and tumble dryers negotiated	• 5 year programme begins to install 2 dedicated CFL fittings in every household
2000	• VIP procurement winner launched. • Begin 2nd stage (integrated panel) procurement • Voluntary agreement (VA) negotiated	• VA to remove all D-rated washing machines • Introduce revised Energy Label for washing machines • 1st stage VA for tumble dryers and dishwashers	• Energy Label becomes mandatory for bulbs • begin 15 year programme to retrofit 8 million targeted households • Voluntary agreement (VA) negotiated
2001	• Programmes for VIPs to increase penetration to 5% new sales • Launch 2nd procurement programme for VIPs (without foam), winner 2003 • VA period begins	• Introduce revised Energy Label • Tactical policy programmes for heat pump tumble dryers to increase penetration to 5% new sales • 2nd stage VA for washing machines negotiated	
2002	• Programmes for VIPs to increase penetration to 10% of new sales • Integrated panel procurement launched	• Programmes for heat pump tumble dryers to increase penetration to 10% of new sales • 1st stage of 2nd VA for washing machines	
2003	• Programmes for VIPs to increase penetration to 20% of new sales • VIP 2nd procurement winner launched	• Programmes for heat pump tumble dryers to increase penetration to 20% of new sales • 2nd stage VA for tumble dryers and dishwashers • Re-design tumble dryer and dishwasher labels	• 2 bulbs in every household achieved as a direct result of EST Actions (not including indirect benefits)
2004	• Programmes to increase penetration of new VIPs • 2nd revision to label	• Programme to ensure 20% penetration of new tumble dryers	• 2 dedicated fittings in every household achieved as a direct result of EST Actions (not including indirect benefits)
2005	• Programmes to ensure 20% penetration of new VIPs	• programme to ensure 20% penetration of new tumble dryers	• Integral ballast luminaires included as part of building standards
2006	• Programmes to ensure 20% penetration of new VIPs	• 2nd stage VA for washing machine • Re-design washing machine label	
2007	• Programmes to ensure 20% penetration of new VIPs		
2008	• Programmes to ensure 20% penetration of new VIPs		• All magnetic ballast CFLs phased out by this date
2009	• Programmes to ensure 20% penetration of new VIPs		
2010	• Programmes to ensure 20% penetration of new VIPs (till 2014)		

Table 1.24.b Policy timetable for Scenario 2 (ovens, hobs, brown and generic standby)

	Ovens	Hobs	Brown	Generic Standby
1998	• **Following Kyoto:** see Table 4.3a			
1998	• SAVE study interim report on ovens published		• Study reports on On-mode for TV, video, satellite and cable • EU award label on standby	
1999	• SAVE study reports • Technology procurement on ovens for launch in 2000		• Voluntary agreement (VA) reached on On-mode, pending test procedure • Standby mode agreement active	• Voluntary agreement (VA) reached with transformer manufacturers
2000	• Standards (20% improvement) and labels agreed simultaneously • Only products remaining on the market are eligible for labels • 'A' category of label defined by procurement programme • Ovens procurement winner launched (52% improvement in efficiency based on known technology)	• SAVE study on hobs published	• IEC test procedure on On-mode and standby mode • VA active for On-mode • Develop an Energy Label for TVs and videos on whole duty cycle	
2001		• Technology procurement on hobs announced, to get induction hobs to market at reasonable cost		
2002	• Labels introduced simultaneously • Programme to increase market penetration of A-rated ovens to 5% new sales	• Winner of hobs technology procurement announced • Agreements on hob label	• Energy Label on duty cycle implemented	
2003	• Programme to increase market penetration of A-rated ovens to 10% new sales			
2004	• Programme to increase market penetration of A-rated ovens to 20% new sales	• Energy Labels for hobs introduced		
2005	• Programme to ensure 20% penetration of A-rated ovens	• Programme to take A-rated hobs to 5% market penetration		
2006	• Programme to ensure 20% penetration of A-rated ovens	• Programme to take A-rated hobs to 10% market penetration		
2007		• Programme to take A-rated hobs to 20% market penetration		
2008		• Programme to ensure 20% penetration of A-rated hobs		
2009		• Programme to ensure 20% penetration of A-rated hobs		
2010				

- at the end of the voluntary agreement period the Energy Label will be revised to take account of the new market; and
- after the end of the voluntary agreement the underlying rate of change returns to the rate in the Reference Case.

These rules were interpreted for each appliance group as follows:

- cold appliances are assumed to achieve a 15% reduction in energy consumption from 1999-2004;

- in addition to the existing agreement for washing machines, a second agreement is assumed, and delivers twice the savings per appliance that the underlying rate of improvement would have delivered, equal to a 7% reduction in energy from 2000-2005;
- dishwashers and tumble dryers have been estimated to deliver 2.5 times the savings per appliance than the underlying rate of improvement would have delivered (equal to 13% savings for dishwashers and 7% for tumble dryers) within the 5 year period of the agreement;
- for ovens and hobs, only small savings can be achieved by agreements since technology changes are necessary to access significant savings. Here 5% savings over 5 years are assumed;
- for lighting the programme is as for Scenario 1, with the exception of CABE, and;
- for brown goods and generic standby, the current agreement for TV and VCR is strengthened (by 1W) in this scenario. Other standby (satellite, cable and microwave) are similar to the current TV and VCR agreement. The on-mode for TVs is assumed to deliver savings 5% below the Reference Case at the end of a 5 year period, and again, significant technology changes are necessary to achieve larger savings.

The timetable of actions and the main assumptions of Scenario 2 are listed in Tables 4.3a (for cold and wet appliances and lighting) and 4.3b (for ovens, hobs, brown goods and generic standby).

1.24.3 Estimated costs and benefits

The costs of Scenario 2 are equivalent to those of Scenario 1, because the same programme of investment is assumed as in Scenario 1. However, savings are lower, and the long term decision-making framework for manufacturers (in terms of product design and tooling decisions), and governments (in terms of programme design for CO_2 emissions), is less certain (see discussion in Section 3.6.1).

There are some key uncertainties in this scenario. The form of the voluntary agreements determines whether the savings are additional or overlap with the UK procurement and rebate programmes. Several previous voluntary agreements have been based on the average product sold. If this is the case in future, Government may be subsidising the introduction of new products while manufacturers would be able to keep inefficient products on the market. The average efficiency would improve, but the savings from the two programmes would be overlapping. If the voluntary agreements took the form of commitments to remove the worst products from the market (similar in effect to minimum standards), the savings would be additive to the savings from rebates to a greater extent.

If rebate and procurement programmes are widespread across Europe, some of the voluntary targets could be more demanding. For example, if vacuum panels are on the market, it may be possible to reach an agreement on a separate target for the percentage of market penetration of vacuum panel refrigeration appliances. Such additional savings have not been accounted for here.

In summary, this scenario provides savings of 1.4 MtC that could be made at a cost of around £2.7 bn, but with a saving over the period of £5.5 bn, and a cost to benefit ratio of 1:2 (ie a lower level of saving, compared to Scenario 1, at a higher cost per kWh saved). In addition, there is:

- uncertainty about the extent of CO_2 savings by 2010 because of the interaction between voluntary agreements and rebates;
- uncertainty to manufacturers, in particular for new investment in design and tooling, because of a lack of a clear objective and timetable;
- substantial support for new technologies through procurement programmes and rebates equivalent to that in Scenario 1;
- maximum equity, through socially targeted rebates or appliance replacement programmes; and
- no guarantee of economies of scale on efficiency changes because of the lack of efficiency standards. This implies that while the government and the taxpayer incur costs, savings are not as substantial compared to scenario 1.

Table 4.4 Policy timetable for Scenario 3

	Cold	Wet	Lighting	Ovens	Hobs	Brown	Generic Standby
1998		• Labels agreed for dishwashers and washer dryers • Voluntary agreement (VA) removing all E, F and G-rated washing machines	• DELight reports	• SAVE study interim report published		• Study reports on On-mode for TV, video, satellite and cable • EU award label on standby	
1999	• Standards set already • 1st revision of label introduced	• VA negotiated for dishwashers and washer dryers		• SAVE study reports	• SAVE study interim report published	• Voluntary agreement (VA) reached for On-mode, pending test procedure • Standby mode agreement active	• Voluntary agreement (VA) reached with transformer manufacturer s
2000	• Voluntary agreement (VA) negotiated	• VA to remove all D-rated washing machines • Revise washing machine Energy Label • 1st stage VA for tumble dryers and dishwashers	• Energy Label becomes mandatory for bulbs.	• Voluntary agreement (VA) negotiated	• SAVE study reports	• IEC test procedure for On-mode and standby • VA active on On-mode • Develop an Energy Label on TVs and videos on whole duty cycle	
2001	• VA period begins	• 2nd VA for washing machines negotiated	• Voluntary agreement (VA) negotiated		• Voluntary agreement (VA) negotiated		
2002		• 1st stage of 2nd VA for washing machines	• VA period begins	• VA with 15% improvement in standing loss • labels introduced simultaneously		• Energy Label on duty cycle implemented	
2003		• 2nd stage VA for tumble dryers and dishwashers • Re-design tumble dryer and dishwasher labels			• VA with 15% improvement in standing loss • labels introduced simultaneously		
2004	• 2nd round of standards (voluntary) • 2nd revision of label						
2005			• All luminaires to take CFLs or integral ballast CFLs	• 2nd stage of VA			
2006		• 2nd stage VA for washing machines • Re-design washing machine label			• Second stage of voluntary agreement		
2007							
2008							
2009							
2010							

1.25 SCENARIO 3 - THE UK FOLLOWING A REGULATION-CONSTRAINED EUROPE

This scenario assumes that future policy actions take the form of an extension of current principles (ie voluntary agreements and limited EST investment) and that there is no substantive new action by either the EU or the UK. It is defined as weak UK and weak Europe. Decisions taken already are included in the Reference Case. If future policy actions continue in this vein, there will be small additional savings beyond the Reference Case. The timetable of actions assumed for this scenario is given in Table 4.4.

The savings from voluntary agreements are assumed to be identical to those identified in Scenario 2 for cold, wet, cooking and brown appliances. The savings from lighting are very minor (Appendix C, Figure C.4) and result from an assumed doubling of the current rate of increase of CFL sales during the five year period of a voluntary agreement. Clearly the likely savings from voluntary agreements are open to debate. Stronger voluntary agreements would produce greater savings. As stated in Section 4.3, assumed savings in Scenarios 2 and 3 are based on the effectiveness of previous and existing voluntary agreements.

In summary, this scenario provides savings of 0.4 MtC at a cost of around £0.125 bn, but with a saving over the period of £1.5 bn, and a cost to benefit ratio of 1:12 (ie a much lower level of saving, compared to Scenario 1, at a lower cost per kWh saved). In addition, this scenario entails:

- uncertainty for manufacturers (for investment in design and tooling) and for Government (in terms of policy decisions on CO_2 emissions), because of the lack of clear objective and timetable;
- high cost to manufacturers for new technologies through the lack of procurement programmes and rebates, and the reduced likelihood of new energy efficient technologies (eg VIPs) appearing;
- poor equity - the absence of socially targeted rebates implies that energy efficiency will only be available to a proportion of the 75% consumers who can afford to buy new appliances; and
- no guarantee of economies of scale on efficiency changes because of the lack of efficiency standards. This implies little cost to government and taxpayer, but no savings.

1.26 ANALYSIS AND CONCLUSIONS

The major variable in the three policy scenarios developed in this chapter is the level of political commitment to meeting emissions reduction targets in the UK and in Europe. The other criteria assumed in the scenarios are certainty of savings, cost to different stakeholders and equity. These are by no means the only criteria for policy, and different criteria could be important in other circumstances. The policy options and decision rules used to construct these scenarios (described in Chapter 3) are sufficiently adaptable to allow the development of alternative scenarios.

Of the three illustrative scenarios:

- **Scenario 1 will provide the greatest, guaranteed energy savings** (26% of projected consumption, depending on the level and timescales of action) with least uncertainty for manufacturers, because clear signals are given with regard to standards, and the greatest support in developing and marketing new technologies. This scenario also provides most savings for consumers because the savings are made through economies of scale (discussed in section 3.5.2). Savings are therefore made at the lowest net cost to all stakeholders, and a net cost to benefit ratio up to 2010, of 1:3.9 (undiscounted, but with substantial savings to accumulate after this date);
- **Scenario 2 will provide much lower savings** (of the order of 14% of total consumption), but with the same level of cost as Scenario 1, because the investment programmes are the same as those in Scenario 1. Scenario 2 savings are therefore achieved at the highest cost per kWh and a cost to benefit ratio of 1:2, again undiscounted, but with substantial savings to accumulate after this date. In

the absence of EU efficiency standards there is little opportunity to build on these savings with economies of scale, and reduced certainty for manufacturers. Key uncertainties include the extent to which rebates and procurement exist elsewhere in Europe and, therefore, the savings that could be made by voluntary agreements, and the extent to which savings from agreements and investment programmes may actually overlap;

- **Scenario 3 will provide the least savings** (4%), subject to uncertainty, but at the least cost and a good cost to benefit ratio of 1:12.

Table 4.5 summarises projected electricity consumption and CO_2 emissions under the Reference Case for comparative purposes. Table 4.6 below presents some of the key costs and benefits for the three scenarios to different groups (eg manufacturers and consumers), and cumulative terms and annual savings in the target year of 2010. It is important to bear in mind that not all of the savings from the policy actions here will have accumulated by 2010, so there will be substantial savings after 2010, and that the cumulative money savings and cost to taxpayers have not been discounted. These figures are therefore indicative rather than concrete.

Table 1.26 Summary of Reference Case electricity consumption and CO_2 emissions

	RC 1990	RC 2010
Electricity consumption (TWh)	69.7	80.3
CO_2 emissions (MtC)	14.7	10.3
Electricity consumption relative to 1990		115%

Table 4.6 Summary of savings and costs for the 3 scenarios

		Scenario 1	Scenario 2	Scenario 3
UK Savings	Electricity in the year 2010 (TWh pa)	20.9	10.9	3
	UK CO_2 in the year 2010 (MtC pa)	2.7	1.4	0.4
	Money (£bn cumulative to 2010)	10.5	5.5	1.5
	Certainty for decision-making (see 3.6.1)	high	middle	low
Cost to UK	To manufacturers	minimum	minimum	higher
	To taxpayers (£bn cumulative to 2010)	2.7	2.7	0.125
	Ratio of cost to benefit	1:3.9	1:2.0	1:12.0
Savings per household	Electricity in the year 2010 (kWh/yr)	785	407	113
	Money in the year 2010 (£/yr)	58.90	30.52	8.50
	Equity	good	good	poor
Cost per household	Money each year 1998 - 2010 (£/yr)	9.30	9.30	1.00

There must clearly be large tolerances surrounding estimates of savings depending on timing, certainty, and the level of supporting programmes. Costs will be critically dependent on the emphasis given to social objectives (eg how low-income household are targeted). The costs quoted are a maximum and could be reduced. In Scenarios 1 and 2, the investment programme described is focused on equity as well as increasing market share for efficient technologies, and is thus larger than would be needed for increasing market share of efficient technologies alone. Savings depend on the level of takeback (see Appendix A) from improvements in efficiency. These uncertainties are in addition to those included in the sensitivity analysis in the Reference Case (such as ownership and underlying technical change).

The potential electricity savings under different scenarios are shown in Figure 4.3. Given the projected increase in households and in appliance ownership, Reference Case consumption increases by 15% between 1990 and 2010. Relative to a 1990 baseline, Scenario 3 results in an 11% increase in consumption, Scenario 2 leads to stabilisation and Scenario 1 leads to a 15% reduction. Savings in 2020 could be even greater than those shown here in 2020, depending on future technological innovations and on new policy implemented after 2010. The scenarios assume no new policy developments after 2010, and that policies up to 2010 take time to work through the stock. The savings by appliance group for each scenario are shown in Appendix C.

In terms of CO_2, relative to 1990 there is, even in the Reference Case in the UK, a decline in CO_2 from appliances up to 2000 due to the shift in generating capacity from coal to gas. However, in the Reference Case, emissions rise from 2000 onwards, eating into other savings made by 2010, and by 2020 emissions are projected to be close to 1990 levels. This a strong indication that intervention is necessary. Scenario 1 is the only scenario that maintains up to 2020 the reductions achieved through changes in the supply mix up to 2000. In Scenarios 2 and 3 emissions rise from 2000 onwards (see Figure 4.4).

Savings from lights and appliances can be accessed relatively quickly given that light bulbs and appliances have a much more rapid turnover than the building stock. Strong programmes in these areas may therefore be crucial. Even in lights and appliances, the effects of policies (eg a minimum standard) implemented in 2000 will not be fully realised until after 2010, since only around 1/12 of the stock is replaced in any one year. In comparison, given the present (unsustainable) rate of building and demolition, only 1/5000 houses is replaced each year.

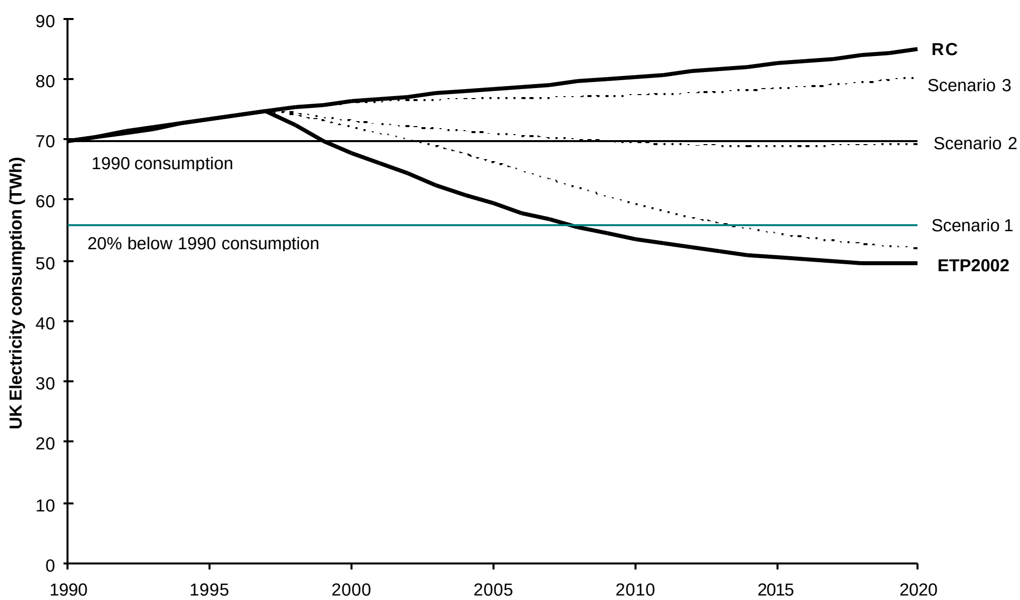

Figure 4.3 Electricity consumption by domestic lights and appliances in the 3 scenarios, UK, 1990-2020

The scenarios described here illustrate three versions of possible future reality, but between them is a whole spectrum of possible futures. For example, Scenario 1 assumes mandatory standards introduced under a framework directive, but this is not the only option for a standards programme. The principle of least life cycle cost could be agreed as a target by the Council, and a mixture of mandatory and voluntary standards implemented on a case-by-case basis, tougher in some appliance groups than in others. However, this approach may in practice be slower, and may result in less demanding standards, providing less than optimum economic and environmental savings to the consumer and a lower level of certainty to manufacturers.

Some elements of policy are common to all three scenarios:

- the assumption of retailer education in support of the Energy Label;
- the assumption of greater support for enforcement and prosecution over Energy Label categorisation;
- the assumption of tighter tolerances on EU test protocols;
- procurement and rebates are common to Scenarios 1 and 2;
- voluntary agreements are common to Scenarios 2 and 3.

Perhaps the most crucial common element is the debate concerning the way forward. Each scenario develops a strategy which recognises the role of different policy instruments and the costs to different stakeholders. Any route forward needs to be underpinned by monitoring changes in efficiency, price, and technology over time, as well the effects of these variables on cost-effectiveness, to allow both prospective and retrospective analysis of policy.

All of the scenarios presented in this chapter are based on improving the efficiency of appliances sold; no account is taken of changes in usage of the existing stock in UK households. Changes in usage may provide further opportunities for savings, but at unknown cost and with low guarantee. This potential is considered in the next chapter.

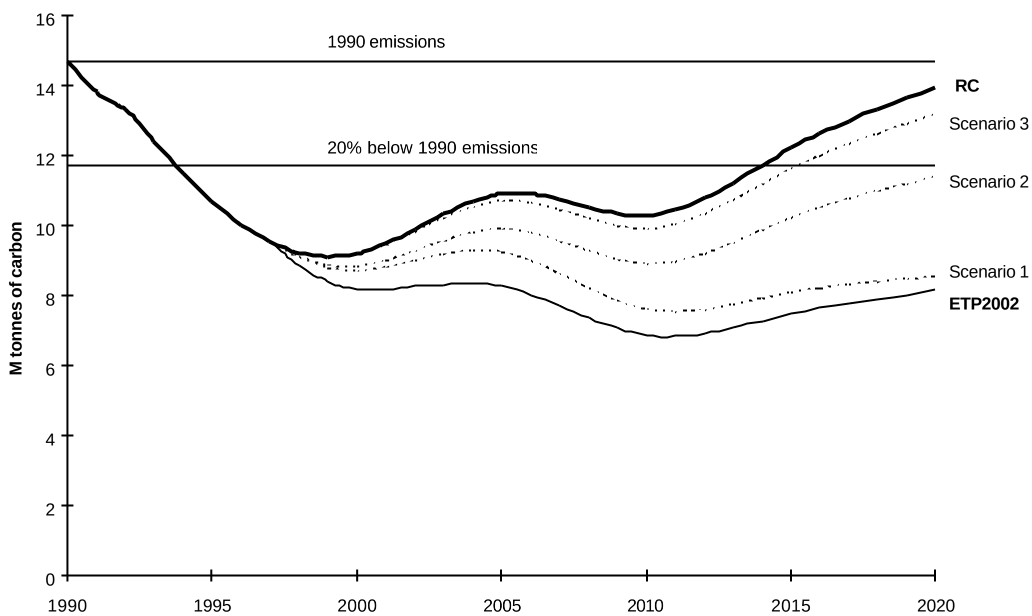

Figure 4.4 CO_2 emissions from domestic lights and appliances in the 3 scenarios, UK, 1990-2020

CHAPTER 5: CHANGING BEHAVIOUR

The energy saving goal that underpins the market transformation principles and scenarios detailed in Chapters 3 and 4 could also be augmented by altering the way householders use lights and appliances. This chapter describes the concept of the Behavioural Potential (BP) and argues that potential savings of up to 1 MtC are available from more efficient usage. In an attempt to answer the question of how much of this potential is actually accessible, the types of behaviour-oriented policy that have been implemented to date (and their limitations) are reviewed, and suggestions offered for accessing behavioural savings in the future. The link between behavioural and economic barriers to the spread of energy efficient appliances is briefly discussed. Finally, new data on social characteristics are presented as a possible basis for increasing policy effectiveness through targeting.

1.27 THE BEHAVIOURAL POTENTIAL

The BP is an estimate of how much energy could be saved through behaviour. It is presented as a percentage of the Reference Case consumption in 2010. Although the savings from behavioural changes and those from technical change may overlap to a certain extent and are not purely additive, the BP estimate is separate from the estimated energy savings of the ETP level described in Chapter 2 and the policy scenarios in Chapter 4. In calculating the BP, three criteria were used to identify 'acceptable' changes, as follows:

- the change should not result in a (significant) loss of service to the consumer;
- must be available at zero cost to the householder;
- must be actions which the householder can take immediately.

The proviso that there should be no loss of service provides a limit to the BP and fits with the philosophy underlying ETP. Clearly the BP does not identify all of the potential energy savings through behaviour.

The most problematic part of using the BP definition to estimate potential savings is deciding what constitutes a loss of service. The approach that has been adopted is to minimise wasted energy. This has the advantage of being relatively easy to estimate, even though it risks over-simplifying the concept of service. For example, at present washing machines tend to be loaded at less than their maximum capacity. The easiest way in which to estimate the behavioural savings potential is to assume that all washing machine loads would be full loads. However, this overlooks the fact that users may need to do smaller loads of washing in order to have the right clothes clean at the right time. Therefore, by including actions such as loading washing machines more fully, the BP will represent a lower energy consumption limit in the sense that what constitutes service is defined in a rather limited manner for some appliances.

Many energy-saving actions have not been included because they do not fit within the definition of BP. For example, moving a refrigerator into a cooler area of the kitchen is not included because it may not be possible without re-designing the kitchen, and buying new cooking pans to replace old ones with warped bases is not included because it entails expenditure. Neither does the BP include switching to gas appliances or time-shifting usage patterns to reduce peak demand. Some of these additional behavioural energy savings are discussed in the next chapter.

1.28 SAVINGS AVAILABLE THROUGH BEHAVIOURAL CHANGE

The energy savings that have been identified as available through certain modifications of appliance usage behaviour are detailed below and summarised in Table 5.1. The information on which the estimates of BP have been based is incomplete and has often had to be supplemented by assumptions. These are noted and are conservative in order to avoid over-estimating the BP. The savings available from each behavioural change are based on Run 3 technology, ownership and usage figures for 1996 unless otherwise stated. The savings available from each appliance group are given as percentages of projected electricity consumption by that appliance group in RC 2010 (Chapter 2).

It has been estimated that if all households took Actions 1-17 in Table 5.1 domestic electricity consumption by lights and appliances could be reduced by almost 12%. This is equivalent to around 8 TWh of electricity consumption and almost 1 MtC in RC 2010. The potential for energy savings through behaviour can be expected to change over time in line with prevailing trends in appliance ownership and usage and technological change.

1.28.1 Summary of BP available savings

Table 5. 1 Potential energy savings from behavioural change

Appliance type	**Behaviour**	**Estimated BP (% consumption)**		**Projected savings in 2010**	
		Per action	**Per appliance type**	**(GWh)**	**(MtC)**
Fridges, freezers and fridge-freezers	**1.** regular defrosting	1.5 - 2.5			
	2. clean condenser coils	0.6			
All Cold:			**2.5**	402	0.05
Washing machine	**3.** lower temperature cycles	17			
	4. more efficient loading	14	*29*		
Tumble dryer	**5.** more efficient loading	7	*7*		
Dishwasher	**6.** more efficient loading	17			
	7. low temperature setting	11	*26*		
All Wet:			**17**	2114	0.27
Electric hob	**8.** put lids on saucepans	13.5			
	9. use pressure cookers	9	*22*		
Electric oven	**10.** use microwave instead	12.8			
	11. eliminate unnecessary pre-heating	5	*13.5*		
Microwave	**12.** unplug when not in use	28	*28*		
Kettle	**13.** eliminate reboiling	10			
	14. boil minimum water	14	*23*		
All (electric) cooking:	*(including increase in microwave consumption from **10**.)*		**20**	2625	0.34
Lighting:	**15.** eliminate 'unintended on-time'	10	**10**	2025	0.26
TV	**16.** Switch off standby	11	*11*		
Audio	**17.** Switch off standby	16	*16*		
All Brown:			**12**	1137	0.15
TOTAL BP:	**Actions 1-17**		**11.6**	**8303**	**1.06**

1.28.2 Cold

Cold appliances are not greatly affected by consumer behaviour, as they have to be switched on all the time to fulfil their function. However:

1. The presence of frost increases consumption by 5-10% (Vestfrost, pers comm), and about 60% of cold appliances contain a frozen space (not including ice-boxes) which does not automatically defrost (ie appliances without the frost-free feature). Assuming that 50% of these are not defrosted regularly, regular defrosting could save approximately 1.5-2.5%.
2. Dust or fluff on the condenser can reduce efficiency by up to 6% (Bos, 1993). Assuming that 10% of appliances are never cleaned, 0.6% of consumption could be saved by all consumers cleaning their condenser coils.

If all consumers undertook these actions, cold appliance consumption could be reduced by 2.5%, which is equivalent to energy savings of 402 GWh in 2010. Putting hot food in the appliance is also known to increase consumption, however, no measured data are available.

1.28.3 Wet

There is significant potential for behavioural energy savings from washing machines, tumble dryers and dishwashers since energy consumption depends on the number of cycles (ie on consumer behaviour). Based on relative consumption by washing machines, tumble dryers and dishwashers in 1996, the total BP savings available from the wet appliances amount to 17% or 2.1 TWh in 2010.

Washing machines

3. Washing at 60°C uses 30% less energy than washing at 90°C, and a 40°C wash cycle uses 40% less energy than a 60°C wash (GEA, 1995). On the basis that 38% of washes in 1996 were done at 60°C and 6% at 90°C, savings of 17% could be made if consumers were to use a 60°C cycle for all washes they would normally do at 90°C, and a 40°C cycle where they would normally use 60°C. This is because most of the energy consumption of washing machines goes into heating water (hot-fill machines included). It is assumed that there is no deterioration in the quality of the wash, since the detergent industry has developed modern formulations which perform well at lower temperatures (Swaine, 1993).
4. Most consumers tend to underload their washing machines (GEA, 1995). DECADE have assumed that, for the same number of items washed, a 14% increase in the average load from 3 kg to 3.5 kg would reduce the number of wash cycles by 14%. The load increase assumed for the BP is based on what is perceived by the consumer to be a 'full' load even though this falls well below the manufacturer's stated maximum (most machines have a stated load capacity of 4.5 or 5 kg).

These actions could reduce washing machine electricity consumption by 29%. A recent survey shows that over 90% of people tend to divide their wash by colour or fabric type (LEEP, 1996a). The necessity of dividing the wash reduces the potential saving in real life, but this has not been taken into account in the estimate of BP.

Tumble dryers

5. Most consumers underload their tumble dryers. The BP assumes that the average load increases in line with more efficient loading in washing machines (ie from 3 to 3.5 kg). The available savings are less than for washing machines, partly because tumble dryers are less widely owned and partly because over half of a tumble dryer's energy consumption depends on the load, so that larger loads require more drying energy (GEA, 1995). The BP estimate assumes that the increase in drying energy is proportional to the mass increase of the load (no technical data are available). A recent survey suggests that most loads contain only 3-5 items (CA, 1997), but for the purpose of estimating BP, DECADE have assumed that the average real-life tumble dryer load bears the same relation to the manufacturer-stated load capacity as is the case for washing machines.

Most consumers use the high heat setting even when their machine has a choice of temperature settings (eg LEEP, 1996a). However, using a lower setting is not an option included in the BP since lower drying temperatures require longer drying times and consume more energy than a shorter, hotter cycle for the same load. The BP could save 7% of projected tumble dryer electricity consumption in 2010.

Dishwashers

6. The average measured load for a dishwasher with a capacity of 12 place settings consists of the mass equivalent of 7 place settings (GEA, 1995). Increasing the average load to the mass equivalent of 9 place settings would enable a 17% reduction in the number of cycles and electricity consumed. The assumed increase is conservative since the need to wash bulky items such as saucepans, the constraint of limited crockery or a low rate of crockery use may mean that it is neither desirable nor possible for the consumer to load exactly 12 place settings.

7. A 55°C cycle consumes 30% less energy than a 65°C cycle (GEA, 1995). Energy savings can only be made where machines have a lower temperature option. Based on LEEP's finding that 83% of dishwasher-owning households have machines with a choice of temperature settings, the BP assumes that the remaining 17% of dishwashers do not have a lower temperature option. A usage questionnaire administered to the same households established that 45% of all dishwasher cycles are run at the standard 65°C programme (LEEP, 1996a). Based on these measured ownership and usage patterns, energy savings of 11% could be made if all but 17% of 65°C cycles were run at the lower temperature setting of 55°C.

If all dishwasher-owning households were to modify their usage as above, total dishwasher electricity consumption could be reduced by 26%.

1.28.4 Cooking

Cooking appliances are a source of large potential savings. As in the wet appliances, electricity consumption is more strongly influenced by the habits and choices of the user than by the efficiency of the appliance. Behaviour impacts on cooking consumption at all stages of food preparation, from the choice of appliance used to the number of times the oven door is opened during cooking. Energy advice leaflets issued by the Government and by Public Electricity Suppliers (PESs) often contain numerous hints for reducing cooking consumption, but the BP estimate takes into account only those actions for which reliable data are available. Based on actions 8-14, around 20% of the energy consumed by the four major cooking appliances could be saved, equivalent to 2.6 TWh in 2010 (around 40% of this is from electric kettles, and 30% from electric hobs). This estimate takes into account the increase in microwave consumption that would occur if microwaves were used instead of standard electric ovens (action 10 below).

Electric hob

8. Several studies have shown that using lids on saucepans increases efficiency. Assuming that pans are boiled for 10 minutes on average and that saucepan lids are used only 50% of the time, 13.5% of hob electricity consumption could be saved by all consumers using lids. The estimated efficiency increase with lids is derived by linear extrapolation from the results of two studies (Brundrett & Poultney, 1979; Gledhill & Brodie, 1994). The BP assumes that appropriately sized saucepan lids are always available, but this is unlikely to be the case for all households.

9. Pressure cookers, owned by 31% of UK households in 1996 (CA, pers comm), are 69% more efficient than standard cookware (ESource, 1996). Using pressure cookers for 40% of the standard hob tasks (eg cooking vegetables) currently done in saucepans in those households which own pressure cookers could save an estimated 9% of hob consumption.

These two actions combined could save 22% of the electricity consumed by hobs.

Electric oven

10. The most effective way to reduce oven electricity consumption is to use a microwave, which uses only 20% of the energy of a standard electric oven (ESource, 1996). This is only possible for the 32% of households that own both appliances (BRE, 1995b). A microwave is not always a satisfactory substitute for a traditional oven; the BP assumes that 40% of standard electric oven cooking tasks could be done by a microwave, in those households owning both appliances, without significantly affecting the acceptability of the product. This could save around 13% of electric oven consumption.

11. It is assumed that 5% of all oven on-time is unnecessary pre-heating (Wilson & Rees, pers comm) and that microwave ovens are already being used for 40% of all electric oven cooking procedures in households owning both appliances.

Actions 10 and 11 could save 13.5% of oven electricity consumption in total.

Microwave

12. Switching off microwaves between usage sessions could reduce consumption by 28% without affecting the primary function of the appliance. The standby function in digital microwaves (eg those which maintain a 24 hour clock display and/or a delay timer) currently accounts for 51% of consumption, and digital microwaves currently make up 57% of the stock (Molinder, pers comm). The BP estimate assumes an average daily microwave usage of 20 minutes (Molinder, 1997). Although secondary functions (eg timer or clock display) would be disrupted by switching off, these are not considered to be essential services.

Kettle

13. Reboiling accounts for 20% of kettle electricity consumption. The BP estimate assumes that more than 50% of people regularly reboil kettles. 10% could be saved if consumers avoided this.

14. 27% of users fill the kettle every time they use it, regardless of how much water is needed (Nicholls & Rees, 1983). DECADE have assumed that the kettle only needs to be half full on 50% of these occasions. Kettle consumption could be reduced by 14% if consumers were to boil only as much water as is necessary.

The BP represents a 23% saving of total kettle electricity consumption.

Additional potential savings from cooking

Further opportunities for saving energy through changes in cooking behaviour have not been included in the quantitative estimate of BP because no measured data were available. These include:

- using an electric kettle instead of a pan on an electric hob to boil water needed for cooking;
- cooking more than one meal at a time and freezing for later use;
- removing limescale from the kettle at regular intervals;
- turning the oven off ten minutes before the end of cooking so that the food finishes cooking from the heat remaining in the oven.

1.28.5 Lighting

The only behavioural change that has been considered for lighting is that of eliminating 'unintended on-time' (ie switching off the lights on leaving a room). A number of issues have been ignored, for example cleaning bulbs and shades and not using higher wattage bulbs than necessary. An American study estimated that 'unintended on-time' accounted for 34% of bulb burning hours (Stum, 1992). The Danish Government's figure is 20% (DEA, 1995). Information on wasted lighting energy is very scarce, and there is no evidence for the UK to date. The behavioural saving potential has been estimated at 10%, which could save 2.0 TWh in 2010.

1.28.6 Brown

TVs and audio equipment

16. Standby consumption (in televisions with remote control functions) accounted for 11% of all electricity consumed by TVs in 1996. Switching off the television at the set rather than leaving it in standby mode could save this.

17. Switching off remote control audio equipment when not in use could save the 16% of consumption known to be due to standby.

Actions 16 and 17 could save 12% of all electricity consumed by TVs and audio equipment, equivalent to just over 1 TWh in 2010.

Additional potential savings from brown appliances

Further savings could be made for VCRs (standby accounts for 87% of UK VCR consumption) and cable and satellite decoders (standby accounts for 83-86%). However, these have not been included in the Behavioural Potential since primary user-programmable functions are disrupted when the appliance is switched off at the socket. It is assumed that this constitutes a loss of service since the usefulness of the appliance is significantly affected. This is in contrast to microwaves, where the clock display is not considered to be part of the primary function of the appliance.

Having estimated the BP, the next key question is whether users' behaviour can actually be changed in order to make these savings? As stated by Moezzi (1996), "the challenge lies in understanding which behaviours can be reasonably modified and which are so socially ingrained that cost savings and imposed morality are unlikely to over-ride them." In this sense BP is different from the ETP which definitely would be accessible given the right policies.

1.29 HOW MUCH OF IDENTIFIED BP IS ACCESSIBLE?

The importance of the behavioural element of consumption is acknowledged by UK Government-led energy efficiency campaigns. However, despite numerous campaigns most people are still far from conserving in their use of appliances. The new Government has stated its strong commitment to achieving "real changes" in the way energy is used in the home (DETR, 1997). Evaluations of a range of policies to date can provide insight into the likely success of future policies aiming to access the BP. The following discussion aims to provide an overview of the different types of current and past behaviour-oriented policy and to highlight the challenges that will need to be met if significant behavioural savings are to be made in the future. Reference has been made to examples and concepts relating to appliance purchase, but it should be emphasised that the BP is purely concerned with changing usage.

1.29.1 Current UK policy

The most important of the current schemes consists of the Local Energy Advice Centres or LEACs run by the Energy Saving Trust (EST) for the Department of the Environment, Transport and the Regions (DETR). Over the first three years of the initiative, LEACs administered energy advice to 206,000 domestic clients, representing less than 1% of potential clients in the UK. DECADE's Consumer Response Survey (CRS) found that few people knew that there was a LEAC in their area, suggesting that the major need for the LEACs is to make people more aware that they exist.

The EST also administer the "Energy Efficiency" campaign to encourage consumers to buy the most efficient products and services. The campaign's main messages are that "Energy Efficient products use the latest technology" and that "the efficient use of energy in the home is an easy way to save money". In the first year, the overall cost was £4 million, over half of which was invested in the 'Einstein' television commercials. Another objective is to generate consumer recognition of the campaign logo to be attached to energy efficient products and services, and to communicate the concept of efficiency as "intelligent, aspirational [and] technologically advanced." (EST, 1997). Campaigns to link energy efficiency with being 'smart' may be most successful with the Younger Aspirants group identified through market segmentation analysis of DECADE's CRS (DECADE 1997): status and peer-group pressure were found to strongly influence purchasing behaviour in this segment.

As a condition of their public electricity supply licence, PESs are obliged to publish codes of practice for domestic customers, which may be sent out in response to queries about the bill. These codes of practice include 'energy saving tips' for the efficient use of appliances, and some also provide information about the electricity consumption (and running costs) of various appliances. It is worth noting that while Southern Electric supply electricity to the order of 2.5 million domestic customers, only 14,000 copies of their code of practice 'Use Electricity Wisely and Save Money' were sent out over the last year. Furthermore, in a typical year only around 6,000 domestic customers query their bill or ask for advice on how to reduce it (Southern Electric, pers comm). These figures suggest that, even at the best estimate, PES codes of practice may reach less than 1% of UK households each year. The impact of the information on appliance use behaviour is not known.

1.29.2 Lessons learned from past efforts

Information campaigns

The success of campaigns which depend on inspiring consumers with financial motives to save energy have been limited for a number of reasons including:

- Energy spending constitutes a very small proportion of the average UK household budget;
- Energy services have high priority in many households;
- Most households are not aware of the economic cost of certain energy consuming activities;
- Where energy conserving behaviour exists, it is more likely to be linked to factors other than saving money, eg personal values, knowledge of energy and environmental issues and a sense of personal responsibility (Strang, 1996).

'Helping the Earth Begins at Home' was judged to have failed in its objective of "fostering a sense of global consciousness", because it appeared to present consumers with the responsibility for an environmental problem on a global scale. This reinforced the sense that global warming was a scientific (and therefore abstract) problem, distant in time, space and causality, and that consumers were powerless to do anything about it (Hinchcliffe, 1996). In order not to be counter-productive, information campaigns must propose solutions and convince consumers that they can play a successful role.

The airing of the "Einstein" commercials on national television demonstrates confidence in the ability of systematic mass media broadcast to disseminate information and ideas, but its power to persuade people to actually change their behaviour is not known. It is significant that only 14% of the CRS respondents could recall the slogan "Helping the earth begins at home", and only 39% recognised the slogan current at the time of the survey, "Wasting energy costs the earth".

Targeted energy advice

The savings delivered by the LEACs demonstrate that advice is successful when consumers request it for an identified problem and particularly when it is combined with feedback. LEEP found no evidence that appliance-specific energy advice provided to a sample of 100 low-income households produced savings for any type of appliance (LEEP, 1996b). This failure could have come about either through resistance to change or because the energy behaviour of the household had changed prior to receiving advice as a direct result of involvement in the BillSavers scheme. Some participants were unable to profit from advice because of structural lifestyle constraints, underlining the importance of ensuring that energy advice is appropriate to the needs and circumstances of a particular household.

Feedback on actual consumption

Providing feedback helps consumers evaluate their personal energy consumption, an important first step towards more informed energy use (Mudyn & Ryzak, 1997). A Finnish study found that feedback could decrease monthly electricity consumption by 5-7% compared to an estimated saving potential of 11-16%, mostly through turning off lights in empty rooms and using heating and hot water more efficiently (Haakana *et al*, 1997).

Electricity bills are a potentially useful vehicle for delivering messages about energy efficiency. Their arrival on the doorstep sharpens the desire to cut costs. Bills could carry information to:

- make people aware of their household energy use;
- compare current usage with previous bills;
- compare the household's consumption with regional and national trends.

The provision of this kind of information may well become a commercial necessity for PESs as a consequence of the liberalisation of the electricity supply market. Many households keep their electricity bills (Hedges, 1991) suggesting that the raw materials do exist for feedback policy in the UK. Nevertheless, there are significant obstacles to implementation on a regional or national scale. For instance, updating the billing system so that all bills reflect actual rather than estimated consumption (this process could be accelerated as the supply industry prepares for liberalisation), and the question of the most appropriate timescale for providing feedback to households.

1.29.3 Future challenges

Changes in appliance usage behaviour need to be sustained rather than short-term. The effectiveness of any BP-oriented policy will depend in part on the support of manufacturers, retailers and other non-government bodies, and on targeting for maximum effect.

Long-term change

Patterns of energy use are the result of deeply ingrained habits and day-to-day routines, and are often constrained by the structural aspects of lifestyle. It is therefore unrealistic to expect to be able to effect immediate changes in behaviour, or to assume that any changes will be sustained in the absence of reinforcement. BP policy needs to be long-term, for example incorporating energy issues into educational curricula, or a series of initiatives put into effect over several years.

Persuading consumers to adopt more energy efficient behaviour may be considered analogous to the uptake of a new, energy-efficient appliance. One of the ideas put forward by innovation theory, that "policy initiatives do not exist in isolation, should be designed to be complementary, and should be in stages to make a progressive and logical transition," (Chapter 4) is relevant here. In parallel to market transformation, the most effective combination of policies for a behavioural transformation will depend on policy objectives as well as the appliance type, trends in usage and the complex factors underlying those trends. BP policy must accommodate the multi-factorial nature of energy behaviour and the possibility that there may exist a "critical threshold" for behavioural change which may be more effectively reached by a combination of initiatives (Strang, 1996).

Alternatively, changing energy behaviour could be compared to the diffusion of an innovation along social or cultural channels (Banks, 1992). Providing people with a powerful model of energy efficiency, thus allocating higher social value to the role of 'energy conserver', and promoting the idea that this behaviour is widespread among the general public could encourage people to make energy efficiency a priority for day-to-day consumption.

Role of non-government bodies

Energy efficiency may soon become a priority in consumer purchasing (Electrolux, pers comm). Until this happens manufacturers and retailers should be encouraged to promote the efficient use of appliances in the home. In a recent voluntary agreement on reducing domestic washing machine consumption, CECED have stated that "it is essential to motivate the consumer to take his share in the process" and proposes that participating manufacturers "will actively promote consumer awareness to save energy when using a washing machine" (CECED, 1997). Another way in which appliance manufacturers could reinforce policy involves the incorporation of easy-to-use energy efficient usage options into all new models. The application of fuzzy logic to control systems means that such options no longer imply reduced performance (IER, 1997).

The powerful influence of retail staff at the point of sale has been demonstrated in a previous report (DECADE, 1997) and could be utilised. Electricity utilities could harness electricity bills for feedback purposes, as discussed above.

Targeting policy for maximum effect

Which groups of consumers are likely to respond?

Consumer profiles can help to identify the most responsive segment of the population. For example, 35% of the CRS sample were influenced by the Energy Label in their decision to purchase a new fridge and bought a more efficient fridge than other consumers not influenced by the label. Furthermore, 50% of the sample expressed values (eg thrift or environmental concern) which made them more rather than less likely to be responsive to arguments for energy efficiency (DECADE, 1997). A Swedish survey found that, while almost half of 2,009 consumers had a positive attitude to conservation or a desire to save money, only 13% (the so-called "knowledgeable energy savers") would respond effectively. The authors concluded that over half of the sample were unlikely to respond to policy of any description because they were indifferent to energy/environmental conservation and prioritised non-conserving values (Kruse, 1992).

Consumers in the CRS sample were grouped on the basis of attitudinal variables, and the four segments resulting from this analysis displayed distinctive patterns of appliance purchasing criteria. Attitudinal variables are demonstrably influential for the purchase of energy efficient technologies, particularly if those technologies are innovative or highly visible (eg compact fluorescent light bulbs or CFLs) (Banks, pers comm). However, applying this technique to appliance usage patterns and receptivity to policy requires different criteria. Segmentation by lifestyle is promising in this regard, since as well as attitudes and values, the concept of 'lifestyle' accommodates the more structural and social variables by which usage is often constrained (Section 5.5, below).

What determines consumer responsiveness?

In a recent survey, only 11% of 3560 respondents were confident that using mains electricity is a cause of atmospheric pollution (GfK, pers comm). In the eye of the consumer, domestic energy use is only tenuously linked to the concept of environmental pollution, and this acts as a barrier to action (Kempton, 1993; Hinchcliffe, 1996). The low understanding of energy issues highlights the need to improve awareness (eg by including these issues in school curricula). Environmental concern is relatively high in the UK, however expressed attitudes bear little relationship to acts of energy efficiency in the home (Kruse, 1992). On the other hand, practical and technical knowledge of energy issues is positively correlated with efficient energy use (see Banks, 1992).

Energy consumption by a particular household is constrained by the circumstances of that household, such as income, number of people, dwelling type (see Section 5.5 on social characteristics, below). An understanding of these constraints can contribute to designing policy aimed at those groups with the largest behavioural saving potential. Most consumers are convinced that they could not reduce their consumption and maintain their standards of home comfort and security (Hedges, 1991) or, if they understand the link between energy and the environment, that their actions will make any difference.

What is the best means of conveying information?

Administering tailored advice to self-selecting consumers is demonstrably the most effective means of conveying information. Of the 13,500-16,500 consumers who visit Copenhagen Energy's Energy Advisory Service for Household Consumers each year, 80-90% request and receive advice concerning the use of appliances, for instance how to make the most efficient use of the oven or maintain the refrigerator for maximum running efficiency (Copenhagen Energy, pers comm). The average visit to the showroom results in a saving of 3% of the consumer's annual electricity bill, while telephone advice results in a 1% saving. Visits to the showroom were the most popular and effective means of securing savings and delivered

6,234 MWh between 1992 and 1996, compared to 600 MWh from telephone advice (Copenhagen Energy, 1996). This reflects the similar success of the LEACs in the UK (EST, 1996).

1.29.4 Implications for policy

Policy that aims to influence appliance usage should consist of a range of initiatives and take into account public knowledge, attitudes and values regarding the environment. Central to the BP policy debate is whether savings achieved through attempts to influence behavioural decisions that must be regularly repeated (ie appliance usage) would be cost-effective compared to policies designed to influence one-off decisions by consumers (ie appliance purchase). Appliance usage is often determined by cultural and social factors beyond individual control, and behavioural savings are likely to be small compared to a one-off investment in efficiency (eg purchasing a more efficient appliance).

1.30 BEHAVIOURAL BARRIERS TO EFFICIENT PURCHASING

Theoretically, consumers should always purchase the appliance that meets their needs at the least life-cycle cost. Howarth notes that "According to the simplest neo-classical models of competitive markets, perfectly informed, rational individuals consider the total costs of their decisions when purchasing energy-consuming equipment. If the value of the energy savings generated by improving the energy efficiency of a device exceeded the cost of the improvement, competitive producers could increase their profits by exploiting consumers' willingness to pay for the change. It follows that under these assumptions that all efficiency measures that were cost effective at prevailing prices would be realised by competitive markets" (Howarth & Anderson, 1993).

However, energy efficient appliances do not spread as rapidly as this assumption dictates. Barriers to energy efficiency include:

- a lack of information for consumers;
- a lack of understanding of running costs;
- structural barriers such as the landlord/tenant problem (in which the landlord is unwilling to invest in efficiency because only the tenant will benefit from the savings);
- focusing on reducing first cost rather than total cost; and
- availability of capital.

A number of these theoretical barriers are rooted in the behaviour or decision-making of the consumer, and are similar to those identified by behavioural studies. The aim of the brief discussion that follows is not to present the economist's view in full, but to illustrate the common ground between behavioural studies and the economist's approach. This is done for the two examples of cold appliances and lighting.

For cold appliances, the main barrier to the diffusion of energy efficient technology (apart from the long natural replacement cycle) has been identified by IEA (1997) as the consumer's lack of the specialised knowledge necessary to calculate returns on their investment. Initial purchase price is seen only as a minor barrier since efficiency tends to carry relatively small price differentials and can offer short payback periods relative to the life span of the appliance. Although within size constraints it would be economically rational to buy on the basis of efficiency, most consumers in the CRS defined price and reliability as the most important factors influencing their choice of cold appliance (DECADE, 1997). Before the advent of the EU Energy Label, information on efficiency was not widely available, therefore consumers were unable to select on this basis. However, informed decisions depend on consumers being able to understand and to interpret the Label, for which many consumers are ill-equipped. If the amount of work needed in order to do this is perceived as being too large, the rational consumer is unlikely to make the effort. In other words, the transaction costs (ie the time, effort or money expended in making and/or implementing a purchase decision) are too high. Minimum efficiency standards will eventually remove this informational barrier, but the process could be speeded up by centralised information services to encourage consumers to take full account of efficiency in purchasing.

The behavioural barriers to the spread of new efficient lighting technology are slightly different, and include: the high initial purchase cost of CFLs; consumer uncertainty as to whether they will realise the expected economic benefits; the complexity of service available compared to largely individualised demand; and the frequent need for specialised knowledge in order to use CFLs to advantage, for instance in order to distinguish suitable and unsuitable fittings. As a result, transaction costs are high relative to the direct costs of the equipment purchased, which rationalises the continued use of less energy efficient lighting and explains why price incentives by themselves are not sufficient reason for consumers to adopt CFLs. IEA states that lighting programmes are “more likely to succeed if they account for the complexity of adoption decisions, rather than merely providing direct subsidies,” eg through the provision of expert help by retailers and/or utilities.

These examples show that consumption behaviour that is financially ‘irrational’ may be rationalised by the in-kind costs incurred and risks perceived by the consumer. An economic analysis of behaviour suggests that a policy focus on information and advice could encourage more efficient usage through improving consumers’ technical knowledge of energy issues, as well as promoting the diffusion of efficient technology.

1.31 SOCIAL CHARACTERISTICS

Targeting behavioural policy such as advice and information campaigns means identifying those who are most likely to change their behaviour. It also requires the message to be aimed at particular types of usage (eg using lower temperature settings in washing machines) or at consumers who own high-consuming appliances and are in a position to take the appropriate action. Certain social characteristics can be linked with ownership and/or high levels of usage (eg ownership and usage of tumble dryers increases with household size). Social characteristics are also helpful for understanding trends in ownership. For instance, currently there may be strong relationships between income or family size and ownership of a particular appliance. But as appliances become cheaper (ie more accessible) or technological changes lead to the manufacture of smaller appliances, such relationships could weaken. Careful plotting of the social characteristics of new owners will thus enable underlying assumptions concerning levels of appliance ownership in the DECADE model to be confirmed or re-assessed.

1.31.1 Recent findings

Understanding of appliance ownership and usage has been enhanced by two new sources of data. The BillSavers2 project studied 100 higher-income households in Edinburgh (LEEP, 1996a). In addition to data on socio-economic parameters and ownership, LEEP collected detailed measurements of appliance-specific electricity consumption (through monitoring) and usage (through energy diaries). These data complement a similar study of low-income households carried out by LEEP (BillSavers1), the results of which have been used to inform previous reports (DECADE, 1995; 1997). The other new data source consists of a sample of 661 households in south-east England (Mansouri & Newborough, 1996).

As might be expected, household size and income are the major determinants of appliance ownership and use, depending on appliance type. These strong relationships may obscure others that may be more subtle yet equally significant. The main points of interest are listed below.

Cold

- Different types of cold appliance showed different relationships between household size and ownership. Upright freezers are most commonly owned by households of 4 people, while chest freezer ownership is more common in larger households.
- Electricity consumption by cold appliances is strongly influenced by household income. Fridges in low-income households consume more electricity than fridges in higher-income households, but the relationship is reversed for freezers and fridge-freezers. This may be because fridges in low-income

households tend to be older, less efficient and are more likely to be faulty. Affluent households are more likely to be able to afford larger freezers, fridge-freezers and high-consumption features such as frost-free (DECADE, 1997).

Wet

- Different types of households show differences in wet appliance electricity consumption. This is due to the number of cycles, rather than to the efficiency of the machine (as in cold appliances). For example, washing machines in pensioner households consume 30% less electricity than washing machines in single-person households, while couples with children use their dishwasher twice as much as couples without children.
- The average size of households owning tumble dryers or dishwashers is greater than four.
- Up to one third of higher-income households in Edinburgh never used their tumble dryer, while less than half of owners in the south-east England sample used it regularly. The reasons for this may include user awareness of running costs, since average annual usage was 92 hours in low-income households and 143 hours in higher-income households.
- The number of tumble dryer cycles is approximately three times greater in winter than in summer, and is reflected in strong seasonal variations in electricity consumption.
- Washing machines in households which also own tumble dryers use on average 35% more electricity than washing machines in households which do not own tumble dryers, even after taking into account the effect of household size. This suggests that households owning tumble dryers tend to make more frequent use of their washing machine.

Cooking

- Electric oven ownership is higher, and gas oven ownership correspondingly lower, in higher income brackets, and two-person households have the highest ownership of electric ovens. These findings may be explained by the fashion for dual-fuel cookers with electric ovens and gas hobs, which are more frequently owned by higher income households (BRE 1995b).
- Household size is a strong predictor of electric cooker (ie oven, hob and grill) electricity consumption.
- Single parents used almost twice as much electricity for cooking as a single person, but only 75% as much as couples with children. Two-person households used more than twice as much electricity for cooking as single person households.
- Electric ovens account for over half of annual electric cooker consumption despite the fact that significantly more time is spent cooking on the hob than in the oven.
- Electric cookers in households owning microwaves consumed 27% less electricity (120 kWh per year) than cookers in households without microwaves, suggesting that microwaves are displacing ovens in households that own them (DECADE, 1995).

Lighting

- There is a strong linear relationship between lighting consumption and number of rooms: an 8-roomed house consumed on average 1350 kWh per year, almost twice as much as a 4-roomed house.
- Household income was a good predictor of CFL ownership in the BillSavers2 sample (figure 5.1). Average CFL ownership in this sample was 1.4 bulbs per household, which compares favourably with the national average of 0.6. Environmental concern is commonly claimed as a motive for the purchase of energy efficient light bulbs (Mansouri & Newborough, 1996). This compliments the CRS finding that high levels of environmental concern were most commonly expressed by consumers in higher income brackets (DECADE, 1997).

Brown

- Ownership of second and third colour televisions is dependent on the number of people in the household.

1.31.2 Implications for policy

BP policy aimed to influence usage could target wet and cooking appliances since these groups show the largest potential for behavioural change. However, appliance usage is often highly constrained by the structural aspects of lifestyle (eg the amount of time spent at work) or the number and age of the household members, and is generally not associated with attitudinal variables such as have been shown to influence appliance purchase. This suggests that the highest consuming households may not necessarily have the greatest potential for savings in real life, and therefore may not be the most suitable target for behavioural campaigns.

Whether social variables can be used to define groups of people based on their response to policy has not yet been demonstrated, but patterns should continue to emerge from detailed studies. At present, while the potential for behavioural savings is significant and to a large degree untapped, installing more efficient appliances into high-consuming households is more likely to make savings than exhorting people to change long-established patterns of use.

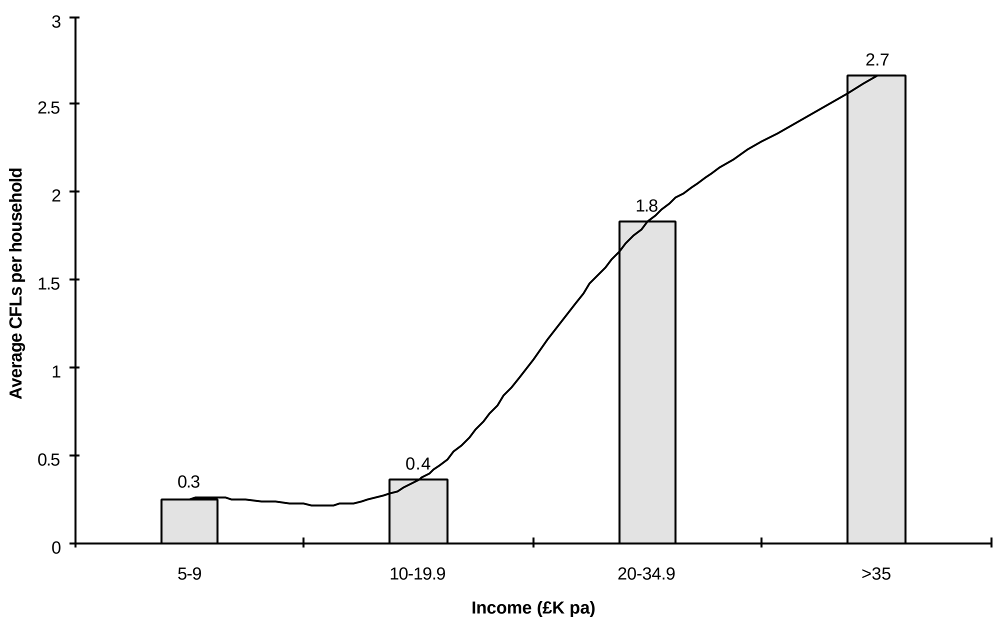

Figure 5.1 Average number of CFLs per household and household income

Source: LEEP, BillSavers2 (1996)

1.32 CONCLUSIONS

The potential exists for electricity savings of almost 12% from domestic lights and appliances by consumers making changes to the way they use their appliances without having to accept reduced service or incurring additional expenditure. Based on Reference Case technology and 1996 appliance ownership and usage, this represents a saving of around 8 TWh or 1 MtC in 2010. The end-uses with the highest potential for behavioural savings are: cooking appliances (behaviour could save over 2.5 TWh in 2010, of which more than one third derives from the more efficient use of electric kettles), wet appliances (over 2 TWh, over two thirds of which from washing machines) and lighting (2 TWh). The feasibility and cost of effecting the behavioural changes necessary in order to make these savings has not been quantified, and there are few indicators about the degree to which changes in usage would be permanent. A survey of previous behavioural policies indicates that, on a per household basis, targeted energy advice administered to self-selecting consumers is the most successful means of securing savings. Social characteristics and lifestyle segmentation analysis provide a basis for discerning the most suitable consumer segments for targeting by behavioural policy (ie which consumers are willing and able to change their behaviour).

However, real-life BP may be less than estimated BP since appliance use is often constrained by the structural aspects of lifestyle. Energy savings from behavioural change could be significant, and may overlap to a certain degree with those available through technical change, but on the whole they are likely to be small compared to a one-off investment in efficiency such as purchasing a more efficient appliance.

CHAPTER 6: FURTHER CARBON SAVINGS

In Chapters 2 and 5 the technical and behavioural potentials for energy savings have been identified and quantified, and policies to access these potentials have been suggested. However, there are still further means by which electricity or carbon dioxide savings may be achieved without affecting the level of service received by the consumer, and these are outlined and discussed in this chapter.

Firstly, CO_2 emissions factors for appliance groups are modelled separately in order to determine which are most polluting per kWh used. This analysis will help identify those appliance groups where greater opportunities for CO_2 savings exist. Annual CO_2 emissions per unit of demand are also calculated for 1995, and for the two different scenarios, RC and ETP2002, for 2010. Secondly, options for fuel switching from electricity to gas for selected appliances are identified and the CO_2 savings which would result are quantified. Finally, electricity savings are identified from behavioural or infrastructure changes which do not fit within the definition of behavioural potential identified in Chapter 5.

There are other policy or technical options, such as a carbon tax or a change in the generating mix, which could reduce CO_2 or electricity usage. However, this report focuses on those changes which are specific to lighting and appliances and not those which would affect energy policy or society more widely.

1.33 CO_2 EMISSION FACTORS FOR DOMESTIC APPLIANCES

Throughout most of this report a reduction in electricity usage has been treated as identical to a reduction in CO_2 emissions. However, CO_2 emissions per kWh vary with the generating mix used to produce the electricity, which in turn depends on demand. The overall demand for electricity varies with time of day, day of the week and month of the year as does the demand for electricity by individual appliances. For example, cooking tends to be concentrated in the early evening, lighting in dark winter days. Therefore, as this chapter will show, because CO_2 emissions per kWh are time-dependent, average CO_2/kWh varies between appliances as a result of differences in their time-dependent usage patterns.

Quantifying CO_2/kWh for different appliance groups allows identification of those for which more CO_2 savings will result for each kWh of electricity saved. It may also be possible to reduce CO_2 emissions without reducing electricity demand for some appliances by time-shifting their use to lower CO_2 emissions time.

Dr Mark Barrett was commissioned to use his 'EleServe' model to estimate carbon emission factors for each appliance group. An outline of the modelling process is given in Appendix D and the results of the modelling are presented below. The CO_2 emissions per unit of electricity per appliance have been calculated for 1995, and for the two different demand scenarios, RC and ETP2002, for 2010. These are shown graphically as a percentage of average kg CO_2/kWh for all UK domestic electricity for each appliance (Figure 6.1).

Cooking is the most carbon intensive domestic end use, followed by lighting and peak heating; off-peak heating is the least intensive. It is possible that EleServe underestimates the carbon emissions of cooking because of the difficulty of accurately predicting the generation sources used around the time of peak demand.

The differences between off-peak and peak carbon emissions, as illustrated by off-peak heating and cooking, point to the advantages of using electricity at off-peak rather than at peak times. There is already an economic benefit to using off-peak electricity for those people on dual tariff electricity. However, most appliance use is either socially (eg lighting and cooking) or technically (eg cold appliances must be constantly switched on) determined and is not amenable to time-shifting to off-peak times.

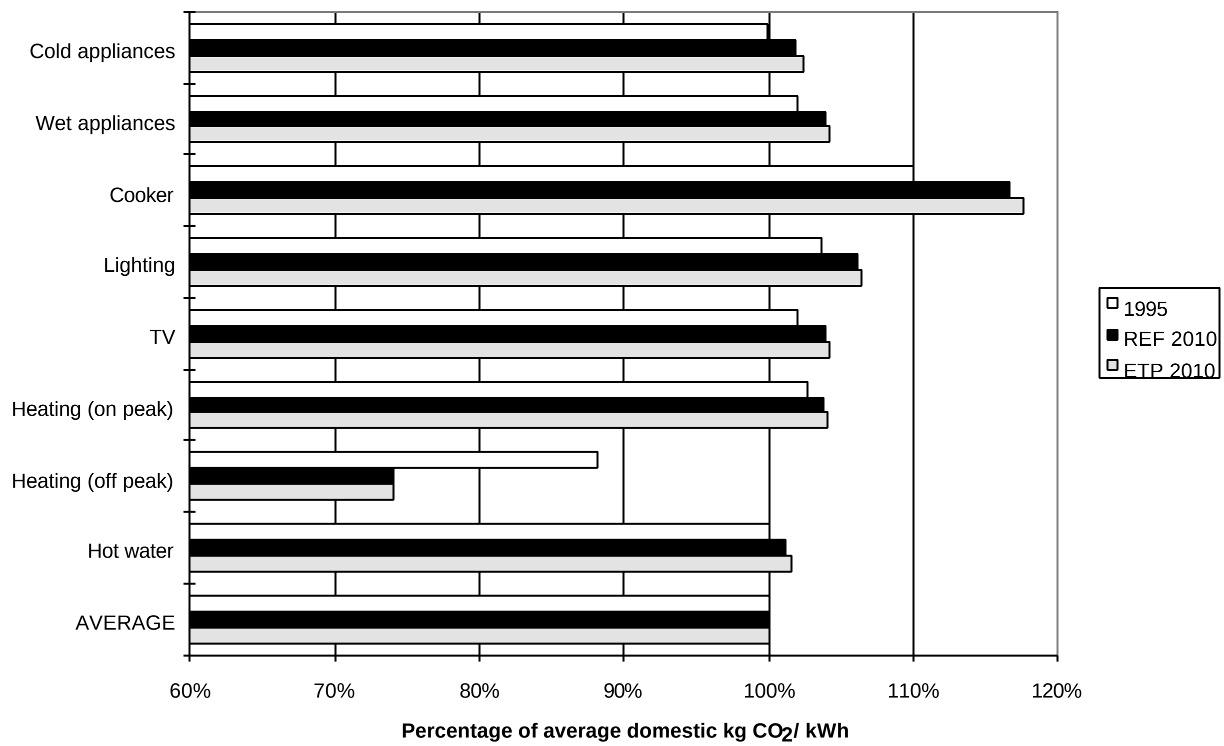

Figure 6. 1 Relative CO_2 emissions per kWh from different appliance groups

Only the wet appliances are amenable to time-shifting without requiring significant behavioural change. If they were used at off-peak times their relative carbon emissions would decrease from 102% to 88% of average, a reduction of 14% carbon emissions for the same electricity use. Using Chapter 2 carbon emission factors, this would amount to a saving of 0.26 MtC in 2010. These appliances are already used off-peak by a considerable proportion of those using dual-tariff electricity (EHCS, 1996), which has been taken into account when calculating emissions factors for the wet appliances. This suggests that time-shifting is a behavioural change that (at least some) people are prepared to make, where there is a financial incentive to do so.

In 2010 under both scenarios the difference between peak and off-peak electricity demand is much increased compared with 1995. This can be explained by the projection that in 2010 low or zero carbon energy generation sources will make up the majority of the off-peak electricity supply and high carbon sources such as coal and oil will only be used at peak times (Appendix D, Figure D.3).

The other major result from EleServe is the calculation of total domestic carbon emissions separately under the RC and ETP2002 scenarios to 2010 using carbon emission factors specific to each scenario (Table 6.1). Total carbon emissions fall in both scenarios up to 2000. Thereafter they rise in RC as demand increases, whereas in ETP2002 carbon emissions fall. Carbon emission factors fall across the period in both scenarios, but fall faster in ETP2002 than in RC. They differ between RC and ETP2002 in 2010 due to the different generating mixes that would be required to meet demand under each scenario (see Figure D.3, Appendix D).

Also included in Table 6.1 are carbon emission figures from EP65 (CL scenario: EP65, 1995), and the carbon emission factors used in Chapter 2 for comparison. Clearly there are differences between the projections made by EleServe and those in EP65. This is hardly surprising given the difference in the structure and assumptions of the two models. It is worth noting that EP65 electricity supply figures for 1995 were the results of a projection, which under-estimated electricity supply in 1995 at 297 TWh, the actual figure was 333 TWh (DUKES, 1996). It is this actual figure which was used in EleServe, the 10% electricity supply underestimate in EP65 explains some of the difference between the EleServe and EP65 carbon emissions in 1995.

Table 6. 1 Carbon emission factors and total carbon emissions, UK, 1995-2010

	Carbon emissions (MtC)			*Carbon emission factors (kg CO_2/kWh)*		
	RC	ETP2002	EP65	RC	ETP2002	Chapter 2
1995	48	48	40.2	0.57	0.57	0.53
2000	40	35	36.6	0.44	0.41	0.44
2005	44	33	38.4	0.44	0.40	0.51
2010	46	30	36.5	0.42	0.37	0.47

Using the kg CO_2/kWh figures provided by EleServe, 2010 carbon emissions under RC would be 9.2 MtC, and ETP2002 would be 5.4 MtC (which compare with 10.3 and 6.9 MtC respectively using EP65 conversion factors). Thus, the savings predicted using differentiated conversion factors for RC and ETP2002 are greater at 3.8 MtC than those where a single conversion factor is used, 3.4 MtC (Chapter 2).

The precise details of EleServe's output are less important than the general conclusions that can be drawn. This work is not being put forward in order to challenge other electricity supply projections but to facilitate discussion of the issues that arise and highlight interesting areas for further research.

1.34 FUEL SWITCHING FROM ELECTRICITY TO GAS

Using natural gas has the major environmental benefit that CO_2 emissions per unit of delivered energy are 0.19 kg CO_2/kWh (BRE, 1995a) compared with 0.53 kg CO_2/kWh for electricity (Table 6.1). Thus the potential for savings by converting from electricity to gas in the domestic appliance sector are significant, with each kWh of gas producing approximately 3 times less CO_2 than each kWh of electricity delivered to the home. The reason for the difference comes mainly from the conversion of primary fuels into delivered energy in the power station, the average efficiency of which is 36% for conventional steam stations (DUKES, 1996). However, most electricity is then used with 100% efficiency in the home. The gas delivered to the home is still primary energy where there are conversion losses of approximately 50% (this figure is extremely dependent on the appliance, boiler or water heater design in question). Despite these conversion losses, using gas results in lower carbon dioxide emissions.

Since natural gas became readily available in the UK as a domestic fuel in the early 1970's, gas (including town gas, prior to 1989) has grown from providing 24% of energy supplied to the domestic market in 1970 to 66% in 1995 (DUKES, 1996). British Gas supplies gas to over 19 million homes in Great Britain (British Gas, 1996). There are approximately 24 million UK households in 1996, implying that 79% of households have access to gas.

Gas is a cheaper fuel than electricity per kWh and, all other things being equal, it is to the consumer's economic advantage to choose gas wherever possible. Indeed, the majority of space and water heating is fuelled by gas. However, with appliances the situation is more complex. The ownership of gas appliances has declined since the 1970's. For example, in the 1970's a proportion of UK households had a gas washing machine or clothes boiler and gas clothes airers were used to dry clothing. These laundry products are now almost exclusively electrical. At present, gas consumption by appliances is a very small proportion of the total domestic gas use, with gas cookers being the only gas appliance in wide ownership.

1.34.1 CO_2 savings potential

Data on gas appliance efficiency are hard to come by. At present there are no EU Energy Labels for any gas appliances and no test procedures for measuring efficiency. This makes calculating CO_2 savings from switching from electricity to gas difficult and subject to error. In addition, there is known to be significant potential for increasing the efficiency of gas appliances - switching to more efficient gas appliances would achieve greater savings than those estimated here.

Summary

The potential savings from switching from an electric to a gas appliance at the same level of service are summarised below (Table 6.2).

Table 6. 2 Potential CO_2 savings obtainable by switching from electricity to gas

Appliance	*CO_2 Savings (%)*		*Savings in 2010 (MtC)*
	per appliance	*Total UK*	
Tumble dryers	50%	40%	0.24
Ovens	50%	40%	0.20
Hobs	66%	53%	0.22
Kettles	90%	72%	0.40
TOTAL			**1.06**

The totals for the UK are based on all those households which are currently connected to mains gas (79%) switching to the appliance in question.

Tumble Dryers

Despite a marketing drive in the early 1990's to promote gas tumble dryers, the penetration figure remains extremely low. Five years ago models were available from Cannon, Parkinson Cowan and Crosslee. In February 1997 only one manufacturer in the UK, Crosslee, continues to manufacture gas tumble dryers. Sales have been steady at 3-4,000 appliances per year rising to 5,000 in 1995 (Crosslee Sales Department, pers comm).

Based on the energy consumption per cycle of gas and electric tumble dryers, a typical gas tumble dryer on the UK market generates half the carbon dioxide emissions of the average new electric tumble dryer.

Ovens and hobs

In 1972, 56% of cookers were gas, however, by 1993 dual-fuel cooking was gaining popularity, favouring gas hobs and electric ovens. This clearly indicates that gas and electricity are discriminated between as cooking fuels.

Several major cooker manufacturers were contacted in 1995 for efficiency ratings (Ethical Consumer, 1995). Most of the companies were able to give data for electric models, but only one gave figures for gas ovens. The companies' explanation for this lack of information was that energy efficiency was not an area of consumer concern. Despite the proven savings on cost to the consumer and on CO_2 emissions of gas cooking equipment, the gas ovens tested proved to be 3 times less efficient than the best electric models. However, on average, gas ovens produce about half the carbon dioxide emissions of electric ovens, and gas hobs produce about one third those of their electric counterparts. These figures are necessarily approximate due to the current lack of good data.

Kettles

Ownership of electric kettles has risen from 59% in 1971 to 93% in 1992, despite ownership of electric hobs having only increased from 40% to 46% over the same period (ie gas hobs are in wide ownership). This suggests there is a considerable potential for people to return to using kettles heated on gas hobs, should they wish to do so.

If a kettle heated on a gas hob replaced the use of an electric kettle CO_2 emissions could decline to as little as one tenth their present value. This saving would result from the combination of less carbon-intensive fuel, lower water consumption in gas-top kettles (in which it is not necessary to cover the element), and reduced likelihood of consumers needing to re-boil a kettle which whistles upon boiling.

1.35 FURTHER BEHAVIOURAL AND INFRASTRUCTURAL CHANGE

In Chapter 5 the concept of behavioural potential (BP) was developed as an estimate of how much energy could be saved by changes in behaviour which would not result in a significant loss of service to the consumer. To be included as part of BP the changes in behaviour had to be available at zero cost to the householder and must have been actions which the householder could take immediately. However, these are not the only type of actions which can be taken by the consumer to change the energy consumption of their appliance in use.

Set out below is a list of actions which could be taken by the consumer either at some cost, or which are changes which may require a different infrastructure which would save energy (Table 6.3). Some of the assumptions made in these calculations are quite uncertain, however, care has been taken to make them conservative.

Table 6. 3 Potential energy savings from behavioural and infrastructure changes

Appliance	**Behaviour**	**UK Savings Potential (%)**	**Savings in 2010**	
		Per action	**GWh**	**MtC**
All Cold	**1.** repair faults	2.3%		
	2. refrain from positioning next to heat source	1.5%		
	3. refrain from enclosing in badly constructed fitted cabinets	2%		
	Actions 1 - 3	5.7%	918	0.12
Washing machine	**4.** connect to hot water supply	1.3%	70	0.01
Dishwasher	**5.** connect to hot water supply	27%	618	0.08
Hobs	**6.** buying new pans without warped bases	3%	95	0.01
TOTAL	**Actions 1 - 6**		**1700**	**0.22**

Cold appliances

The energy consumption of cold appliances can be decreased by a changing a number of factors, some of which would require more major changes to lifestyle and infrastructure than others.

1. Energy can be saved by repairing faulty appliances. Billsavers data showed 9% of appliances in middle-income households and 52% in low-income households to be faulty but working. Faults increased energy consumption by 5-20%. Energy savings of 2.3% could be achieved by repairing faults on the assumptions that 23% of UK cold appliances are faulty (assuming twice as many middle-income as low-income households) and that the average energy saving after repair is 10%. However, identifying faulty cold appliances is often difficult.

2. Energy consumption can increase by 10-20% if cold appliances are positioned next to an oven or other heat source. Assuming 10% of appliances are badly positioned, energy savings of 1.5% should be possible if those appliances were moved to a more suitable location.

3. Fitted cabinets can cut off the cool air flow to cold appliances with a resultant 10-90% increase in energy consumption (DECADE, 1995). Assume 20% of cold appliances are in restricted air-flow cabinets resulting in a 10% increase in energy consumption. Altering the cabinets to allow free air flow would save 2% of cold appliance electricity.

Washing machines and dishwashers

Electricity savings in washing machines and dishwashers can be made by connecting these to hot water supplies because the energy used for heating the water is external to the appliance. This water will usually be heated by gas.

4. For washing machines connecting to hot water supply saves 30% of appliance electricity use for washes at 60°C. 10% of UK appliances not connected at present and 42% of washes are done at 60°C and above (Chapter 5). This gives a potential energy saving of 1.3%.

5. For dishwashers connecting to hot water supply saves 30% of appliance electricity use. 90% of UK appliances not connected at present. This gives a potential energy saving of 27%.

However, clearly energy (either electricity or gas) is still used to heat the water, so the figures in Table 6.3 are over-estimates of the system energy savings. There is the additional consideration that the actual savings will depend on the length of pipe run from water heater or tank to the machine: the longer the pipe run the more ‘dead’ (i.e. cold) water there will be.

Hobs

6. One third less energy is required when cooking with flat-bottomed pans on hobs (DECADE, 1995). Assuming 10% of cooking is done with warped pans, replacement of these could result in 3% energy savings.

1.36 CONCLUSIONS

Time-shifting the usage of appliances, switching to gas and undertaking further changes in behaviour or infrastructure all have the potential to make energy and/or CO_2 savings.

The work on appliance-specific carbon emission factors has two clear outcomes:

- reducing energy consumption at times of peak demand will affect carbon emission more than at off-peak times, therefore more effort should be concentrated on cooking and lighting in particular;
- time-shifting use of appliances to times of lower demand can achieve CO_2 savings.

Focusing on electricity generation and supply highlights the large reductions in generation capacity requirements, fuels and other resources for generation that are brought about by energy saving under the ETP2002 scenario. The benefit of avoiding the need to invest in supply is not analysed in this report. Others, notably Krause *et al* (1995), have looked at this aspect in detail.

The three key gas appliances are cookers (including ovens and hobs), kettles and tumble dryers. Of these, tumble dryers would seem to present the best opportunity for fuel-switching as gas tumble dryers can present the same service to consumers as those powered by electricity, whereas gas cookers and kettles provide a somewhat different service to electric cookers and kettles. The EST are currently undertaking preliminary work into the feasibility of promoting (and subsidising) the purchase of gas tumble dryers.

The UK Government and the EU have historically been reluctant to suggest a preference for one fuel over another. Movement of companies to present themselves as energy rather than as gas or electricity companies (combined with the environmental benefits) may make promotion of fuel switching more politically acceptable. For example, British Gas have stated in their 1996 Annual Review: “We are also looking at offering a combined gas and electricity service to domestic customers once the electricity supply market is opened up to competition, which is expected to happen in 1998.” In another example of the same development, Southern Electric are now also advertising savings to be made by signing up to ‘Southern Electric Gas’.

All of the actions identified in this chapter could be undertaken in addition to the policies in Scenario 1 (Chapter 4) to achieve greater CO_2 savings. Savings from further behavioural and infrastructural change may be difficult to access, as in some cases they require considerable investment by consumers. However, their inclusion helps illustrate the wide range of actions which can result in significant CO_2 savings.

CHAPTER 7: SUMMING UP - 2 MTC BY 2010

More than 2 MtC could be saved by 2010 in the UK through policies to reduce electricity consumption in domestic lights and appliances. These savings would be achieved without any drop in the level of service provided to consumers and are delivered through the sale of more energy efficient lights and appliances. The policies depend upon a strategic approach to carbon dioxide emissions in this sector that is strongly supported both in the UK and in the European Commission.

The UK Government has set a target of a 20% reduction in CO_2 from 1990 levels by 2010, from all sources of emissions. This is a total of 35.4 MtC to be cut from the level expected in 2010 under present trends. This is a challenging target and will require strong policy strategies from all sectors. Savings will be most attractive where they can be made at zero or negative net societal cost, where certainty is high, and where savings can be made quickly due to relatively high rates of turnover. Appliance programmes score highly in all three regards.

The EU approach to Kyoto has been to assess the individual Member States' programmes, which add up to an expected 10% saving. This compares with the European Community's goal of 15%. The opportunities to cover the shortfall come under the EC's common and co-ordinated policies designed to find the extra 5%. The scenarios presented in this report are clearly relevant within Europe, given the reliance on European policy actions and the potential for other European countries to replicate the suggested UK procurement and rebate programmes.

The Kyoto discussions are expected to be framed in terms of CO_2 savings only, for pragmatic reasons. However, the production of electricity is responsible, directly or indirectly, for the emission of other greenhouse gases. Whilst these may not be part of international agreements, they are still contributing to global warming.

1.37 Reference Case

Under the Reference Case (Chapter 2), electricity consumption in domestic lights and appliances is projected to increase by 6 TWh from 1996 to 2010. This is a slower rate of increase than has occurred in the previous 25 years, during which time consumption has doubled. Nevertheless, the effect of present policies is insufficient to offset the growth in electricity demand due to an increasing number of households, patterns of higher usage and increased appliance ownership.

The acquisition of additional data since Run 2 in 1995 has resulted in little overall change in consumption in Run 3, whilst improving confidence in the output. The model has been enhanced to include confidence limits and these provide even greater support for the results of Run 3. The error margins for current energy consumption are relatively narrow (only a 5% chance that true energy consumption differs from the figure given by more than ± 9%), but are greater for past and future consumption, and increase into the future. By 2020 the error margins for electricity consumption have widened to ± 22%. Future uncertainty increases due to the difficulty of confidently projecting appliance ownership levels, changes in technology, number of households, use of appliances and response to policy - all the variables that determine total electricity consumption. For instance, there is uncertainty about the total number of light bulbs in the home in future, the anticipated technical efficiency in ovens and hobs, the effect of minimum standards in 1999 on the rate of technological change in cold appliances, and the future levels of washing machine use.

One issue that might be thought to cause variation in appliance consumption is economic factors, including both income elasticity and price elasticity. With regard to income elasticity:

- Firstly, increasing household income is likely to mean increased appliance ownership and this has been incorporated into the model, with future ownership modelled as a projection of existing trends. Whilst appliance purchase may vary with economic conditions, appliance ownership is less influenced, since many purchases are replacement purchases, and in less favourable economic conditions, new purchase is postponed and average appliance lifetimes increase. The net effect on ownership and therefore consumption is not large;
- Secondly, in terms of income and usage, households in more recent hardship may reduce use (eg newly unemployed families may reduce tumble dryer usage, or pensioners may tend to under-illuminate their homes) but this has been accounted for by using measured consumption data. In general appliance usage is broadly resistant to changes in economic conditions;
- Thirdly, a general increase in household income over time is unlikely to prevent low-income households suffering lower levels of service (both ownership and usage), unless these problems are tackled explicitly by policy. This theme has been incorporated in the modelling of the Reference Case and Scenarios 1-3.

With regard to price elasticity, evidence analysed in the course of DECADE suggests that while price elasticity is likely to vary between end uses (being less elastic for cold appliances, and more elastic for lighting) consumption in appliances is relatively inelastic with energy price compared to other end uses such as space heating. As a result, increases in electricity price (eg through a carbon tax) are unlikely to restrain appliance use. For these reasons the analysis concentrates on technical and behavioural issues, rather than economic issues.

In addition to a growth in electricity demand in lights and appliances, CO_2 emissions per unit of electricity are likely to start increasing as emissions factors rise again after 2001. The reductions of the last few years have been achieved by the growth in gas-powered electricity generation and the greater use of nuclear power. As these changes take place at a slower rate and with the probable decommissioning of some Magnox stations, CO_2 emission factors will begin to rise. This will mean that the growth in demand coincides with more polluting electricity to give a double impetus to higher levels of CO_2 emissions.

This is the backdrop for the Government's commitment to reduce CO_2 emissions by 20% over 1990 levels, from all fuels and all sectors, by 2010.

1.38 Economic and technical potential

The Economic and Technical Potential (Chapter 2) is substantial: 33% of the Reference Case could be saved by 2010, and 42% by 2020. The major savings come from lighting and the cold appliances, though tumble dryers, TV screens, ovens and hobs also represent substantial opportunities for the development of innovative, efficient technology that is cost effective for the consumer. As discussed throughout the report, the ETP level identified here is likely to an underestimate of the cost effective savings which could be achieved through more efficient technology.

If the market is allowed to develop naturally (ie without further policy intervention) the ETP level currently envisaged may take several decades to reach, or may never be reached. The proposal in Scenario 1 is for the ETP level to be reached by or before 2010 for appliances and by 2020 for lighting. This would save at least 2MtC.

1.39 Policy choices

Savings could be accessed by a range of policies, over a variety of time scales (Chapter 3). The primary policy division is between decisions made by national government and those promulgated by the European

Commission. Domestic lights and appliances are internationally traded goods. Mandatory requirements (either Energy Labels or minimum levels of efficiency) must therefore be introduced at the level of the single market, in order to avoid barriers to trade within that market. Mandatory standards and labels produce substantial savings at minimal cost to the consumer and government. Voluntary agreements and Energy Labels make a less dynamic combination. This is because the negotiations for voluntary agreements are driven more by what could be achieved in the short term at the least first cost to manufacturers, rather than, for instance, the importance of international emissions targets, or least life cycle costs to consumers.

National governments can, either independently or with other Member States, provide policy support by technology procurement to underwrite important innovative products, and through rebates and financial incentives.

1.40 Strategies for market transformation

Individual policies are important, but the combination of policies into a coherent strategy invariably provides greater savings as a result of the synergy achieved. This underlines the importance of a strategic approach to policy that combines all levels of government and a clear timetable. The choice of policies, their timing and sequence can be specific to the particular appliance group. Chapter 3 noted three key points in terms of programme design:

1. Innovation, consolidation and maturity are very different stages in the development of a technology and need to be dealt with in different ways by policy. Innovation can be promoted by incentives or procurement. Market consolidation involves overcoming many sub-barriers and requires substantial financial support over 3-4 years. Market maturity can be encouraged through minimum standards;
2. The long term costs of mature markets have been overestimated because analysis has ignored the fact that the current additional price of efficiency (if any) may be due to existing structural barriers. If these are removed, the cost of efficiency may be close to zero;
3. The real costs of programmes are policy dependent. Much of the additional cost involves start-up costs which can be supported through procurement and rebates, while minimum efficiency standards access economies of scale, and may approach zero cost to consumers.

In addition to these guides, there are a number of wider criteria in developing a strategy.

- **Level of reduction:** Three different scenarios have been developed, each of which delivers a different level of savings. 2010 has been chosen as the end date, because it is the basis of the climate change discussions in Kyoto in December 1997.
- **Degree of certainty:** The targets to be agreed in Kyoto are in the context of legally binding commitments. Thus it has been assumed that the Government's objectives for any strategy for 2010 will include the confidence that the target can be achieved. Certainty is also important to manufacturers in providing a framework for investment and development over a 12 year period. With domestic lights and appliances, this confidence can be improved through a clear strategy, using combinations of policies and inclusion of mandatory regulation.
- **Equity:** another objective that is thought to be important to the UK Government is equity. Many low-income households purchase less efficient, second-hand appliances, because that is all that they can afford. To enable poorer families to obtain good, efficient appliances is expensive, but in Scenarios 1 and 2 this task is combined with the promotion of new technology, so that the policy is achieving two objectives at the same time. These dual objectives justify the most expensive part of the scenarios - establishing the base level of demand for a new technology and ensuring that the poor benefit.
- **Costs:** In all scenarios, the costs to consumers are negative, because of the emphasis on minimising life-cycle cost (any additional costs of the proposed technologies are repaid within a few years from the savings during use). The costs to manufacturers are minimised through the definition of a clear framework, so that they can plan developments over the next ten years with confidence, and use rebates to support the dissemination of innovative products. The emphasis on minimum standards will

reduce any fears manufacturers have about unfair competition from producers outside Europe - all appliances have to comply, whatever the country of origin - and thus the market for their newly-developed products is assured. There are costs to the Government and these vary with the different scenarios.

1.41 Scenarios

Three scenarios which are based on the different permutations of policy in Europe and the UK have been described. Policies on efficient appliances could be promoted with either a strong or a weak level of commitment, in both these legislative arenas.

The scenarios have been based on the assumption that to get a new technology up to around 20% of the market requires support through a combination of procurement and rebates from strong national policies. Once new technologies have been successfully developed, they provide the basis on which to build a regulatory framework of minimum standards. If there is a strong EU commitment, then the remaining (approximately) 80% could be delivered within the tight timetables required. A higher level of rebates will be needed if equity is an important issue. Given that 25% of cold appliance purchases are second-hand, and 33% of households are in receipt of some form of means-tested benefit, up to one-third of savings may come from rebates.

These policies are realistic if the political will is there to support the strategy, but they will not be achieved without a firm and co-ordinated approach that extends throughout the European Union and the UK.

1.41.1 Comparison of scenarios

The scenario that is most successful in achieving the objectives defined above is the pairing of a strong Europe with a strong UK: Scenario 1. This Scenario would save 25% (20 TWh) of the electricity for UK domestic lights and appliances in the Reference Case in 2010, demonstrating that the 2MtC is a substantial and useful contribution to the Government's overall target of 20% reduction in CO_2 emissions. By 2010, the value of Scenario 1 to the average household would be an average annual saving of £60 in the electricity bill, at today's prices. This saving would be equally distributed across income groups, because of the use of targeted rebates. The electricity saving is worth £1.4 bn in 2010.

The cost of Scenario 1 is £2.7 bn for the UK over the whole period, but this cost is increased by the assumed objective of equity, through installing efficient equipment in low-income homes. The greatest savings come from cold appliances and from lighting and these are also major areas of expenditure. Within both these sectors, there are two or more innovations to work through the market, hence the additional costs. For refrigeration appliances, there is the two-stage introduction of vacuum insulation panels. In the lighting sector, the traditional incandescent bulb is replaced by a sequence of compact fluorescent bulbs. The older magnetic bulbs are already being phased out and replaced by electronic CFLs. CFLs currently have integral ballasts as part of the bulb, but major savings will be made when these ballasts are built into the light fitting instead and the bulb becomes much cheaper. These dedicated fittings prevent households from reverting to older, less efficient bulbs and thus guarantee the savings.

All the expenditure, whether by individual households or the £2.7 bn from national policies, will be cost effective. The source of the £2.7 bn has not been identified, since whether this sum is raised through a levy on electricity usage (as for the present Energy Efficiency Standards of Performance), or whether it comes from general taxation (as do most of the Energy Savings Trust's funds) will depend upon other government policies.

How do savings in domestic lights and appliances compare in terms of cost to savings in other areas? According to the English House Condition Survey Energy Report (EHCS, 1996) a 30% saving in space heating energy would cost £27 billion, and a 50% saving would cost over £80 billion. Space heating accounts for 56% of all domestic energy. Lights and appliances are around 15% of domestic energy consumption and under Scenario 1 a 25% saving costs £2.7 billion. Per unit of energy saved, Scenario 1 for lights and appliances costs £0.72 billion per 1% of domestic energy saved whereas improvements to space heating are £1.6-2.85 billion per 1% of domestic energy saved. However, improvements to space heating will displace mostly gas, and the carbon content per kWh of delivered energy for gas is less than a third of that for electricity. Thus improvements in lights and appliances save carbon emissions at a cost around an order of magnitude lower than improvements to space heating. Water heating is not included in this analysis, though a forthcoming EU study treats water heating as another appliance group and shows costs to be close to those for other appliance groups.

Scenario 2 provides about half the savings of Scenario 1, but for the same cost. This is because the savings achieved by investment in national programmes are not amplified by firm European policies, but are linked to weaker voluntary agreements with manufacturers. Scenario 3 would save only 0.4 MtC in 2010, but at lower cost to the Government than Scenario 1 or 2. In this scenario, there are voluntary agreements with industry in most sectors, but no technology procurement or rebate programmes to be funded nationally. Scenario 3 is cheap, uncertain and inequitable.

1.41.2 Alternative scenarios

There are alternative ways in which scenarios could be assembled, based on the principles discussed in Chapter 3. For example, the cost of national policies could be reduced. For instance, £2.1 bn of the £2.7 bn expenditure is on the lighting programmes. If these are omitted, Scenario 1 delivers 1 MtC for about £0.5 bn. The rebates targeted on low-income households are only appropriate if equity is a Government objective. Another way to reduce the cost of Scenario 1 to the UK would be for several European countries to share the technology procurement programmes.

The mix of policy in the UK to address climate change will depend upon the options and costs of reducing CO_2 emissions in other sectors. It could be that there are more cost effective savings elsewhere. However, as has been pointed out, savings will be most attractive where they can be made at zero or negative net cost, where certainty is high, and where savings can be made quickly because of relatively high rates of turnover. Appliance programmes score highly in all three regards.

1.42 Additional savings

The major savings are achieved through the purchase of more efficient equipment as a result of the market transformation strategies defined in the scenarios. Further savings might be available through changing behaviour, at no cost to the householder and with no diminution of service (Chapter 5). The potential identified is around 8 TWh, almost 12% of the Reference Case in 2010. The savings from behavioural changes and those from technical change overlap to a certain extent (which differs between scenarios) and are not purely additive. This substantial saving might be a chimera; it will undoubtedly be expensive to access and, perhaps, of limited durability. However, some savings from the wiser use of equipment might be delivered by successful awareness and education campaigns.

Other reductions would come as a result of investment in infrastructure within the household, particularly if this permits the use of gas instead of electricity (Chapter 6). Fuel switching opportunities exist for cooking and gas tumble dryers and, indirectly, through the use of hot-fill machines where the water is heated by gas externally to the machine, rather than by electricity in the appliance. Both washing machines and dishwashers can be hot-fill. Additional household capital investment, external to the appliance, could make savings, for instance through the more careful positioning of refrigerators and freezers in fitted kitchens. If the cold appliance is tightly enclosed in a cabinet without adequate ventilation, heat from the compressor builds up and can double electricity consumption.

A more sophisticated aspect of assessing carbon dioxide savings comes from linking the time that an appliance is used with the electricity generation mix providing the electricity at that moment. At times of peak electricity demand, more of the supply comes from rarely used stations that generate at above-average levels of pollution. These CO_2 pollution peaks coincide with peaks from appliance usage. The highest levels of CO_2 emissions result from cooking. This insight provides a special focus to policies to improve the efficiency of cookers and to look at the opportunities for fuel switching to gas cooking. Although only an initial study, it indicates a new way in which policies could deliver additional savings. All of these extra options could be useful in meeting the challenge of a 20% reduction in UK CO_2 emissions by 2010.

1.43 The british presidency, Europe, Kyoto and beyond

EU Member States have current national programmes which add up to an expected 10% saving in CO_2, compared with the European Community's goal of 15%. The opportunities to cover the shortfall come from both new national programmes and from the EC's common and co-ordinated policies. A key follow-up action from this report would be to quantify savings from each scenario across the EU. As a rule of thumb, given the relationship between the UK and EU populations, if the UK saves 2.7 MtC, the EU may save around 14 MtC pa under Scenario 1, 7 MtC under Scenario 2, and 2 MtC under Scenario 3 (though these may be overestimated given the high appliance ownership, lower appliance efficiency, and high average carbon emission factor in the UK compared to the rest of the EU).

There is a key opportunity with the coincidence of the climate change negotiations in Kyoto, and the British Presidency of the Council of Ministers beginning in January, for agreement on a new approach. With a commitment to a 20% reduction in CO_2 the Labour Government has put itself in a leading position. A new pan-European approach to appliance market transformation could help underpin that position with at least 2 MtC savings in the UK, and at the same time would help Europe to make concomitant savings.

Any minimum standards agreed within the European Union will undoubtedly make additional savings elsewhere since European manufacturers export to Eastern Europe and beyond, and because more efficient appliances are produced by companies wishing to import to Europe. However, a strong framework for mandatory standards is more than the sum of its parts. A Framework Directive may be copied in other markets: parts of Latin America and China are adopting US test protocols and standards, while other countries may follow an EU model. If other countries follow a particular set of tests and standards they tend to develop stronger relationships with manufacturers experienced with that framework, and technology agreements and export agreements may follow. This exporting of a policy model provides benefits not only for manufacturers but also for governments. It may ease the climate negotiations in Kyoto if developing nations have a clear policy model to adopt to begin the task of monitoring and reducing CO_2 emissions.

1.44 Developing a strategic policy towards lights and appliances

There are several key discussions and questions arising from this study.

Firstly, where would the money to fund UK procurement and rebates come from? Possible sources include:

- investment by the Public Electricity Suppliers (eg as a result of agreement over the Rational Planning Techniques Directive);
- investment by the Energy Saving Trust or by Local Authorities under the Home Energy Conservation Act (HECA) through levy financed demand side management programmes;
- general taxation, specifically through measures to improve conditions for low-income households.

To put the extent of the funds required into perspective, it equates to approximately ten times the £1 per customer per annum that OFFER currently puts into Standards of Performance money. However, OFFER announced cuts in electricity bills on 17 October 1997 equal to £24 off the average bill over the next two years, with the reduction taking place in two stages, £16 in April 1998 and £8 the following April. If the cut planned for April 1999 were diverted to fund Scenario 1, it could deliver a saving of £60 in the average electricity bill by 2010.

Secondly, to what extent is equity as well as efficiency a priority for government? Equity has been assumed to be a priority in the construction of the scenarios. Expenditure may well be limited in practice, however, and it may be too expensive for government to implement programmes which aim at both increase of market share for efficient technologies, and take-up of efficiency in low-income households. There are clear problems with this approach. Increasing take-up in low-income householders is a key incentive to manufacturers to collaborate on the development of standards programmes. If this rebate programme is removed, the package may appear less attractive to the manufacturers.

Thirdly, is the assumed split in terms of effect between rebates and standards justified? From a theoretical perspective, achieving 20% market share for efficient technologies was assumed to be the key for removing structural market barriers. However, if equity issues are included, the share of savings that come from investment rather than regulation may change, and if 8 million households (33%) are accepted as being in receipt of some form of means-tested benefit and therefore in poverty, as much as 33% of savings may have to come from investment rather than regulation.

Fourthly, all of the analysis so far has been carried out on the basis of the UK situation. Given that many options may only be introduced at the level of the single market, more analysis of potential savings in other countries and discussion about the foundation for policy (eg policy selection criteria) would be crucial in preparing for EU-wide agreement on a future strategy.

Finally, a great deal of further evidence is needed to support the process of market transformation regardless of the approach taken in future (assuming a more integrated approach). This need is persistent and could be met by monitoring and research in order to establish at least the following points:

- whether unexpected developments are occurring in the underlying trends in consumer behaviour, for instance, increasing ownership of frost-free freezers. These trends could be counter-productive as they result in increased consumption and, therefore, the need for more stringent policies to achieve the net saving;
- the relationship between cost and efficiency in sales data as examined in DECADE (1997);
- the extent to which Energy Label categories should be revised given the effects of changing sales patterns, and previous rounds of efficiency standards and voluntary agreements;
- the effectiveness (or otherwise) of individual programmes as part of an overall strategy, and (most importantly) the relationship between investment and regulation for any individual product category;
- the effects of changes in technology, equipment and energy price on the level of Economic and Technical Potential, as defined by the least life cycle cost (and therefore the optimal level for mandatory efficiency standards);
- whether new technologies are now viable and can be included as a procurement initiative; and
- whether, as a result of the above, what is being achieved is in line with the overall strategy, or whether the strategy needs to be reviewed.

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APPENDIX A: GLOSSARY

BP (Behavioural potential) - an estimate of how much energy could be saved by changes in behaviour relative to projected consumption in the Reference Case. The behavioural changes identified for the BP must meet three criteria: they must be actions which do not result in a loss of service to the consumer, which the consumer can carry out immediately and at zero cost. The BP does not therefore identify all of the potential energy savings through behaviour. The proviso that there should be no loss of service fits with the philosophy underlying ETP.

Brown appliances - see Appendix B.

Business As Usual (BAU) scenario - see Reference Case.

Carbon dioxide (CO_2) - a major greenhouse gas and the main gas produced when fossil fuels are burnt. One molecule contains one atom of carbon and two atoms of oxygen, with the relative weights of 12:16:16. Carbon dioxide can be weighed on the basis of either the carbon content (12) or the whole molecule (44). In this report the weight is based on carbon content and given as MtC (million tonnes of carbon). This is the convention now used in government documents.

CEC (European Commission) - the civil service of the European Community. Directorate General XVII (Energy) is responsible for the SAVE programme, of which the DECADE project is a part.

CECED - the European-wide association of manufacturers of domestic electrical appliances.

CEN (Committee for European Normalisation) - the committee responsible for harmonising standards and test procedures across Europe.

CENELEC - a subsidiary of CEN dealing with standards and test procedures for electrical goods.

Cold appliances - see Appendix B.

CRS (Consumer Response Survey) - This survey, carried out by DECADE in 1995, focused on consumer responses to the Energy Label on cold appliances. It was also designed to collect a wide range of data that would present a complete picture of energy decision-making by consumers. 150 households took part (100 in Oxfordshire, and a further 50 in Edinburgh). The survey consisted of a self-completion questionnaire followed up by an in-depth interview with the representative of the household. Analysis of the sample, using a range of variables thought to be important in determining responses to policy, resulted in a four-group segmentation which is discussed fully in DECADE (1997).

DEA - the Danish Energy Agency.

Demand side management (DSM) - policies to reduce the demand for electricity, either in a general sense or, often, as a specific policy of an electricity utility.

EA (Electricity Association) - UK organisation representing the 19 electricity companies involved in generation, transmission and distribution of electricity in the UK, and known as the Electricity Council prior to electricity privatisation in 1991.

EACEM (European Association of Consumer Electronics Manufacturers) - the European trade association representing the major manufacturers of brown goods.

ECU (Environmental Change Unit) - The Environmental Change Unit is Oxford University's centre for the organisation and promotion of research and teaching on the environment. Research themes include energy efficiency, climate change impacts and responses, land degradation and rehabilitation, and solar power. The DECADE project is part of the Energy and Environment Programme. The ECU is on the web at: http://www.ecu.ox.ac.uk.

Ecolabel - a label assessed on the basis of a complete life cycle analysis. Criteria allow only the best 10 or 20% of products on the market to qualify, but the manufacturer has to pay a licence fee to use the Ecolabel logo.

EESOP (Energy Efficiency Standards of Performance) - the Public Electricity Supply companies (PESs) are required by the Electricity Regulator (OFFER) to spend the equivalent of £1 per customer per year, during the period 1994-98, on the more efficient use of electricity. This amounts to a total investment of £100 million, 25% of which was originally targeted at electrical appliances in the domestic sector. However, less has been spent in practice since insufficient schemes were forthcoming. Most of the investment to date has been on lighting. Whether or not EESOP will be extended until March 2000 has yet to be confirmed.

ELDA database - a comprehensive database of domestic electrical appliances containing all relevant product information including energy efficiency and performance. The database was developed in Denmark and is used by Danish utilities such as Copenhagen Energy to advise consumers on the most suitable appliance for their needs. Scottish Hydro Electric is currently involved in a project to adapt the database for use in their shops by entering data on appliances available in the UK. Scottish Hydro hope that by offering their customers a wider choice of appliances and best advice on all product features, the database will help to encourage growth in the market for energy efficient appliances.

Energy efficiency - energy consumed by an operation or series of operations per unit capacity (eg kWh/kg) and per unit of performance (eg at 60°C).

ETP (Economic and technical potential) - ETP is technically feasible *and* cost-effective to the consumer. Cost effective means it is the minimum life cycle cost (See Life Cycle Cost). Feasible means it is proven technology. Other assumptions are average usage patterns, current EU prices for electricity, water and equipment, average market mark-ups and an 8% discount rate. If energy or equipment prices change significantly, or if new technologies become available, then the ETP may change. It does not include any reduction in consumption from changes in behaviour and so does not represent the technical limit or the lowest limit on consumption.

ETP2002 - a scenario in which all appliances are assumed to reach ETP efficiency level by 2002.

EU (European Union) - The EU was established by the Maastricht treaty and comprises the European Community (Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, United Kingdom, Austria, Finland and Sweden), a Foreign Defence and Security Co-operation Mechanism and a Home Affairs and Justice Co-operation Mechanism.

European Commission - see CEC.

Frost-free - Frost builds up in a freezer or fridge-freezer as the air inside cools and contracts, sucking in warm humid air, which then freezes. In a 'frost-free' appliance, air is driven by fan through a duct and cooled outside the cabinet insulation, so that between cycles the evaporator plate rises above freezing and any ice melts. If cycling takes place more frequently, for example in an inefficient appliance with poor temperature controls and/or a large heat load through the walls, or a very humid kitchen, there will be more frost. Some 'auto-defrost' appliances also have an electrical resistance heater which is triggered after a certain time to melt any ice. Fans, heaters and the loss of efficiency from cooling outside the insulation all result in additional consumption which, for a fridge-freezer in the UK, can be up to around 270 kWh pa or an extra 50% of the consumption.

GB (Great Britain) - the three mainland countries of England, Wales and Scotland, ie not including Northern Ireland.

GEA (Group for Efficient Appliances) - a consortium of researchers from EU national energy agencies, funded by the SAVE programme and national governments. The ECU represents the UK in this group, which has reported on the cold and wet appliances.

Household - this is the same as the census definition: a group of people (who may or may not be related) living, or staying temporarily, at the same address, who have a regular arrangement to share at least one meal daily *or* share common housekeeping. This is the definition used in all official UK Government publications.

IEA (International Energy Agency) - independent organisation of 24 Member countries, established within the framework of OECD to carry out a comprehensive and co-operative development programme for sustainable international energy trade.

Infrastructure - the internal physical structural aspects of a household, eg the layout of the kitchen and the plumbing.

kWh (kilowatt-hour) - measure of electrical energy consumed; 1 kWh is equal to 1000 watts used for 1 hour.

Life cycle cost - The cost of the appliance to the consumer over the lifetime of the appliance (ie running costs as well as purchase price). Design changes in favour of efficiency may increase purchase price yet make such large savings in running costs that, over the life of the appliance, they reduce the total life cycle cost. Other more expensive design options may increase life cycle cost. A case could be made for any combination of options which did not increase the life cycle cost above its current level, but resulted in the minimum level of emissions (Figure A.1). However, ETP in this report is based on minimum life cycle cost, which pays back over 4-5 years.

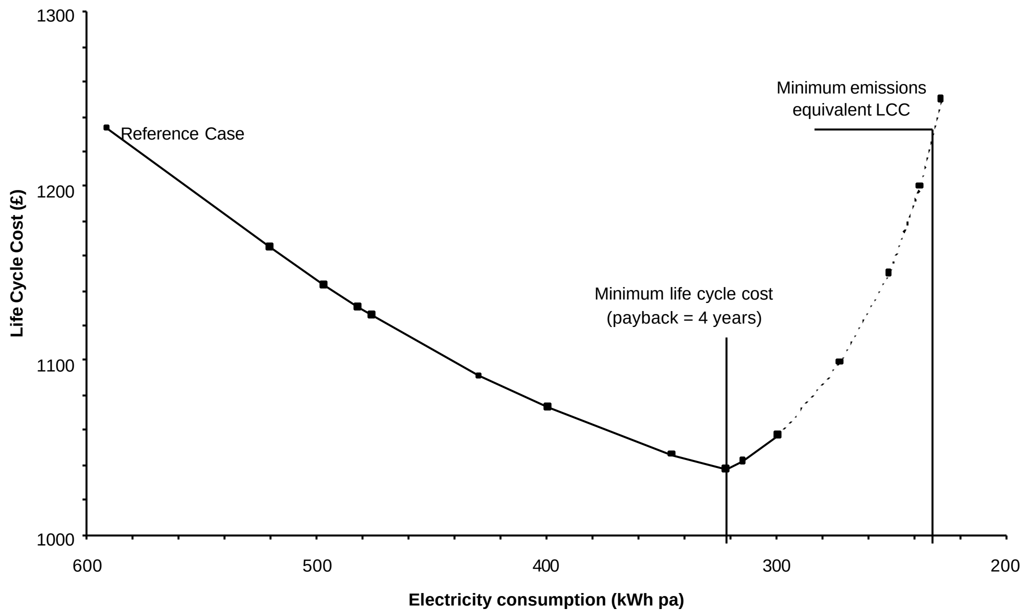

Figure A. 1 Electricity consumption and life cycle cost for fridge-freezers

Life time (of an appliance) - the time taken for half the number of appliances to leave the stock (also known as life span). In the DECADE model, for example, this is taken to be 13 years for refrigerators, 18 years for fridge-freezers and 14.5 years for a tumble dryer.

LEEP (Lothian and Edinburgh Environmental Partnership) - LEEP undertook a detailed, two-year survey of 100 low-income households and 100 middle-income households in Edinburgh from 1994-1995 and 1995-1996 respectively. DECADE have supported these studies and collaborated in analysing the data collected.

Minimum standards - legislation to enforce a minimum level of energy efficiency, a maximum level of energy consumption or the presence or absence of a particular technology.

MtC - million tonnes of carbon. The carbon dioxide molecule contains atoms of both carbon and oxygen, as shown by its chemical formula CO_2. The weight of a molecule of carbon dioxide includes both the elements of carbon (atomic weight of 12) and oxygen (each of the two atoms has a weight of 16), to give a total of 44. The present convention is to refer to the carbon content only, so that the weight of a molecule of carbon dioxide is expressed in terms of carbon alone in most Government documents and in the title of this report.

Ownership - the total number of appliances divided by the number of households owning at least one of that appliance, eg TV ownership in 1996 was 1.7 sets per household.

OECD (Organisation for Economic Co-operation and Development) - an international organisation to promote policies designed to “achieve the highest sustainable economic growth” in Member countries and to contribute to the expansion of world trade “in accordance with international obligations.”

Reference Case (RC) - a projection of usage and ownership and the underlying rate of technical change determined from historical data where available. The only policy intervention included is that which has been implemented or is close to implementation in the UK or EU, ie Energy Labels and a mandatory efficiency standard for cold appliances to be implemented in September 1999. This was formerly known as the Business as Usual (BAU) scenario in previous DECADE reports.

Sales-weighted data - most analyses to date have been on a simple average of models offered on the market. A better approach is to weight the analysis according to sales of each model. The difference between sales-weighted analysis and a simple average is assumed to be small where the database is very large, since there tends to be a wide range of brands on offer in popular market sectors. Where the number of models is small, sales-weighted data are much more important. Sales-weighted data are essential for analysing the effects of policy instruments such as labels, rebates and technology procurement, which might increase the market share of efficient models.

SoP - see EESOP.

Specific energy consumption - energy consumed per unit of service, given a minimum standard of performance (eg kWh/litre of cold space at a specified temperature).

Stock of appliances - all the appliances owned by households.

Takeback - where improved energy efficiency results in an increased level of service rather than reduced consumption.

Test procedure - energy used according to defined conditions and international standards. A standardised test procedure is essential for comparing models on a similar basis, but difficult to translate into actual consumption. For instance, the test procedure for cold appliances (EN 153) assumes a warm ambient temperature (25ºC) to compensate for no door openings.

UK (United Kingdom) - Great Britain plus Northern Ireland.

Usage patterns - the way in which an appliance is actually used in the home. This can include frequency of use (eg, for washing machines, the number of washes per annum) and manner of use (eg the proportion of washes at different temperatures).

VIP (Vacuum insulated panels) - though difficult to manufacture and maintain, a vacuum is a better insulant than conventional foam. Recently several manufacturers have developed VIP prototypes consisting of two plastic sheets, sealed round the edges, filled with gel or glass beads and evacuated.

Watt (W) - SI unit of active electric power; the rate at which electric energy is used.

Wet appliances - see Appendix B.

UNITS OF MEASUREMENT

1 kWh	= 3.6 MJ
1 therm	= 10^5 Btu
1 therm	= 105.506 MJ
1 therm	= 29.3 kWh

POWERS OF TEN

10^1	= deca
10^3	= kilo
10^6	= mega
10^9	= giga
10^{12}	= tera

APPENDIX B: APPLIANCE CATEGORIES USED IN THE DECADE MODEL

The lights and appliances included in the DECADE model follow the conventions adopted by both the Building Research Establishment (BRE) and the Electricity Association. The categories include all uses of electricity apart from space and water heating, which is covered in the BRE's BREHOMES model.

B. 1 COLD APPLIANCES

Refrigerators: one door refrigerators with or without frozen compartment
Fridge-freezers: two door combination refrigerators
Upright freezers
Chest freezers

B. 2 WET APPLIANCES

Washing machines: any automatic washing machine including the washing cycle of washer-dryers
Tumble dryers: all types of dryers including the drying cycle of washer-dryers
Dishwashers: all dishwashers

B. 3 MAJOR COOKING APPLIANCES

Electric ovens: including grills
Electric hobs
Microwaves: includes combination microwave/grill/convection ovens
Electric kettles: includes all types of electric kettle

B. 4 SMALL COOKING APPLIANCES

Hot drinks makers: coffee and tea makers
Sandwich toasters
Pop-up toasters
Deep fat fryers
Electric frying pans
Slow cookers
Cooker hoods
Food preparation appliances: mixers, blenders, processors, whisks etc

B. 5 LIGHTING

Incandescent: 100W, 60W and 40W
Tungsten halogen: an average wattage of 30W
Fluorescent strip: an average wattage of 63W
CFL (compact fluorescent light bulb): an average wattage of 15.3W

B. 6 BROWN APPLIANCES

Televisions
VCRs (video cassette recorders)
Non-portable audio equipment: hi-fi systems, music centres, record players etc
Satellite control boxes for TVs
Cable control boxes for TVs

Portable audio equipment: Cassette recorders, radios etc
Clock radios

B. 7 MISCELLANEOUS APPLIANCES

Irons: steam irons and dry irons
Vacuum cleaners
DIY equipment: drills, torches, battery chargers etc
Garden equipment: lawn mowers, strimmers, hedge trimmers etc
Other home care equipment: sewing machines, floor polishers, lights on extension cords etc
Hair styling equipment: hair dryers, curling tongs etc
Small personal care appliances: electric toothbrushes, electric razors etc
Electric towel rails
Electric blankets
Electric instantaneous showers
Central heating pumps
Personal computers
Computer printers
Facsimile machines
Answering machines
Other office equipment: slide projectors, electric typewriters etc

APPENDIX C: UK ENERGY CONSUMPTION BY APPLIANCE GROUP

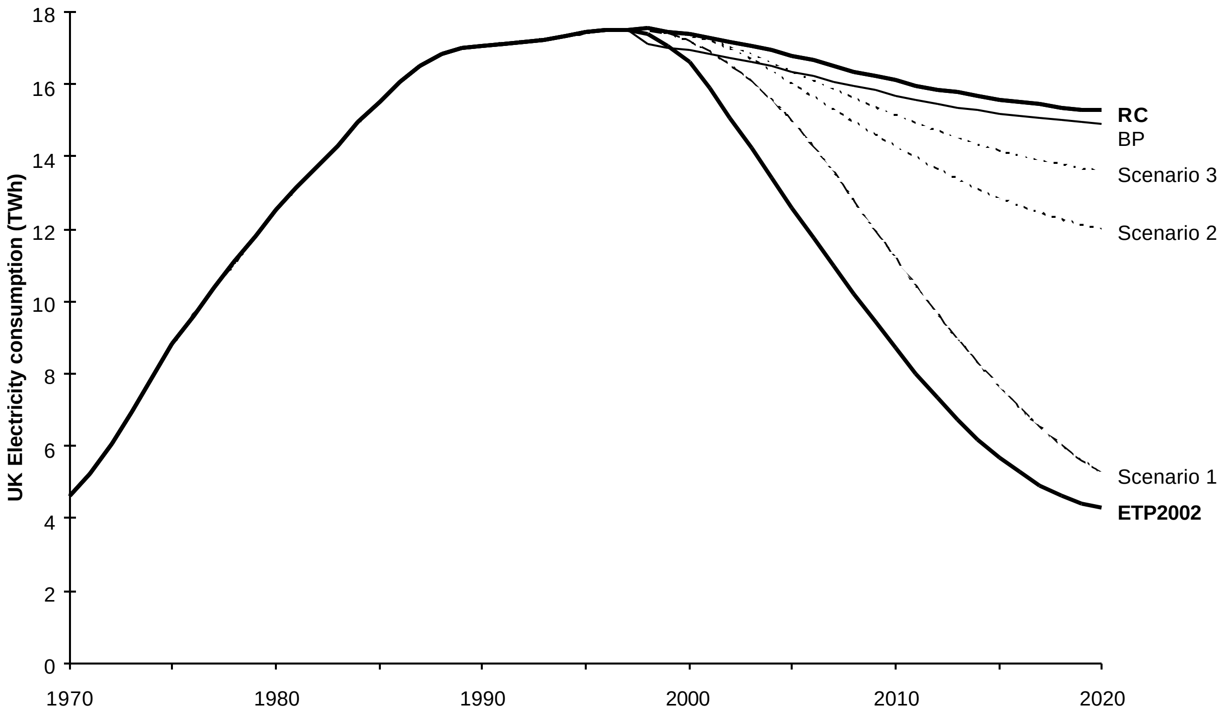

Figure C. 1 Electricity consumption by cold appliances, UK, 1970-2020

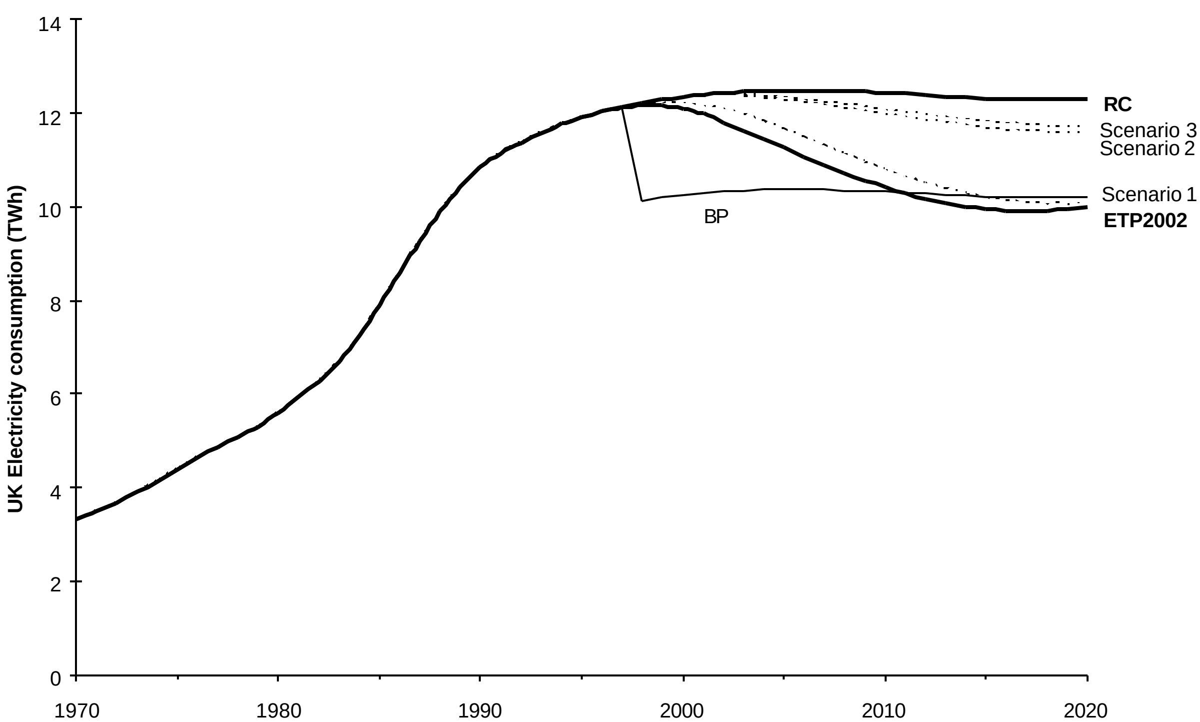

Figure C. 2 Electricity consumption by wet appliances, UK, 1970-2020

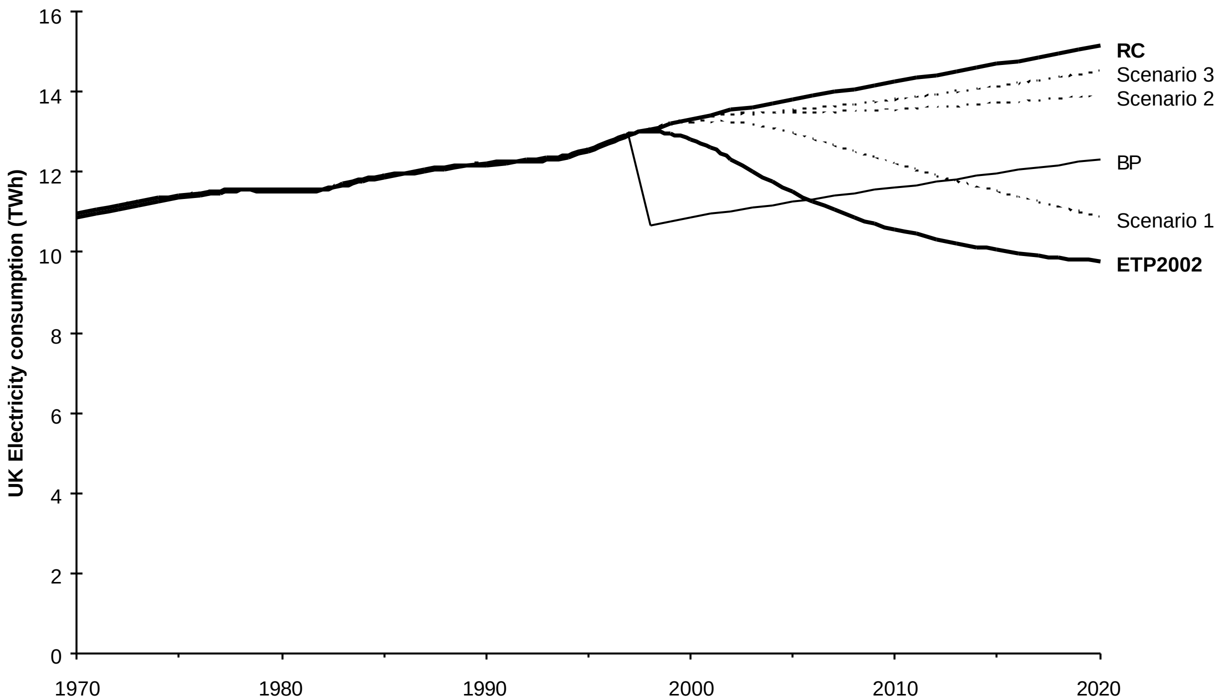

Figure C. 3 Electricity consumption by cooking appliances, UK, 1970-2020

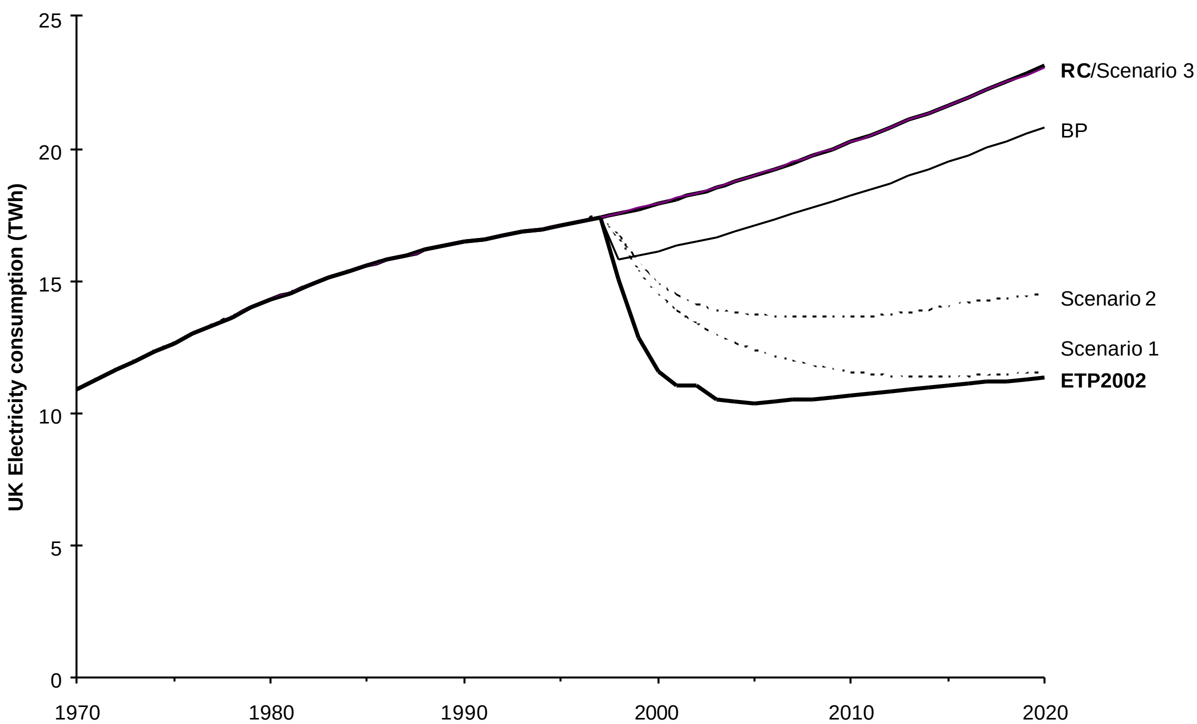

Figure C. 4 Electricity consumption by lighting, UK, 1970-2020

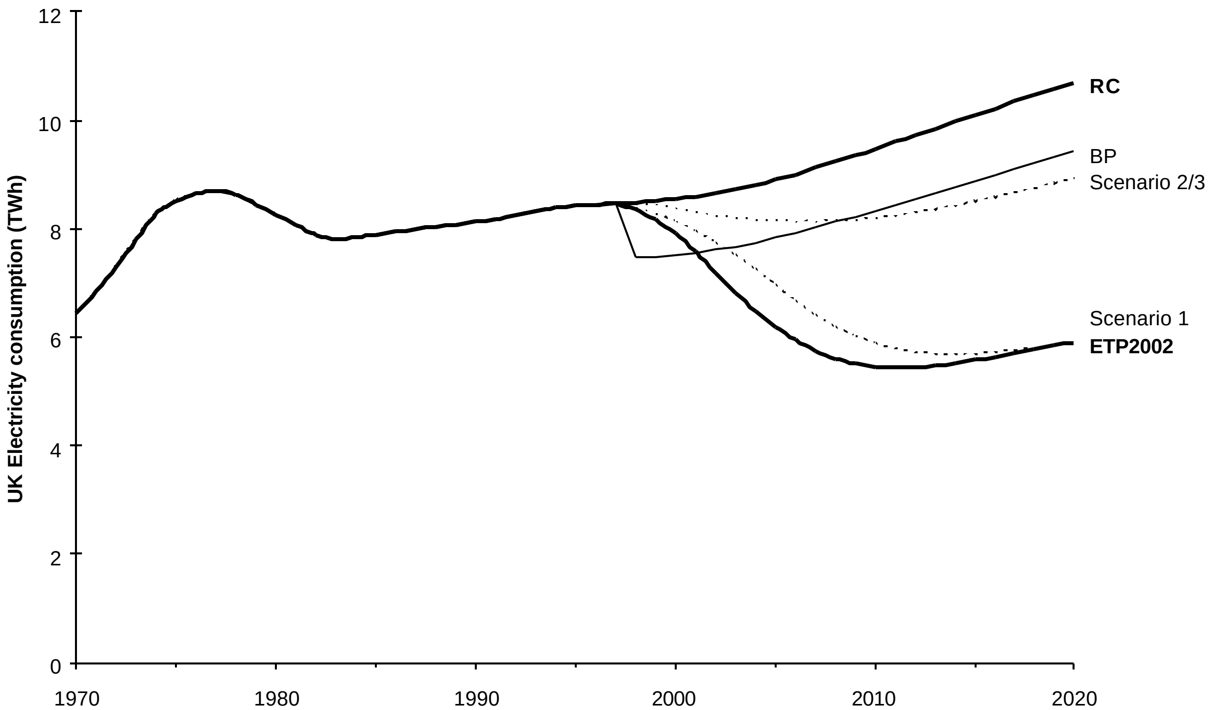

Figure C. 5 Electricity consumption by brown appliances, UK, 1970-2020

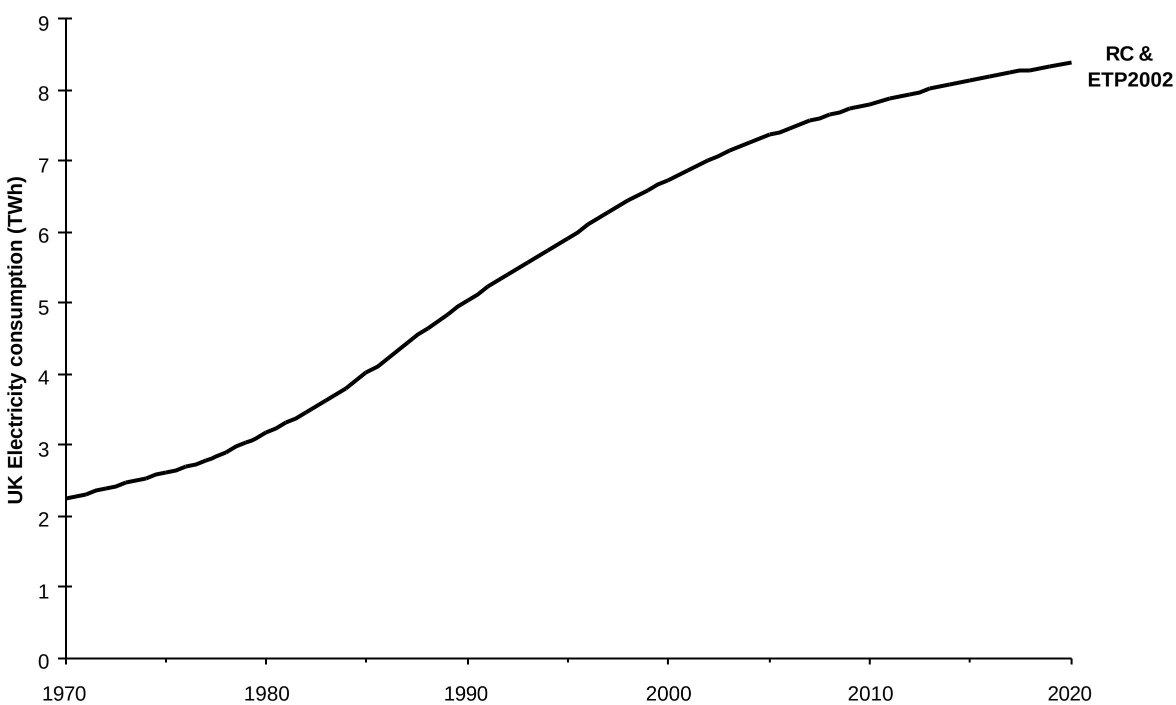

Figure C. 6 Electricity consumption by miscellaneous appliances, UK, 1970-2020

APPENDIX D: MODELLING ELECTRICITY SUPPLY AND DEMAND

Dr Mark Barrett was commissioned to use his 'EleServe' model to estimate CO_2 emission factors for each appliance group in 1995 and in 2010 under both the RC and ETP2002 scenarios. EleServe is an integrated model of electricity demand and supply which is divided into two modules. The demand module makes forecasts for the electricity demand from a number of determinants which include numbers of households, ownership levels, industrial production and efficiency. For the domestic sector a stock model for appliances is employed (this is not as detailed as that used in the DECADE model). For the other sectors typical stock turnover rates are assumed for each end use. The supply module includes an hourly simulation model operated on a power station by power station basis. It calculates generation, fuel burn and carbon dioxide emissions for each station and marginal supply costs, based on published data and expert judgement.

D. 1 ELECTRICITY DEMAND

The first step is to model overall annual demand for the whole UK electricity market from 1995 to 2010 under RC and ETP2002. The estimates for domestic lights and appliance demand have been taken directly from the DECADE model. The demand from other sectors also has to be estimated since it is the total demand which determines generation requirements. RC demand estimates in other sectors are based on less detailed analysis than that for domestic lights and appliances. To match ETP2002 for domestic demand, demand side management savings are introduced across the services and industry sectors beginning in 1998 to a similar level of savings as those achieved in ETP2002. Miscellaneous energy demand remains unchanged.

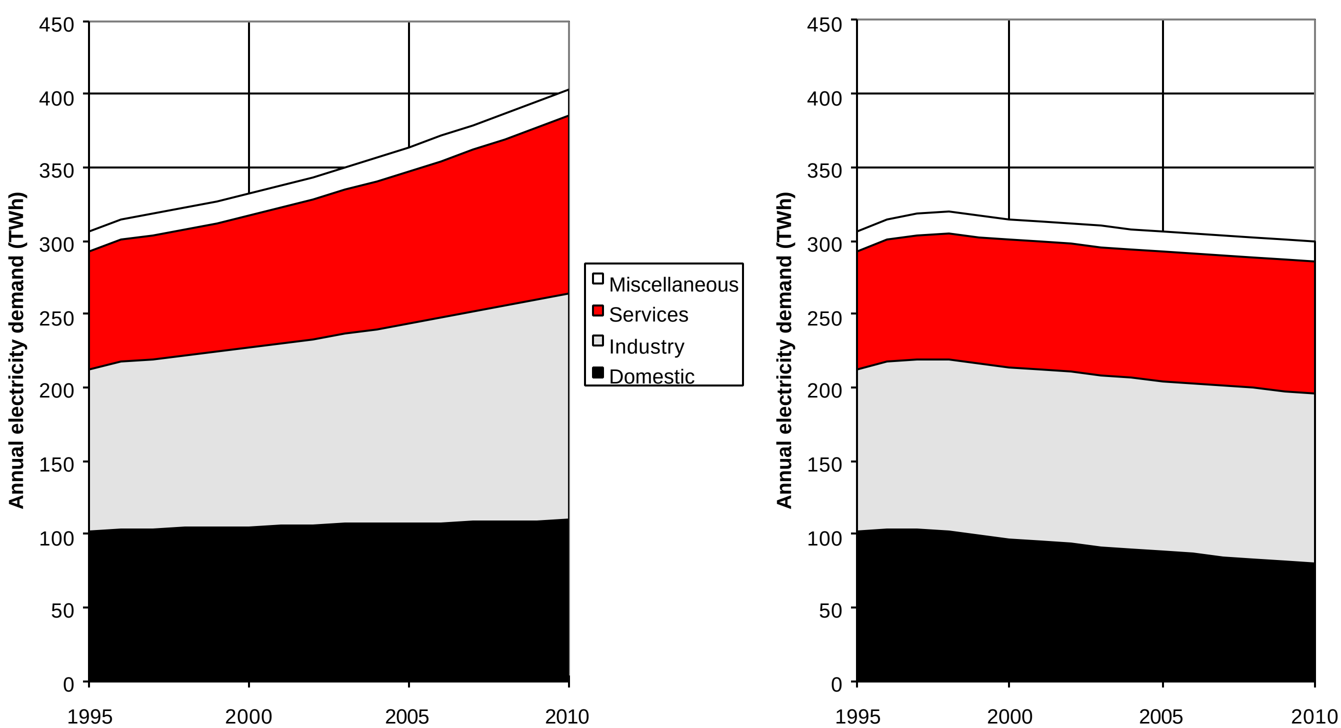

Figure D. 1 Delivered electricity demand forecasts, UK, 1995-2010 RC (left) and ETP2002 (right)

Figure D.1 shows the total UK delivered electricity demand in the two scenarios projected with EleServe. The electricity demand figure for 1995 is that from DUKES 1996 (taking into account that generated electrical energy is 8% larger than delivered electricity because of transmission and distribution losses).

Having estimated total demand per annum, it is necessary to look next at the variation of demand with time. In order to differentiate between domestic appliances, data on their time-dependent usage patterns are required. The data on time profiles have been assembled from a large variety of sources as there is no publicly available comprehensive source of these data. Large changes to the profiles of service demand over the next 10-20 years are unlikely because they are based on long established patterns of human activity, thus the same use pattern has been assumed from 1995 to 2010.

The annual demand for electricity varies through time according to the following factors:

- Social and economic activity - work and leisure activities, and their concomitant energy demands, generally show strong daily, weekly and seasonal patterns;
- Weather - ambient air temperatures and light levels are lowest in the winter and at night, and highest in the summer and the day. Water mains temperatures are lowest shortly after mid-winter. Electricity demands dependent on these factors vary accordingly;
- Technology controls - the time variation of some demand components can be controlled. These components are either ones with storage (eg off-peak storage heaters) or those where a service is not required at a particular time (eg washing machines may be run in the night).

The first two factors result in cyclically varying demand with dominant periods of a day, a week and a year for some appliance groups. The use level in any hour, weekday and month of the year, may be found by combining the hourly, weekday and monthly patterns for a number of sample days distributed across the year. This simplification allows a good representation of actual demand variations without requiring large amounts of data, which are in any case not readily available.

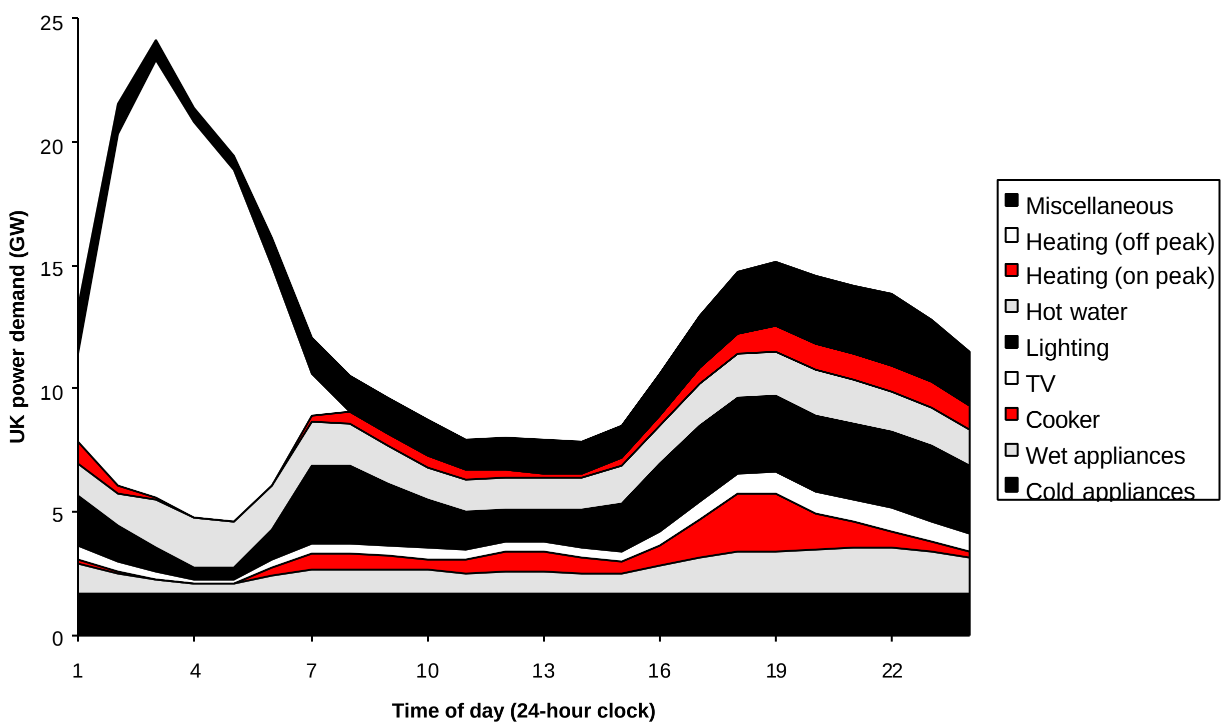

Figure D. 2 Domestic power demand, UK, sample day - Monday, January 1996

The hourly load for each component of demand is found by multiplying the average annual demand (estimated earlier) by the use level to produce the demand in any hour. Figure D.2 shows a sample daily demand curve for the domestic sector across 24 hours in winter.

D. 2 ELECTRICITY SUPPLY

Having established the demand related to domestic lights and appliances and other end uses, the next consideration is how electricity is to be generated to meet this demand.

There are a number of political and economic factors which are especially critical when appraising future electricity generation including: imports and exports of electricity to and from France; lifetime of nuclear plant; fuel prices; fuel availability and contracts, and environmental legislation. It is only necessary to look at the past twenty years to realise how these factors might change radically over the next twenty years. Accordingly any generation scenario put forward, and the concomitant CO_2 emissions, are quite speculative. In addition, the mix of generation is generally becoming more liable to sudden change (and thus less predictable) because of privatisation and the relaxation of operating constraints.

The future generation capacity for RC consists of the following:

- Existing plant, after accounting for plant retirements using assumed lifetimes of 40 years for fossil plant, and 32 years for nuclear;
- Plant which will come on stream with capacities registered with the National Grid Company to 2002/3;
- 6 GW of renewable capacity is assumed to be commissioned over the period 1999 to 2010 (this is similar to the EP65 projections).

EleServe adds new capacity beyond this as necessary to meet the projected demand.

At any given time there is a certain set of power sources available and, within operational constraints, the potential sources of electricity may be ranked by increasing marginal energy cost into a merit order. This is how generation decisions are made in real life and the process is mimicked by EleServe. Within the merit order, the first sources are ‘must run’ autogeneration and cogeneration plant where the electricity and/or heat is used on site, even though they may have high nominal energy costs. The next sources are renewable sources such as wind turbines and hydro-electric schemes which have zero fuel energy costs. These are followed by nuclear plant. Both these source categories have zero operational carbon emissions. The remaining sources are either fossil fuel electricity only plant or imports (which are mostly nuclear generation and tend to form part of the base load). Going down the merit order, the trend for the fossil fuelled plant is for increasing carbon emissions. Thus the general trend is that the average carbon emission per kWh generated increases as the demand increases.

EleServe calculates hourly demand and supply for each hour of each sample day. The generation model goes down the merit order adding the output from stations, accounting for the plant availability, until demand is met.

The result of matching supply and demand in EleServe is shown in terms of fuel mix used for both RC and ETP (Figure D.3).

The demand profiles for each appliance in conjunction with the CO_2 per unit of electricity generated at different times allow the calculation of an annual average emission per kWh per appliance. This has been calculated for 1995, and for the two different demand scenarios, RC and ETP2002, for 2010 and is shown graphically as a percentage of average kg CO_2/kWh for all UK domestic electricity (Figure 6.1).

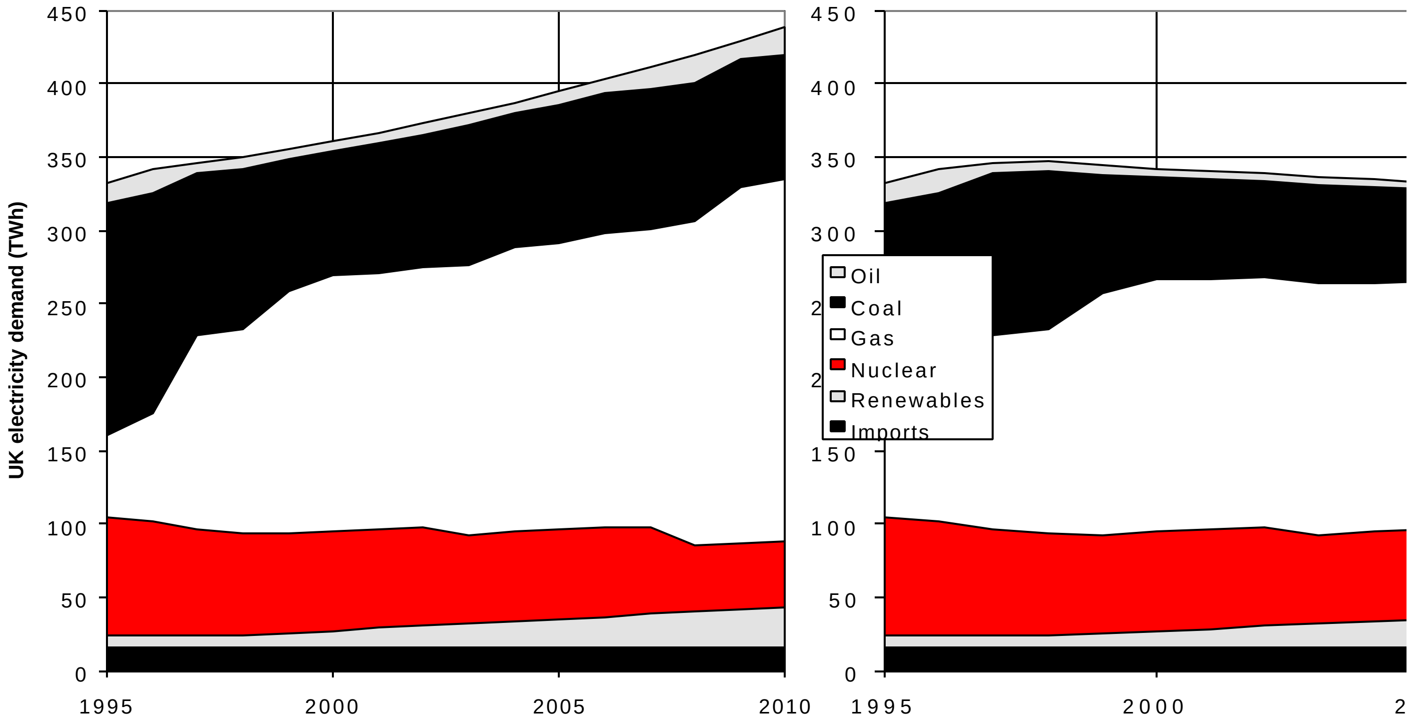

Figure D. 3 Generated electricity supply forecasts, UK, 1995-2010 RC (left) and ETP2002 (right)

APPENDIX E: PROFILES OF AUTHORS

DR BRENDA BOARDMAN (Energy and Environment Programme Leader)

Brenda has been PowerGen Fellow in Energy Efficiency at St Hilda's College since October 1991. She specialises in the efficient use of energy in the UK domestic sector, in particular the policy implications and problems faced by low-income households. She is acknowledged as the leading UK researcher on fuel poverty, and is responsible for the concept of affordable warmth. She has published widely and is regularly called upon for expert contributions to conferences, specialist workshops and the UK media. In addition to managing the DECADE project, she has overall responsibility for the Programme's research for the European Commission and the Department of the Environment, Transport and the Regions, and for research on rural transport.

TINA FAWCETT

Tina contributes towards the analysis of technical trends in appliances and interpretation of sales data. Prior to joining the ECU in November 1996, she gained an MSc in Environmental Technology from Imperial College, London and worked for a number of years in waste management, most recently for the Environment Agency.

HARRIET GRIFFIN

Harriet has a background in Zoology and gained an MPhil from the University of St Andrews where she studied the role of wild bees in crop pollination. Before joining the ECU, where she contributes towards the analysis of trends in appliance ownership and use, she worked for the Agriculture Development Advisory Service.

DR MARK HINNELLS

Mark is responsible for analyses of technical trends in appliances and contributes to policy analysis for market transformation. He is leading the ECU's collaboration on efficiency of domestic electric storage water heaters and represented the ECU on the EU Group for Efficient Appliances study of washing machines, dishwashers and dryers. He has a background in Industrial Design with a Masters Degree from Manchester Metropolitan University and his PhD was on 'Evaluation of environmental impacts of domestic appliances and implications for public policy'.

DR KEVIN LANE

Kevin is responsible for developing the DECADE model, and applying it to policy analyses for EU working groups. He represented the ECU on the EU working group on standby consumption in televisions and videos and on the GEA 'wet' study. With a first degree in digital systems and microprocessor engineering, his doctoral research at Lancaster University was on the development and application of non-stationary time series analysis techniques to climatological data. His final project before joining the ECU was the development of the Derwent Water Resources Model (a computer based management model) for the National Rivers Authority. He was awarded jointly the World Meteorological Organisation's 1996 Norbert Gerbier Prize.

JANE PALMER

Jane Palmer graduated with an honours degree in Natural Sciences from Cambridge University and has a background in Genetics. Jane joined the team in July 1995 and works on the analysis of ownership, stock profile and usage data for the DECADE model. She is also responsible for collecting and analysing the lighting data.